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Productivity with Health, Safety, and Environment

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Chapter 1
Exposure to Peak Sound Pressure Levels in Military Fieldfire Ranges

Assar Luha, Eda Merisalu, Rainer Jõgeva, and Hans Orru

1 Introduction

Members of the Defence Forces are affected during peacetime by exposure to impulse noise, mostly while doing exercises in outdoor and indoor firing ranges. In Estonia, in accordance with the normative regulations [1], the daily noise exposure level of an employee in the case of an 8-h work day should not exceed 85 dB(A) and peak unweighted sound pressure levels should not exceed 137 dB(C). In comparison to the US [2], peak sound pressure levels (peak SPL) should be less than 140 dB on protected and unprotected ears.

Exposure to a military environment where the impulse noise level exceeds the limit level value can result in auditory symptoms such as hearing loss, tinnitus, or a feeling of pressure in the ears [3–6]. Medina-Garin et al. [7] found that the FAMAS assault rifle is the most common cause of acute acoustical trauma. Mrena et al. [4] reported that acute acoustical trauma resulting from firearms generally affects both ears. In contrast, the asymmetry of hearing loss after being exposed to gunfire noise was reported by Moon [8]. Moreover, Rezaee et al. [9] concluded that noise exposure below permissible levels may sometimes lead to acoustic trauma.

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When firing a hand-held firearm, the peak SPL can reach 170 dB(C) and for large calibre weapons like mortars, the peak SPL can reach 190 dB(C). It has been shown that peak SPLs from a 7.62 mm rifle might amount to 152 dB(C), while it can reach 165 dB(C) from an 81 mm mortar, 184 dB(C) from a 120 mm mortar, and 177 dB(C) from a 12.6 mm machine gun [10]. Peak SPLs higher than the limit level value of 137 dB(C) indicate high risk of acoustic trauma in the absence of hearing protection.

According to the authors' knowledge, there are no other ways to eliminate peak sound pressure or to protect the ears than common hearing protection. The most effective way to attenuate peak sound pressure before it reaches the eardrum is to use different types of earplugs or earmuffs. So far the most effective hearing protection for impulsive noise are passive earmuffs [11], level-dependent earplugs [12], active noise reduction earmuffs, and earplugs providing noise attenuation at lower frequencies, but not actively attenuating noise levels higher than 130 dB [10]. The kind of hearing protection that is most effective at attenuating the peak sound pressure depends on the frequency. Passive earmuffs could attenuate noise from 5 to 10 dB in the low (63–250 Hz) frequencies, and up to 30 dB in the middle and higher (500 Hz–8 kHz) frequencies [10].

The current study aims to assess the exposure to peak SPL in military fieldfire ranges and to propose measures to decrease the risks of hearing impairment. This paper focuses on measuring peak SPLs of different weapons and assessing safe distances from noise sources but does not evaluate the effects of the noise spectrum, impulse duration or number of impulses during military exercises.

2 Materials and Methods

A. *Objects*

Four types of weapons or weapon systems were chosen for this study: anti-aircraft guns (the heavy Browning machine gun [12.7 mm] and the ZU-23-2 anti-aircraft cannon [23 mm]), large calibre artillery systems (the M252 mortar [81 mm] and the M41D mortar [120 mm]), simulation devices (the PIL10T imitation explosives packet and the CN69 training grenade), and the AK-4 automatic rifle used by the Estonian Land Forces.

B. *Measurement Procedure*

In the case of anti-aircraft guns and automatic rifles, the noise exposure levels of Defence Forces personnel were measured using CEL-350 (Casella) noise dosimeters. The microphone of the noise dosimeter was fastened to the shoulder strap of the harness near the ear canal of the Defence Force member. During the measuring period, the noise dosimeter registered the equivalent level of noise and the peak SPL.

For anti-aircraft guns, measuring devices (CEL-350 with filters attenuating 10 dB) were placed at different distances from the noise sources along the length of the firing line. Since the measuring was performed on the coast, the condition of an open noise field was fulfilled because there was one reflective surface (the ground). Four measuring points were located to the right of the firing line, being 10, 20, 30, and 40 m away from the group of two Browning heavy machine guns. Six measuring points were located to the left of the ZU-23-2 anti-aircraft cannon, being 10, 15, 20, 30, 40, and 50 m away along the extensions of the firing line on the coast. Since the noise caused by firearms is propagated asymmetrically around the firing position, measuring devices should be placed behind the firing line to assess the spatial propagation of sound. But because there was a forest behind the firing line, it was impossible to place the measuring devices as suggested. Therefore, the sound field was considered to be symmetrical around the firing position.

For large-calibre artillery systems and for training ammunition, noise levels were measured using a Brüel and Kjaer 2260 noise analyser. The measuring locations of the noise analyser were chosen so that the expected noise level would not exceed the measuring range of the measuring device. Based on the measured peak SPL results, the average peak SPL was calculated for a distance range of 0.1–200 m. When peak SPL at the measuring location exceeded the measuring range of the measuring device, peak SPL at that measuring point was calculated.

For the AK-4 automatic rifle, the noise level in the firing range was measured to assess the noise exposure levels of the shooting instructor and the active duty service members who regularly participate in target practice. In order to measure the noise levels, the shooting instructor ($n = 1$) and the measuring technicians ($n = 2$) wore a CEL-350 noise dosimeter.

C. *Calculations*

A logarithmic function (y) and its coefficient of determination (R^2) were found based on the measurement results. The logarithmic function was used to calculate: (a) noise levels outside the measured points and (b) safe distances from the noise source. We have taken into account the inverse square law that the sound intensity level reduces by 6 dB each doubling of distance from the noise source [13].

D. *Regulations*

The results were compared with the limit level value provided in the normative document Health and safety requirements for the working environments affected by noise, maximum noise limits for the working environments and the noise measurement procedure—Regulation No. 108 of the Government of the Republic of 12 April 2007, applicable only in peacetime. In accordance with the limit level value, the peak SPL should not exceed 137 dB(C).

The measuring and calculation results have been compared with the limit level value presented in the normative document based on the worst-case scenario method. The most health-damaging value (i.e. the lowest or the highest value) of the range of results is considered the most likely result.

3 Results and Discussion

A. *Anti-aircraft Guns*

Average peak SPL values in relation to the distance from the shooter are presented in Fig. 1. The peak SPL of anti-aircraft guns exceeds the peak SPL value at distances up to 40 m. For the Browning heavy machine gun, the peak SPL at 10 m was 147.5 dB(C), while for the ZU-23-2 anti-aircraft cannon, it was 148.6 dB(C). Close to the cannon the noise level can be even higher. As Młynski et al. [14] previously reported, gun crew members of the ZU-23-2 K experience peak SPLs of 153.0–158.3 dB(C). The objective distance up to which it should be mandatory to wear hearing protection is 40 m in the case of the Browning gun and 50 m in case of the ZU-23-2.

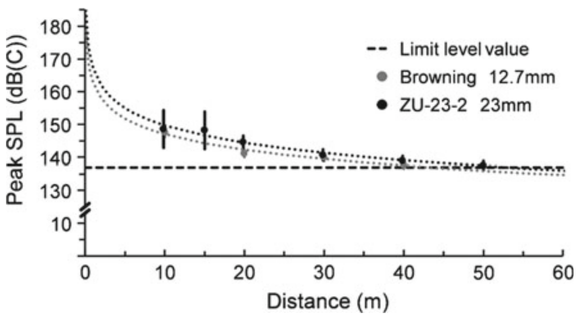
Knowing the peak SPL at different distances, it is possible to calculate the safe distance from the noise source. According to the formed logarithmic functions: for Browning [$R^2 = 0.966$ ($y = -6.882\ln(x) + 162.865$)] and for ZU-23-2 [$R^2 = 0.963$ ($y = -7.637\ln(x) + 167.279$)] (Fig. 1.), peak noise levels are 3–13 dB lower than theoretically calculated peak SPLs at the same distance, which means that natural conditions somewhat attenuate the noise level.

Based on the measurement results at 10, 20, 30, and 40 m, a peak SPL at 0.1 m of 176 dB(C) was calculated for the Browning (according to the inverse square law 189 dB(C)) and 163 dB(C) at 1 m (according to the inverse square law it is 169 dB(C)). Based on the measurement results at 10, 20, 30, 40, and 50 m, a peak SPL at 0.1 m 182 dB(C) was calculated for the ZU-23-2 (according to the inverse square law, equal to 191 dB(C)) and at 1 m 167 dB(C) (according to the inverse square law it equals to 171 dB(C)), respectively.

B. *Large-Calibre Artillery Systems*

Measurement results of the peak SPL of M252 and M41D are presented in Fig. 2. The measurement and calculation results were compared to the limit level value presented in normative documents based on the worst-case scenario method. It appeared that when firing in a firing range with the M252 positioned laterally, the peak SPL amounted to 138.9 ± 3.5 dB(C) at 10 m, 133.9 ± 3.5 dB(C) at 20 m and 131.7

Fig. 1 Measured average peak SPL values and their calculated relationship with distance from a firing group during shooting



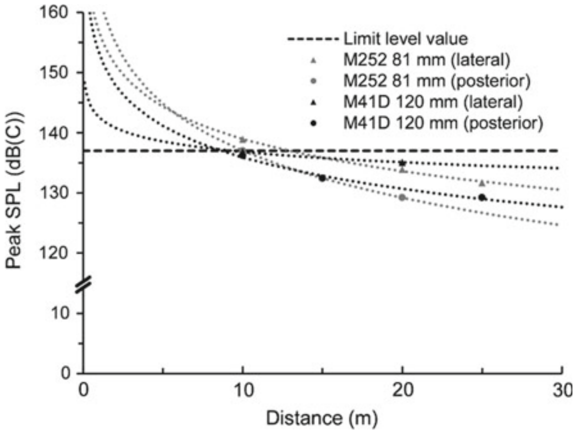


Fig. 2 Measured peak SPL and their relationship with distance from the large calibre artillery systems was calculated with following functions: for M252 (lateral) [$R^2 = 0.996$ ($y = -7.705\ln(x) + 56.707$)], for M252 (posterior) [$R^2 = 1.000$ ($y = -11.253\ln(x) + 62.911$)], for M41D (lateral) [$R^2 = 1.000$ ($y = -2.453\ln(x) + 42.447$)] and for M41D (posterior) [$R^2 = 0.987$ ($y = -7.581\ln(x) + 53.396$)]

± 3.3 dB(C) at 25 m. To the posterior, the measurements were 137.0 ± 3.5 dB(C) at 10 m, 129.2 ± 3.3 dB(C) at 20 m, the estimated short-term peak SPL amounting to 162.0 dB(C).

C. *Training Ammunition*

Figure 3 shows the peak SPL measuring and the calculated results. The training ammunition PIL10T shows the maximum calculated peak SPL of 166.6 dB(C) at 2.5 m (worst-case scenario) and 152.0 ± 1.3 dB(C) at 10 m. The CN69 training grenade made a noise of 132.7 ± 1.3 dB(C) at 2.5 m and 131.1 ± 1.3 dB(C) at 5 m.

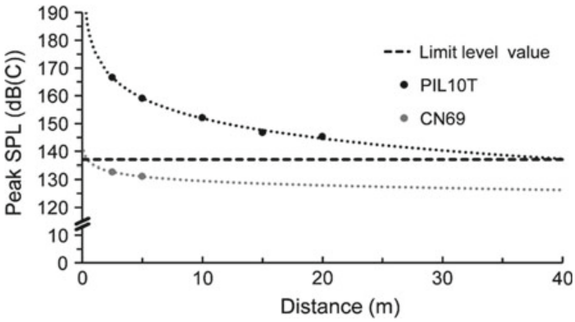


Fig. 3 Measured peak SPL values for unprotected hearing and their relationship with the distance from the training ammunition were calculated with function: for PIL10T [$R^2 = 0.996$ ($y = -10.541\ln(x) + 76.103$)] and for CN69 [$R^2 = 1.000$ ($y = -2.308\ln(x) + 34.815$)]

Table 1 The noise exposure of military personnel shooting rifle AK-4 and calculated peak sound pressure levels (SPL) for unprotected and protected hearing (with different Single Number Ratings, SNR). Background noise level on the firing line: equivalent noise level 41.6 dB, peak SPL = 59.0 dB; *extrapolations based on the measurement result, noise level was actually above the measuring limit (143.5 dB(C))

Location	$L_{p,Cpeak}$ (dB)	Hearing protector	SNR	Predictable peak sound pressure level (dB)
On the firing line	143.5*	None Peltor H61PAW 3 M 1271	0 27 25	143.5* 116.5* 118.5*
10 m posterior from the firing line	115.6	None Peltor H61PAW 3 M 1271	0 27 25	115.6 88.6 90.6
20 m posterior from the firing line	110.4	None Peltor H61PAW 3 M 1271	0 27 25	110.4 83.4 85.4

It was calculated that the safe distance for unprotected ears when detonating the simulation device PIL10T in open field conditions (i.e. outside, on a field with no obstructions) is ≥ 53 m (based on the worst-case scenario method) and ≥ 46 m (based on the mean value). No comparable data for studied training ammunition were found in the relevant literature.

D. *Automatic Rifle AK-4*

Measurement results of exposure to the AK-4 automatic rifle noise are presented in Table 1. The live firing exercise lasted 3 h 10 min, during which 1,200 shots were fired. Hearing protectors with noise attenuation factors SNR = 27 dB and SNR = 25 dB were used. Table 1 shows that the peak SPL of the rifle AK-4 exceeds the peak SPL value at the shooting instructors' position on the firing line. The average peak SPL of the entire target practice time period was >143.5 dB(C). In comparison, it has been shown that shooters as well as shooting instructors are exposed to impulse noise levels greater than 150 dB for most of the weapons and weapon systems used during indoor and outdoor live fire training exercises [15].

E. *Personal Protective Equipment*

Due to the high sound levels, it is mandatory for the shooters to use hearing protection while firing. Currently while working with different weapons or weapon systems, three types of foam earplugs with the noise attenuation property SNR either 15, 25, or 36 dB and earmuffs with the noise attenuation property SNR either 15, 27, or 33 dB were used.

One might ask what kind of SNR is sufficient for the members of the defence forces to achieve the hoped-for hearing protection during fieldfire exercises. Opinions vary, as Lenzuni et al. [16] have argued that a moderate correlation of the peak attenuation with the SNR of the hearing protector might alternatively be exploited to use SNR as a predictor of peak insertion loss. Zera and Mlynski [11] have concluded that the

SNR parameter only approximately represents the decrease in peak SPL. So in our study, we use SNR as an indirect indicator predicting peak SPL loss. The peak SPL condition of ≤137 dB(C) in the outer ear is achievable with hearing protection with an SNR of at least 36 dB or with double protection (i.e. earmuffs and earplugs). Although the peak reduction of the double protection might be not additive due to the effects of bone conduction [17], it is known that the bone conduction limits the attenuation ranging from 40 to 60 dB across the frequencies from 125 Hz to 8 kHz [18]. However, no evidence was found that it is adequate to eliminate the skull transmission of the unattenuated or residual sound pressure to prevent hearing damage from peak sound pressure. When analysing the measurement results, it was established that the distance at which a person who is not wearing ear protection can stand without any significant danger of developing permanent hearing loss is approximately 100 m in the case of the Browning heavy machine guns and ~150 m in the case of the ZU-23-2 anti-aircraft guns. These results are almost in line with Pääkkonen et al. [19] who found a peak SPL of 128–141 dB for the 23-mm antiaircraft cannon (23AAC) at a distance of 100 m. The safe distance decreases significantly if there are any noise absorbing objects in the field (trees, landscape forms, etc.). Assuming that the noise attenuation capability of earmuffs is at least 20 dB, dual hearing protection should be used when situated closer to the weapons than 5 and 10 m, respectively for Browning and ZU-23-2. At this distance, landscape does not have a significant effect on peak noise. To fulfil the requirement of ≤137 dB(C), the noise generated by large calibre artillery systems can be attenuated in the outer ear using foam earplugs and earmuffs at the same time, preferably with SNR 36 + dB. A peak SPL of 137–152 dB(C) can be attenuated with earmuffs. If the peak SPL is under 152 dB(C), as in the case of the imitation explosives packet PIL10T, double hearing protection should be used.

4 Conclusion

Conducting firing exercises at an outdoor firing range contributes to daily noise exposure. During firing exercises, the most studied guns show a peak SPL above 140 dB(C), and thus increase the risk of noise-induced hearing loss. The noise from different weapons can be attenuated most effectively by using earplugs and earmuffs at the same time. Further studies should examine the practical usage and attenuation of personal hearing protection. It seems to be critical to study how the skeletal transmission of noise through human skull or other bones affects the transmission of unattenuated peak noise into the inner ear thereby contributing to hearing loss.

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References

1. *Health and Safety Requirements for the Working Environments Affected by Noise, Maximum Noise Limits for the Working Environments and the Noise Measurement Procedure*, Government of the Estonian Republic regulation, No. 108 of 12 Apr 2007. [in Estonian]
2. *MIL-STD-1474E Noise Limits, Design Criteria Standard*, Department of Defense, 15 Apr 2015
3. A. Collée, C. Legrand, B. Govaerts, P. Van Der Veken, F. De Boodt, E. Degrave, Occupational exposure to noise and the prevalence of hearing loss in Belgian military population: a cross-sectional study. Noise Health **13**(50), 64–70 (2011)
4. R. Mrena, S. Savolainen, U. Pirvola, J. Ylikoski, Characteristics of acute acoustical trauma in the Finnish Defence Forces. Int. J. Audiol. **43**(3), 177–181 (2004)
5. P. Muhr, *Hearing in young men: the influence of military noise and epidemiological aspects, Karolinska Institutet* (Stockholm, Sweden, 2010)
6. Z. Živaljević, L. Živić, Z. Bukumirić, I. Nikolić, B. Vorkapić, N. Baletić, Effect of live ammunition shooting from an automatic rifle on sense of hearing in proffesional military personnel. *Vojnosanitetski Pregled* **75**(7), 710–715 (2018)
7. D.R. Medina-Garin, A. Dia, G. Bedubourg, X. Deparis, F. Berger, R. Michel, Acute acoustic trauma in the French Armed Forces during 2007–2014. Noise Health **18**(85), 297–302 (2016)
8. I.S. Moon, Noise-induced hearing loss caused by gunshot in South Korean military service. Mil. Med. **172**(4), 421–425 (2007)
9. M. Rezaee, M. Mojtahed, M. Ghasemi, B. Saedi, Assessment of impulse noise level and acoustic trauma in military personnel. Trauma Month **16**(4), 182–187 (2012)
10. *Hearing Protection—Needs, Technologies and Performance*, NATO RTO Technical Report, AC/323(HFM-147)TP/337 (2010)
11. J. Zera, R. Mlynski, Attenuation of high-level impulses by earmuffs. J. Acoust. Soc. Am. **122**(4), 2082–2096 (2007)
12. E.H. Berger, P. Hamery, *Empirical evaluation using impulse noise of the level-dependency of various passive earplug designs, in Acoustics '08* (Acoustical Society of America, Paris, 2008), pp. 3717–3722
13. D.M. Howard, J.A.S. Angus, *Acoustics and Psychoacoustics*, 4th edn. (Focal Press, 2009), ch. 1
14. R. Młynski, E. Kozłowski, J. Usowski, D. Jurkiewicz, Evaluation of exposure to impulse noise at personnel occupied areas during military field exercises. Arch. Acoust. **43**(2), 197–205 (2018)
15. S.E. Brueck, C.A. Kardous, A. Oza, W.J. Murphy, *Measurement of Exposure to Impulsive noise at Indoor and Outdoor Firing Ranges during Tactical Training Exercises.* U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Report No. 2013–0124–3208 (2014)
16. P. Lenzuni, T. Sangiorgi, L. Cerini, Attenuation of peak sound pressure levels of shooting noise by hearing protective earmuffs. Noise Health **14**(58), 91–99 (2012)
17. W.J. Murphy, R.L. Tubbs, Assessment of noise exposure for indoor and outdoor firing ranges. J. Occup. Environ. Hygiene **4**(9), 688–697 (2007)
18. E.H. Berger, R.W. Kieper, D. Gauger, Hearing protection: surpassing the limits to attenuation imposed by the bone-conduction pathways. J. Acoust. Soc. Am. **114**(4), 1955–1967 (2003)
19. R. Pääkkonen, A. Parri, J. Tiili, Low-frequency noise emission of Finnish large-calibre weapons. J. Low Freq. Noise Vib. Active Control **20**(2), 85–92 (2001)

Chapter 2
Soft Usability Problem in Consumer Electronic Products

Moonty Baruah and Nandita Bhattacharyya

1 Introduction

With the development of science and technology, there have been a lot of changes in the market of consumer electronic products. The market is flooded with varieties of products because of changing consumer preferences, increasing standard of living and continuously evolving technological innovations. The scenario in the market of home appliance industry is equally challenging. There have been a number of appliances that provide convenience in cooking and other kitchen-related tasks. Though there has been a lot of competition between the manufacturers related to new technological appliances, which have made life easier as well as efficient to the user. But still consumers have lot of complain since they are not that satisfied with the products though the task is made easier but the cognitive load on the user is increased. Since the manufacturers are under tremendous competitive pressure to be the first in the market. In hurriedness to launch a product (often) makes it even worse by hindering manufacturers from taking into account the various aspects of users' experiences in their product development process. This competition does not always end up with consumer satisfaction due to the fact that consumers' expectations on product quality and usability deviate from their experiences with those products, and users differ in terms of preferred product properties [1–3]. Such unidentified consumer complaints in the consumer electronic industry are defined as "soft usability problems", which mean consumer complaints related to non-technical usability issues, as opposed to hard usability problems that have to do with technical failures or malfunctions. It may be due to the following reasons electronic consumer products have become

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integrated into one single product, which confuses consumers in perception, expectation and use. Second, manufacturers have kept developing consumer electronics only focusing on new technology, resulting in larger complexity in terms of usability. Thus, an attempt was made to study the soft usability problem in consumer electronic products.

2 Methodology

Jorhat district of Assam was selected purposively for the study. Purposively, cum random sampling method was adopted in order to select representatives' samples for the purpose of the study. A total of 200 respondents were selected purposively for the study. Purposive selection was done to obtain the sample that possessed almost all the electrical appliances in the kitchen in order to fulfil the objective of the study.

3 Results and Discussion

A. ***Personal and background information of the respondents***

This section contains the background information of the respondents pertaining to age, educational qualification, income, type of family etc. Data of the respondents are presented in Table 1. It reveals that there is almost equal distribution of respondents in the age group 26–35(31.5%) and 36–45 years (30.5%). Cent per cent of the respondents were female. It may be due to the fact that, in Indian culture, we have a mind set up that the kitchen is a woman's domain and any involvement with that area would be discouraged. It is clear from the table that the majority of the respondents were married (99%). Sixty-eight per cent of the respondents belong to nuclear family and 74.5% of the respondents reported that about two to five members are present in their family.

B. ***Possession of Consumer Electronic Products***

Consumer electronic products especially the cooking appliances have become a part and parcel of our life today. Market is flooded with new equipments every other day to alleviate the burden of fatigue of the women. The appliances are no longer, a status symbol it has become the need of the hour and in today's world, it is not possible to imagine a kitchen without the modern appliances like refrigerator, mixer grinder, microwave oven etc.

From Fig. 1, it is seen that all the respondents had refrigerator, microwave oven and mixer grinder in their homes. Almost an equal distribution of the respondents (73.5%) had rice cooker and electric kettle (72.5%). About half of them, 53.0% possessed induction, 50.5% had toaster and 48.5% had round ovens in their homes. Jack Hulme. J Beaumon. A and Summers C (2013) in The Energy Follow-Up Survey

Table 1 General characteristics of the respondent

Age 1. 26–35 yrs 2. 36–45 yrs 3. 46–55 yrs 4. Above 55 yrs	Frequency 63 61 43 33	Percentage 31.5 30.5 21.5 16.5
Sex 1. Male 2. Female	– 200	0 100.0
Marital status 1. Married 2. Single	198 2	99.0 1.0
Type of family 1. Nuclear 2. Joint	136 64	68.0 32.0
Number of family members 1. 2–4 2. 5–7 3. 8–10 4. Above 10	149 46 2 2	74.5 23.0 1.5 1.0
Educational qualification 1. Higher Secondary 2. Graduation 3. Post-graduation	10 110 80	5.0 55.0 40.0
Income of the family 1. Rs 30,000-Rs 60,000 2. Above 60,000	44 156	22.0 78.0
Occupation of the respondents 1. Housewife 2. Office job 3. Teaching 4. Business 5. Others	71 30 51 21 27	35.5 15.0 25.5 10.5 13.5

(EFUS) has collected ownership and use patterns for key appliances across England and reported that approximately 80% of households have a microwave. In case of India, baked items were not a part of our cuisine so baking was not a very common practice in India. When cakes became very common then Indian families started owning electric ovens. Microwave oven has become very popular in India nowadays. The major turnaround was the intelligent marketing campaign that we can make even Indian dishes in them. They come with a preset menu for Indian cuisine even. Almost every middle class family owns either OTG or Microwave Oven these days.

C. ***Usage of cooking equipment***

Though microwave oven is present in every household but only 26.5% of the respondent use it daily and similar percentage of the respondents 26.5 used microwave twice in a week. Refrigerator was used daily by the respondent, which indicates that the respondents were fully dependent on it. The next daily used equipment is mixer

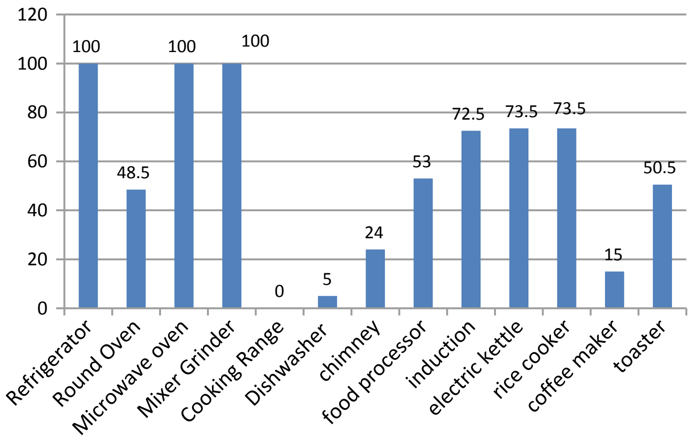


Fig. 1 Possession of cooking equipments

grinder (73%). Previously, grinding stone was a commonly used thing in every household but with the coming of the mixer grinder, people started using mixer grinder, which not only removed the drudgery of the women but was also a very time saving device. From Table 2, it is seen that electric kettle and rice cooker were used daily by 39.5% and 36% of the respondents, respectively. Electric kettle was mostly used more in winter season as compared to summers.

Table 2 Usage of cooking equipment

Equipment	Daily	Once in a week	Twice in a week	Once in a fortnight	Once in a month	Mean score	Rank
Refrigerator	200	–	–	–	–	5	I
Round oven	–	39	3	16	39	1.18	VII
Microwave oven	53	44	53	39	11	3.4	III
Food processor	–	16	–	12	2	0.45	X
Mixer grinder	146	45	7	2	–	4.67	II
Dishwasher	4	2	4	–	–	0.2	XI
Chimney	45	–	3	–	–	1.17	VIII
Coffee maker	–	28	–	–	2	0.57	IX
induction	59	43	2	2	–	1.88	V
Toaster	4	72	12	11	2	1.84	VI
Electric kettle	79	54	2	10	–	3.1	IV
Rice cooker	72	61	7	5	2	3.1	IV

Cooking equipments seem to have some time and/or labour-saving potential, owning the same does not mean that it increases the efficiency rather it is seen that all the equipments are not used to the same degree, some are used daily and some are used once in a fortnight or once in a week. From Table 2, it is seen that among all the equipments possessed by the respondents, the mostly used among all is the refrigerator followed by mixer grinder and microwave oven. It might be because of the design, performance and respondent knowledge about the product.

D. ***Problems faced by the respondents while using electronic products***

Though the modern electronic equipments are manufactured to improve the efficiency of work and make the task easier for the women so that they can manage their personal and professional lives or try to manage time but still these equipments possess a lot of problems for them. These problems are not related to the technical problem of the equipment but mostly due to usability problem so attempt was made to find out the problems faced by the respondents while using electronic products. Of all the equipments possessed by the respondents, 70.5% faced problem while using microwave oven and 69.5% faced problem with using mixer grinder. The problems reported with mixer grinder were electricity shortage, noise, frequent wear and tear of the equipment etc.

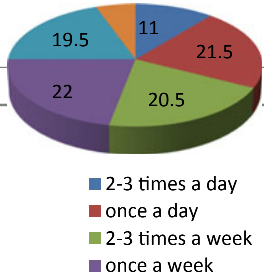
Problems faced by the respondents while using microwave were many like Product has complicated system and it is not user friendly. The microwaves designed for homes have many fancy but unnecessary features, like popcorn or pizza mode, turbo-inverter defrost and other things buttons people never use. The menu style is complicated, and it is very difficult to understand the manual and to implement it while cooking. One has to search on net to find the time and accurate temperatures for cooking respective recipes.

In case of microwave oven, it was mostly because of usability problem. Since consumer complaints were so divergent, from misunderstanding to maintenance, the complaints were divided into six categories according to the type of complaint [4]:

- Awareness-related complaint: difficulties in understanding, finding functions, lack of need with regard to some functions and insufficient information such as no feedback or feedforward.
- Performance-related complaint: low efficiency, slow reaction time and errors.
- Sensation-related complaint: poor sound and touch quality, heavy weight, heat generated by-products, physical fatigue of the product or concern on safety issues, and hard-to-press buttons.
- Structure-related complaint: complaints about wiring and cable system, connection, mechanical structure, shape, and the size of buttons.
- Maintenance-related complaint: dissatisfaction with service, cleaning, special care, and durability.
- Constraint-related complaint: lack of a necessary function, unimproved features compared with its previous version, low compatibility with other products, and low battery life, poor quality of manual.
- Usage of microwave oven.

Table 3 Usage of microwave oven

Frequency of use	n	%
2–3 times a day	22	11.0
Once a day	43	21.5
2–3 times week	41	20.5
Once a week	44	22.0
Once in 2 week	39	19.5
Once in a month	11	5.5



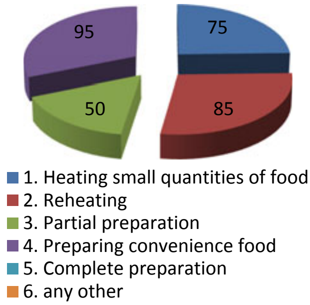


Fig. 2 Usage of microwave oven

From the study, it was seen that respondents mostly faced problems using microwave oven. So information on the use of microwave oven was studied in detail. Accordingly, it was revealed that almost equal respondents used microwave once a week (22%) once a day (21.5%) and 2–3 times a day (20.5%) (Table 3).

From Fig. 2, it was seen that 85% of the respondents used microwave oven for reheating and 75% used it for heating small quantities of food but none of the respondents used it for complete preparation. The reason behind was that the microwave oven was not user friendly. They had a problem in understanding the functions finding difficulty in using specific function. So the problems were categorized and were studied in detail.

F. Categorization of problems while using microwave

Most of the respondents 83.5% reported that users know that a function exists and has no difficulty in finding it, but they don't understand how to use it. Eighty-six per cent of the respondents complained that understanding of all functions is not easy. Similarly, 85% of the respondents have difficulty in finding a specific function.

Respondents didn't face problems in the performance of the microwave oven only 23% stated that the product is annoying, and only 29% stated that sometimes an error occurs. Only a small percentage of respondents 12.5% reported that the product is not loud enough to listen. Sixty-seven per cent were bothered about their health and stated that microwave cooking is not safe enough. Negligible per cent, 3%, stated that they feel uncomfortable because of product's mechanical structure and only 12% stated that the product is too small or big to comfortably use or press (Table 4).

Table 4 Categorization of problems while using microwave

Category	Sub category	Description	Yes	
Function	Understanding	Users know that a function exists and have no difficulty in finding it, but they don't understand how to use it	167	83.5
		Understanding of all functions is not easy	172	86.0
	Finding	Users have difficulty in finding a specific function	170	85.0
	Lack of need	Too many functions are not needed	180	90.0
		Too many functions create confusion	166	83.0
Performance	Time	Product is annoying because it is slow	46	23.0
	Error	Sometimes an error occurs that cannot be solved through a helpdesk	58	29.0
Sensation	Sound	Product is not loud	25	12
	Tactility	Users feel unpleasant touching or using product	–	–
Health	Fatigue	Users feel tired or fatigued in a part of their body while using product	3	1.5
	Safety	Users are worried about harming their health	135	67.5
Mechanism	Cable	Product is annoying because of its cable	25	12.5
	Structure	Users feel uncomfortable because of product's mechanical structure	6	3.0
	Shape	Product is too small or big to comfortably use or press. Problems occur because of its exterior form	12	6.0
	Connection	Ejecting or connecting is irritating	4	2.0
Maintenance	Service	It is difficult to get help or support. Software support is seldom updated	–	–
	Cleaning	It is annoying to clean product	25	12
	Care	Product requires more care	55	27.5
	Durability	Product is not strong or durable enough	58	29.0

(continued)

Nearly 27.5% reported that product requires more care, and 29% stated that the product is not strong or durable enough. They didn't have problems related to improvement of the product from previous version and the or the design becoming boring or old fashioned but stated that the new models of microwave are becoming very complex with many functions in it and as such fear arouses in the minds of consumers to use it. The user interface is a very important part of a program because it is the interface.

With which the user interacts with the product, good user interface helps in accepting or rejecting the equipment. It is the main reason for usage and dependency of the product by the consumers.

Table 4 (continued)

Category	Sub category	Description	Yes	
Constraint	Lack of function	Users feel a need for a specific feature or function, with which the product would be more convenient to use	125	62.5
	Lack of improvement	Product is not improved compared with its previous version	22	11.0
	Insufficient information	There is no feedback or feedforward in use	24	12.0
Trend	–	Product's design soon becomes boring or old-fashioned	22	11.0

4 Conclusion

Product profiles in terms of complexity and intimacy were predictors of the occurrence of specific soft usability problems in consumer electronic products. Electronic products requiring high cognitive load but intimate are likely to raise Awareness, Constraint, and Sensation problems, while ones requiring low cognitive load and not intimate to Maintenance, Structure, and Performance problems. These findings provide information about what factors should be taken into account in developing certain types of electronic products in order to remove the soft usability issues.

References

1. A. Broadbridge, J. Marshall, Consumer complaint behaviour: the case of electrical goods. Int. J. Retail Distrib. Manag. **23**(9), 8–18 (1995)
2. J. Goodman, D. Ward, S. Broetzmann, It might not be your product. Qual. Prog. **35**(4), 73–78 (2002)
3. Kim, C.J., H. Chrisitaans, D.J. Van Eijk, Soft problems in using consumer electronic products, in *IASDR Conference*, Hong Kong (2007)
4. D. Norman, *Emotional Design: Why We Love (or hate) Everyday Things* (ACM, New York, NY, 2004)

Chapter 3
A Systematic Literature Review on Virtual Reality-Based Fire-Safety Training in India

Anmol Srivastava

1 Introduction

Fire is hazardous and can cause severe damage to lives and properties. During fire emergencies, there is often no time to think and respond quickly, thus causing panic and severe loss to lives or properties. In the year 2015 alone, more than 18,000 fire accidents were reported [1, 2] in India. However, a study by [3] indicates that the issue of fire accidents is more severe than reported. The officials are only able to report a few cases that have been registered by the police. A lot of cases go unregistered in reality. While there can be many reasons behind fire accidents, sensitizing people regarding complications of fire and training them to handle various related situations can help facilitate preparedness during fire accidents. Typically, fire trainings are conducted in workplaces to raise fire-safety awareness and teach people regarding fire hazards. However, a quick survey and field observations reveal that such training is not conducted at regular intervals. Further, Indians who are mostly homebound, such as housewives, young children, and elders, there are no fire-safety training available them. This raises questions like how can fire-safety training be provided to the masses? Other settings where fire-safety training is conducted are in fire-fighting trainings, mining, petroleum industry, military, etc. to name a few. Even in settings that have proper setups for providing technical fire-fighting training, difficulties arise in terms of resources. As many of the training modules are built to be stationary (for example smoke chamber), it is not possible to provide training in remote areas and in locations other than the training centres. Hence, going with e-learning modules based on two-dimensional (2D) computer screens are often the best choice. However, these 2D platforms lack the immersion and experience of real-world scenarios, thus raising questions as to how can such fire-fighting and safety training be made more

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realistic? VR provides the ability to immerse in a three dimensional (3D) virtual environment thus enabling users to experience various scenarios. This capability of VR can, therefore, provide a powerful platform for fire-safety training. However, how can VR be utilized for fire-safety training in India? This paper aims to advance knowledge in the area of utilizing VR for fire-safety training in India. The intention is to provide an initial direction for research in this domain.

2 Methodology

A. *Systematic Literature Review*

A systematic literature review (SLR) was conducted based on the method discussed in the literature [4]. SLR provided an in-depth understanding of the research area in concerns and its future direction. It utilizes a systematic approach to identify literatures through a structured set of research questions. Based on the guidelines provided by literatures [4, 5], a protocol (see Fig. 1) was developed for conducting SLR.

Initially, research questions were formulated based on which search strings and literature sources were identified. After carefully reviewing the papers gathered from sources, relevant literatures that answered the formulated research questions or a part of research questions were considered for the final analysis. Title, Abstract, and Keywords (TAK) of the literatures, as described in [4], were adopted for conducting the reviews. This helped in quickly identifying relevant insights and future direction for research.

B. *Research Questions*

Published literatures on fire-safety training in VR were surveyed and reviewed. The following research questions (RQ) were formulated to conduct SLR:

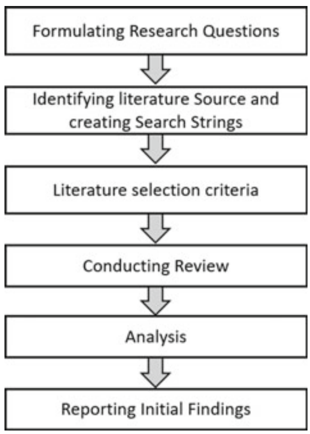

Fig. 1 Protocol for supporting systematic literature review

- RQ1: How does VR assist in fire-safety training?
- RQ2: What are the relevant areas for VR fire-safety training?
- RQ3: What type of VR hardware is utilized for VR safety training?
- RQ4: Are there any VR-related fire-safety training published research in India?

III. *Search strings, literature sources and screening process*

For the selection of literature sources, ACM, Springer Link, Science Direct and IEEE were considered. The search string was chosen based on synonyms for 'virtual reality fire training', 'fire-safety training', 'fire-hazard' and 'Virtual Reality'. As the goal of the study was to identify the current state of the art in VR fire-safety training in India, keyword 'India' was applied with the search strings, i.e. 'fire-safety training in India' AND 'virtual reality'. The instances of the search strings were also modified to 'fire-hazard training in VR in India', 'fire safety' AND 'VR' AND 'India'. It was found that there were very no search results for VR-related fire training in India to the best of author's knowledge. Hence, the scope of the literature review was broadened to consider VR-related studies outside of Indian context. In certain cases, literatures from other sources were also considered if they were addressing the research questions. Different instances of the search string were also designed in order to suit the source databases. However, the logical value was kept the same. Table 1 shows the number of search results for the search instance 'fire-safety training VR'. It was observed that the search results also displayed literatures not pertaining to fire-safety training. Hence, a critical reading approach [6] was utilized to identify relevant literatures that can address the RQs. Out of a number of literatures available from the search results, 30 (N = 30) were shortlisted for review. In the case of a few literatures, screening was done based on the in-depth reading. Table 2 depicts the total number of literatures finally selected for SLR from the selected database.

In addition to the literatures selected from databases, additional survey of VR based hardware utilized in fire training was conducted. This was conducted mainly to address RQ4.

IV. *Literature selection criteria*

Selected papers were collated in a spreadsheet format in TAK format. Further reading on TAK reading was conducted based on which duplicate studies were removed.

Table 1 Search results in literature source

Database	Search string	Number of search results
ACM	Fire-safety training VR	31,528
Science direct	Fire-safety training VR	689
Springer link	Fire-safety training VR	74
IEEE	Fire-safety training VR	3

Table 2 Search results in literature source

Database	Selected for Review
ACM	5
Science direct	9
Springer link	1
IEEE	1
Total	**16**

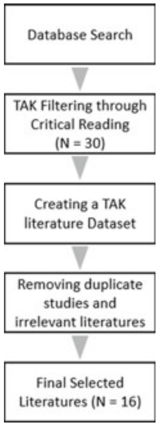

Fig. 2 Literature selection criteria

Finally, a review of N = 16 selected literatures were conducted. Figure 2 depicts the literature selection process. Section III presents a review of selected literatures.

3 Literature Review and Mapping

A. *Literature review*

Bernardes et al. [7] describe a theoretical methodological framework for providing fire-safety training to company workers in office settings. The authors [7] suggest that VR can be utilized effectively to train workers to handle real-life stress situations. Zuo-fu et al. [8] present a discussion on utilizing VR to train fire-safety professionals in hazardous conditions such as chemical leakage and fire explosions. An experience emergency training system is discussed with a posit that it will improve the emergency response among professional fire-fighting rescue team. Chun et al. [9] utilize web VR to provide collaborative immersive emergency drill training to petrochemical workers. Moreno et al. [10] studied how VR based fire-spread simulations. Various simulations dealing with fire-extinguishment actions, natural and artificial firebreaks and variable wind conditions have been discussed. Fanfarová et al. [11] propose a new

Table 3 Mapping research questions and literatures

Research questions	Literature
RQ1	[18–21]
RQ2	[8, 9, 14–16, 20] [10–12]
RQ3	[21, 22]
RQ4	–

simulation model design for fire and rescue service. The study [12] also presents VR-based simulation training of roof fall after blasting in mines. Literature [13] discusses various modalities such as screen-based, projector-based and head-mounted (HMD) type VR for training purposes. Requirements such as consideration for user task, input–output modalities and software databased requirements have been outlined. Zang et al. [14, 15] discuss a study on fire safety education. Yang et al. [16] utilize VR for gas explosion training. Kobes et al. [17] utilize VR for behavioural assessment of participants to study pre-evacuation behaviours and exit movements during fire incidents. A team-based fire-fighting training platform has been discussed by Ref. [18]. Various VR, augmented reality and haptics were utilized. A storytelling-based approach to VR fire-training has been adopted by Querrec et al. [19]. Vega et al. [20] utilize a gamified view for VR fire training for the campfire. A multi-sensorial aspect to VR fire training has been discussed in the literature [21].

B. *Mapping literatures to research questions*

Table 3 Presents the relevant literatures that addressed formulated research questions.

4 Analysis

The literature review reveals that there is a dearth of published VR-based research studies in India. The search strings, to the best of author's knowledge, did not yield any results pertaining to the use of VR-based fire-safety training in India in the searched databases. It was also identified from web searches that VR-based training modules are being developed by corporate startups in India. However, no published research evidence was found.

The review also highlights potential areas of research in this direction. These areas can be extended in the context of India for further research considerations. Figure 3 highlights potential direction for research in this area based on SLR.

Table 4 depicts the relevant literature based on which potential technologies utilized for VR fire-safety training were identified. Relevant research area for which various technological implementations have been done is highlighted. Simulation modelling has also been considered under technology emphasis as various algorithms/numerical methods have been utilized to model real-world situation and

Fig. 3 Potential research areas for VR fire-safety training identified from SLR

Table 4 VR technologies reported in literatures

Technology emphasis	Relevant topic, literature
Head-mounted HTC	Education [14, 15]
Web VR	Petro-chemical industry [7]
Multi-sensorial	Heat simulation [21]
Haptics, gestures	Using Leapmotion [13], Using Haptics [17]
Simulation modelling	Fire conditions [10], Fire simulation [11], Roof-fall [12], Numerical analysis for modelling fire [17]
Tele-presence/collaborative	[22]

behaviours in several literatures. This aspect highlights another aspect of important research area for VR safety training.

5 Conclusion

The paper presents an early work towards understanding how VR can be utilized for fire-safety training. Potential areas and research directions have been identified. However, the present search does not reveal any published research work in India. More literatures have to be surveyed in the future for gaining critical insights.

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References

1. NCRB, National Crime Records Bureau, pp. 192–206 (2013)
2. OGD, All India level Place of Occurrence-wise Number of Fire Accidents, Persons Injured and Died during 2015 | data.gov.in. https://data.gov.in/resources/all-india-level-place-occurrence-wise-number-fire-accidents-persons-injured-and-died. Accessed 17 Sep 2019
3. P. Sanghavi, K. Bhalla, V. Das, Fire-related deaths in India in 2001: a retrospective analysis of data. Lancet **373**(9671), 1282–1288 (2009)
4. A.M. Nascimento et al., *A Systematic Literature Review about the impact of Artificial Intelligence on Autonomous Vehicle Safety*, Apr. 2019
5. A. Siddaway, *What is Systematic Literature Review*?
6. Reading Critically What Needs To Be Done To Prepare For Critical Reading? What Is The Process For Reading Critically?
7. S.M.F. Bernardes, F. Rebelo, E. Vilar, P. Noriega, T. Borges, Methodological approaches for use virtual reality to develop emergency evacuation simulations for training, in emergency situations. Procedia Manuf. **3**, 6313–6320 (2015)
8. B. Zuo-fu Yua, J.-l. Guana, *Fire and Rescue Combat Technical Training System Construction for Dangerous Chemicals* (2016)
9. W. Chun, L. Lei, Y. Jiwu, Z. Liangyun, L. Gang, Development of emergency drills system for petrochemical plants based on WebVR. Procedia Environ. Sci. **10**, 313–318, Jan. 2011
10. A. Moreno, J. Posada, Á. Segura, A. Arbelaiz, A. García-Alonso, Interactive fire spread simulations with extinguishment support for Virtual Reality training tools. Fire Saf. J. **64**, 48–60, Feb. 2014
11. A. Fanfarová, L. Mariš, Simulation tool for fire and rescue services. Procedia Eng. **192**, 160–165 (2017)
12. E. Isleyen, H.S. Duzgun, Use of virtual reality in underground roof fall hazard assessment and risk mitigation. Int. J. Min. Sci. Technol. **29**(4), 603–607 (2019)
13. H. Zhang, Head-mounted display-based intuitive virtual reality training system for the mining industry. Int. J. Min. Sci. Technol. **27**(4), 717–722 (2017)
14. K. Zhang, J. Suo, J. Chen, X. Liu, L. Gao, Design and implementation of fire safety education system on campus based on virtual reality technology, in *Proceedings of the 2017 Federated Conference on Computer Science and Information Systems, FedCSIS 2017*, pp. 1297–1300, 2017
15. S. Ooi, T. Tanimoto, M. Sano, Virtual reality fire disaster training system for improving disaster awareness, in *ACM International Conference Proceeding Series*, vol. Part F1481, pp. 01–307 (2019)
16. W. Yang, G. Fu, J. Zhang, S. Qing, N. Shao, Z. Chang, Analysis and methods of the blasters' unsafe behavior taking gas explosion accident as an example. Procedia Eng. **45**, 220–224 (2012)
17. M. Kobes, I. Helsloot, B. De Vries, J. Post, Exit choice, (pre-)movement time and (pre-) evacuation behaviour in hotel fire evacuation—Behavioural analysis and validation of the use of serious gaming in experimental research. Procedia Eng. **3**, 37–51 (2010)
18. J. Lee, M. Cha, B. Choi, T. Kim, A team-based firefighter training platform using the virtual environment, in *Proceedings of the 9th ACM SIGGRAPH Conference on Virtual-Reality Continuum and its Applications in Industry—VRCAI '10*, p. 299 (2010)
19. R. Querrec, P. Chevaillier, Virtual storytelling for training: an application to fire fighting in industrial environment. Lect. Notes Comput. Sci. (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics) **2197**, 201–204 (2001)
20. J. Vega, S. Rose, C. Eckhardt, L. Tahai, I. Humer, K. Pietroszek, VR wildfire prevention: teaching campfire safety in a gamified immersive environment, in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, vol. Part F131944 (2017)

21. E. Shaw, T. Roper, T. Nilsson, G. Lawson, S.V.G. Cobb, D. Miller, The heat is on: exploring user behaviour in a multisensory virtual environment for fire evacuation, in *Conference on Human Factors in Computing Systems—Proceedings*, pp. 1–13 (2019)
22. G. Ha, H. Lee, S. Lee, J. Cha, S. Kim, A VR serious game for fire evacuation drill with synchronized tele-collaboration among users, in *Proceedings of the ACM Symposium on Virtual Reality Software and Technology, VRST*, vol. 02–04, pp. 301–302, Nov. 2016

Chapter 4
Prevalence of Occupational Risk Factors in Commercial Weaving

Geetashree Bori and Nandita Bhattacharyya

1 Introduction

Weaving is an integral part of the women of northeast India from time immemorial. With the changing time and recent development, they have adopted this home-based craft as a full-time profession. Occupational health is an important aspect in any industrial setting, which ensures the total health and safety needs, as well as the overall well-being of the workers at all workplaces. More specifically, workers' well-being is highly associated with the productivity and cost benefits of the industries. Studies have shown that occupational health problems and musculoskeletal disorders are caused due to long hours of work with traditionally designed tools and poor-ergonomic workplaces [1, 2]. Musculoskeletal disorders are the most common risk factors related to poor ergonomics. These injuries will progress to permanent problems if ignored [3]. Therefore, assorted work-related problems from spinning to weaving have been found in commercial handloom weavers.

The Handloom sector plays a very significant role in India's economy. It is an inherited tradition and one of the largest economic activities after agriculture having the capacity of absorbing a greater manpower for livelihood. As per the 3rd Handloom Census carried out by the NCAER (2009–10), more than 43 lakh people are engaged in weaving and allied activities and 77% are the women weavers. About 1.68 million handloom industries in northeast India have provided huge employment to around 4.33 million handloom workers [4]. Additionally, weaving culture is practised assiduously in the Lakhimpur district of Assam by all sections of the people. It is also known for its exclusive commercial handloom production. According to the statistical handbook of Assam (2016), a total of 97349 weavers are found engaged in this profession in the Lakhimpur district of Assam, of whom 8000 are full-time weavers while 89349 are part-time weavers [5].

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The occupational stress of the women weavers results in reduced production and early retirement due to the inefficiency of the weavers. Eventually, negligence relating to stress and fatigue may result in major occupational hazards of the weavers concerning work motivation and quality productivity. Ergonomic evaluation studies have proved the existence of health problems in commercial weavers. Musculoskeletal symptoms or problems and disorders are prevalent in carpet weavers and handloom weavers [6, 7]. In India, several studies on handloom weavers had been carried out. To cite a few: musculoskeletal pain among women weavers in India was reported by Dewangan et al. [8]; repetitive strain injury among handloom weavers was studied by Banerjee and Gangopandyay [9]; work stressors and musculoskeletal disorders in power loom and handlooms among male and female workers, Nag et al. [1], were common occupational hazards. Hence, ergonomic intervention was found necessary, Borah and Kalita [10]. Recognizing the pivotal significance of commercial weaving in the state of Assam, which provides livelihood to the majority of the population through entrepreneurial development, efforts have been made to study the occupational health problem prevalent among the commercial weavers. Based on this rationale, the present study was undertaken with the following objective—to study the prevalent occupational risk factors in different types of handloom weaving in Assam.

2 Methodology

2.1 Selection of Weaving Unit and Handloom Weavers

The present study was carried out in the Lakhimpur district of Assam through a multistage sampling design. Lakhimpur is known for its commercial handloom production (Statistical handbook of Assam 2016). To select the handloom units for the present study, a list of registered handloom weaving units under primary weaver's cooperative society (PWCS) and Self-Help Groups (SHGs) covering two sub-divisions was collected, using three types of looms, i.e., Frame loom using jacquard, frame loom using dobby, throw-shuttle loom using dobby. A total of 180 weavers, 60 weavers engaged in each category of looms were selected purposively. Each participant in the study was interviewed and observed. Various parameters were used, i.e., weight, height, and time were recorded by weighting balance, anthropometric rods, and stopwatch. QEC (Quick exposure Checklist) to assess exposure to WMSD risk factors in the workplace, RULA (Rapid Upper Limb Assessment) to evaluate the working posture, ACGIH-HAL was selected to evaluate hand activity and exertion [11–13]. Photography and video recording were performed for reviewing on-site findings. Pregnant, lactating, and weavers having chronic ailments and physical deformity were excluded from the study.

A pilot study was carried out in various weaving units. Based on the observations on different task performance, few problems were identified. Among the problems identified are the occupational health problems in current working conditions in three different types of looms. Data were collected using a questionnaire based on the following (a) Women weavers according to years of involvement; (b) Assessment of QEC and RULA; (c) Musculoskeletal problems in different body parts in three types of weaving; (d) Assessment of hand exertion in three different types of weaving.

2.2 ACGIH-HAL for Hand Activity

ACGIH-HAL was selected to evaluate the risk factors associated with weavers' hand and wrist [13]. Hand activity and the level of effort for a particular posture were evaluated while performing a short cycle task. Two factors were considered; Hand activity limit (HAL) and Normalized Peak Force (NPF) to assess the risk level. The HAL and NPF are combined on a graph showing the Threshold Limit Value (TLV) and Action Limit (AL). Here, the TLV limit is 0.78 and AL limit is 0.56. If the score of the ratio [Ratio = NPF/(10-HAL)] is greater than TLV, it indicates risk and control should be employed. If the score of the ratio between AL and TLV shows that greater than AL but not exceeding TLV, it indicates that the activity should consider risk control measures and risk monitoring. Moreover, a score below the AL indicates that nearly all workers may be repeatedly exposed without adverse health effects.

2.3 Statistical Analysis

Frequency, percentage, mean, standard deviation, critical difference, paired t-test, and one way ANOVA were worked out for different parameters, and data were interpreted by using SPSS 20.0 statistical package program.

2.4 Job Description and Task Analysis of Three Types of Handloom Weaving

Handloom is a weaving device operated wholly or partly by hand which is used to weave cloth. Commercial weavers are the professional weavers whose main occupation is weaving.

The throw-shuttle loom is a simple frame loom used to weave cloths where the shuttle is thrown from one end to the other as shown in (Fig. 1a) and the weft yarn is beaten by the reed with both the hands. The seat of a throw-shuttle loom is generally not attached to the loom. The frame loom using dobby is a fly shuttle loom as shown in (Fig. 1b). The frame loom using jacquard is a fly-shuttle loom as shown in Fig. 1c, and the seat plank is attached to the loom. Here, the weaver draws the string of the

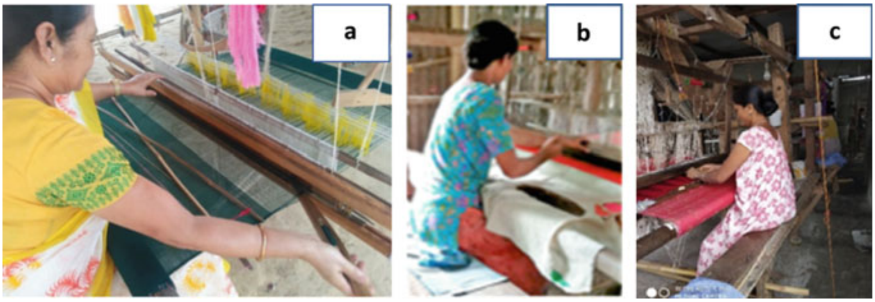

Fig. 1 **a** Throw shuttle loom using dobby **b** Frame loom using dobby **c** Frame loom using Jacquard loom

fly shuttle with a right hand and beat the weft yarn with the left hand in a rhythmic motion. Putting designs in the fabric in all the looms are mostly done by hands.

3 Results and Discussion

Occupational risk in handloom weaving while performing various weaving activities in three different types of handlooms, i.e., frame loom using jacquard, frame loom using dobby, throw-shuttle loom using dobby were assessed by observation of work practices, by using QEC, RULA, and ACGIH-HAL.

3.1 Women Weavers According to years of Involvement

Weaving is a craft that is dominated by women workforce in the north-eastern region as compared with the other states of India where weaving is mostly done by men.

Table 1 shows that 63.3% of women weavers belong to the age group of 31–40 years working for a period of 5–15 years, which shows the utter necessity of family responsibility. Involvement of the weavers working for more than 15 years

Table 1 Women weavers according to years of involvement

Serial number	Age	Frequency	Percentage	Years of involvement		
				5–10	10–15	15 and above
1	21–30	19	21.1	12	7	–
2	31–40	57	63.3	12	45	–
3	41–50	10	11.11	3	5	2
4	51–60	4	4.44	–-	2	2

belongs to the age group of 41–50 and 51–60 years, this shows the longer period of involvement of the women workforce. The hours of work were found to be 6–8 h per day for all the respondents working in three different types of handlooms (Frame loom using jacquard, frame-loom using dobby, throw-shuttle loom using dobby) and rest period was found to be 1–2 h. The workers weaved almost all products namely mekhela-chaddar, sari, bed covers, dress materials, etc.

3.2 Assessment of QEC (Quick Exposure Checklist)

The QEC (Quick exposure checklist) was assessed to check the exposure to occupational risk for work-related musculoskeletal disorders in three different types of looms.

It is revealed from the study that the score of the weavers shown in Table 2 was found to be very high in frame loom using jacquard with back 30, shoulder/arm 40, and wrist/hand 44. Frame loom using dobby and throw-shuttle loom using dobby also show a high score compared to the recommended exposure level given in Table 3. The QEC score of the neck was found to be very high in all three types of looms.

Table 4 shows the percentage rate of the exposure level in three types of looms. The percentage rate of exposure level shows a very high risk in frame loom using jacquard with 80.40% and frame loom using dobby with 74.07%. The interpretation of the action level for the QEC exposure is given in Table 5, which interprets to investigate and change immediately.

Table 2 QEC Score of the weavers in three different types of looms

Looms	Body parts			
	Back	Shoulder	Wrist	Neck
Throw shuttle loom using dobby	24	34	36	18
Frame loom using dobby	26	36	40	18
Frame loom using jacquard	30	40	44	18

Table 3 Recommended exposure level of QEC (Quick exposure checklist)

Body parts	Recommended exposure level			
	Low	Moderate	High	Very high
Back	8–15	16–22	23–29	29–40
Shoulder/arm	10–20	21–30	31–40	41–56
Wrist/hand	10–20	21–30	31–40	41–56
Neck	4–6	8–10	12–14	16–18

Source Li and Buckle [11]

Table 4 QEC exposure levels of different types of looms

Looms	Total actual exposure(X)	Percentage rate of Exposure level(E) = X/Maximum possible total(162)
Throw-shuttle loom using dobby	112	69.13
Frame loom using dobby	120	74.07
Frame loom using jacquard	132	80.40

Table 5 Interpretation of action level of QEC (Quick exposure checklist) score

Action level	Action	
	Interpretation	QEC score Total %
Acceptable risk	Acceptable	<40
Moderate risk	Investigate further	41–50
High risk	Investigate further and change score	51–70
Very high risk	Investigate and change immediately	>70

Source Li and Buckle [11]

Table 6 Interpretation of RULA (Rapid Upper limb Assessment) score

RULA score	Risk level	Interpretation
1–2	Negligible risk	Acceptable posture
3–4	Low risk	Further investigation, change may be needed
5–6	Medium risk	Further investigation, change soon
7	High risk	Investigate and implement change

Source McAtamney and Corlett [12]

3.3 Assessment of RULA (Rapid Upper Limb Assessment)

The RULA score was found between 6 and 7 points in all the three types of weaving. The mean score was found to be 6.54 ± 0.49. The highest score occurred in the right hand of frame loom using jacquard. While comparing with the interpretation given in Table 6, it was found high risk in all the three types of weaving. Therefore, the implementation of change in the loom with a proper investigation is required.

3.4 Incidence of Musculoskeletal Pain in the Body Parts

While performing the activities, the body discomfort level and the location of pain in the body parts were assessed by Borg's 10 point rating scale.

Figure 2 shows three types of looms setting, the highest incidence of pain was

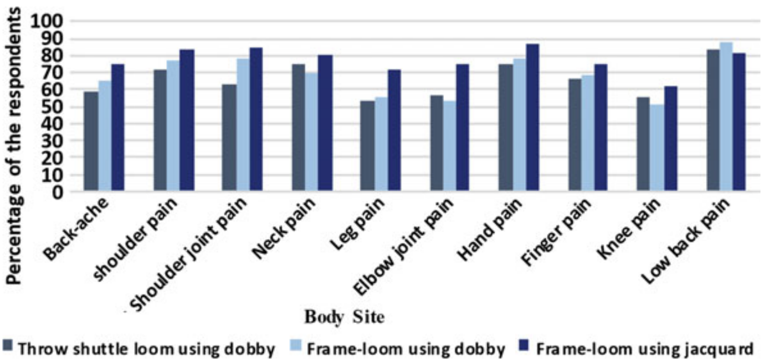

Fig. 2 Percentage of musculoskeletal pain in the body parts in three different types of weaving

found in the back, shoulder, and neck followed by hand and finger in all the three types of weaving. Repetitive hand motions as throwing the shuttle to and fro, putting designs in the fabric for a long duration leads to the incidence of musculoskeletal pain in the neck, shoulder, and hand, and occurrence of grip fatigue. However, weavers of frame loom with jacquard showed a high incidence of pain as compared to frame-loom with dobby and throw-shuttle looms with dobby. The discomfort level was found more in frame loom with jacquard than the other looms due to the height and width of the loom.

3.5 Assessment of Hand Exertion by ACGIH-HAL in Three Different Types of Weaving

The ratio score for hand activity by ACGIH-HAL (The American Conference of Governmental Industrial Hygienists for Hand Activity) is shown in Table 7. The average ratio score was found highest in frame loom using jacquard with 0.89 in the left hand and 1.04 in the right hands, respectively. The ratio scores of both hands

Table 7 Ratio score for hand activity by ACGIH-HAL method N = 180

Types of weaving	Hand exertion (mean ± SD)		
	Left hand	Right Hand	P-value
Throw shuttle loom using dobby	0.50 ± 0.21	0.56 ± 0.16	0.174
Frame loom using dobby	0.64 ± 0.23	0.86 ± 0.21	0.002
Frame loom using jacquard	0.89 ± 0.23**	1.04 ± 0.21**	0.007

**p < 0.05 ANOVA for different types of weaving

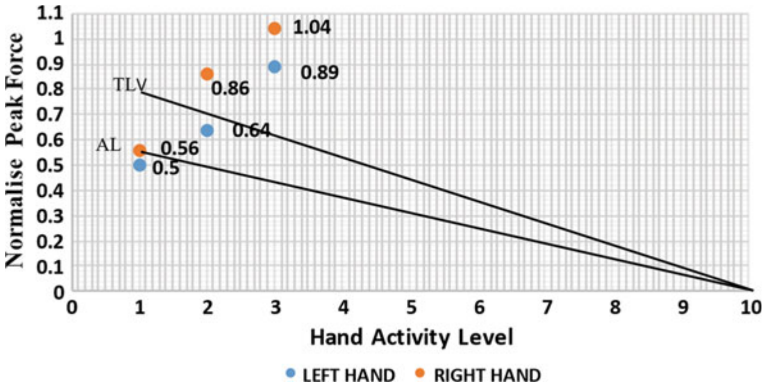

Fig. 3 AL and TLV for hand activity in handloom weaving (AL—action limit, TLV—threshold limit value)

differed according to the weaving types. In throw-shuttle loom using dobby, the hand activity of both the hands did not show a significant difference whereas in frame loom using dobby and frame loom using jacquard right-hand activity was greater, which shows the significant difference between the hands. Repetitive motion and more exertion were found in the right hand due to drawing of the string to and fro in the fly-shuttle loom. The study also shows the significant difference in hand exertion between the three types of loom (Table 7).

Figure 3 shows that the ratio score of left-hand activities was found to be 0.50 in throw shuttle loom using dobby is lower than the AL (action limit). The activities greater than AL but not exceeding TLV (threshold limit value) was found to be 0.56 and 0.64 in the right hand in throw shuttle loom using dobby and left hand in frame-loom using dobby. The activities exceeding the TLV scores were 0.86, 0.89, and 1.04 in the right hand of frame loom using dobby, and in both right and left hand in frame loom using jacquard.

4 Discussion

The preceding results of the present study reveal that work-related pain and discomfort were found in most of the weaving activities in all types of weaving namely throw shuttle using dobby, frame loom using dobby, and frame loom using jacquard due to the awkward posture and repetitive hand motion for a long duration of work. The involvement of the weavers was found between 5 and 15 years for the age group of 31–40 years, which show a long period of work. QEC score was found very high in the back and wrist for the jacquard loom, with scored high in the shoulder in three types of looms. A very high score was found in the neck due to continuous eye-hand coordination while weaving, putting designs, thread mending. RULA score was found 6–7, which revealed high risk, and shows similarities to the findings of

Chantaramanee et al. [2]. High risk in QEC and RULA score shows the requisite of immediate change and implementation. Regarding musculoskeletal pain in body parts, highest percentage of pain was found in the back, shoulder, and neck followed by hand and finger. In handloom, weaving is mostly done by hand so the ACGIH Hand activity limit was studied and found highest in frame loom using jacquard with 0.89 in the left hand and 1.04 in the right hands. The activities exceeding the TLV scores were 0.86, 0.89, and 1.04 in the right hand of frame loom using dobby, and in both right and left hand in the jacquard loom. This shows that hand tools that are not optimally designed for the female strength range might have a higher prevalence of occupational health problems due to more stress and use of the muscles, Nag et al. [14]. Thus, the findings show that frame loom using jacquard is found to have the highest risk compared to the other two types of looms. This may be due to the weaving patterns and the dimension of the looms. Handloom weaving adopts a specific posture due to task demand. Hence, an improved loom with ergonomic features considering the body dimension would help in reducing the prevalence of risk in the handloom weaver. Therefore, it is necessary to design the workstation and the hand tools to improve the working conditions of the worker and decrease the level of exposure to occupational health problems.

5 Conclusion

The study shows a high incidence of pain in the back, shoulder, neck, hand, and fingers. QEC and RULA scores were found high in all three types of weaving. Since frame-loom HWWE2019, 017, v1: 'Prevalence of occupational risk factors in commercial weaving' using jacquard is the most commercially used loom and the risk factor was also found to be more. The occupational risk factors identified were awkward postures and repetitive hand motion. Therefore, to reduce the occupational health risk of the commercial weavers, a more compatible loom and workstation should be developed. Thus, it can be concluded that ergonomically designed workstation and work tools will help in reducing the occupational health problems of the commercial weaver for higher productivity and enhance the quality of life with more work efficiency, health, and comfort of the worker.

References

1. A. Nag, H. Vyas, P. Nag, Gender differences, work stressors and musculoskeletal disorders in weaving industries. Ind. Health **48**, 339–348 (2010)
2. N. Chantaramanee, S. Taptagaporn, P. Piriyaprasarth, The assessment of occupational ergonomic risks of handloom weaving in Northern Thailand. Thammasat Int. J. Sci. Technol. **20**(4), 29–37 (2015)
3. B.C. Cooper, H. Kleiner, New developments in ergonomics. Manag. Res. News **24**(3), 114–117 (2001)

4. National Council of Applied Economic Research. Handloom Census of India 2009–10, New Delhi (2010)
5. Statistical Hand Book, Assam, 2016. Directorate of Economics and Statistics Government of Assam, Guwahati-28 (2016)
6. A. Choobineh, M. Hosseini, M. Lahmi, R.K. Jazani, H. Shahnavaz, Musculoskeletal problems in Iranian hand-woven carpet industry: guidelines for workstation design. Appl. Ergon. **38**, 617–624 (2007)
7. S. Pandit, P. Kumar, D. Chakrabarti, Ergonomic problem prevalent in handloom units of north east India. IJSRP **3**, 1 (2013)
8. K.N. Dewangan, K. Sora, Job demand and human-machine characteristics on musculoskeletal pain among female weavers in India, in *Proceedings 19th Triennial Congress of the IEA*, Melbourne, 9–14 Aug. 2015
9. P. Banerjee, S. Gangopandyay, A study on the prevalence of upper extremity repetitive strain injuries among the handloom weavers of West Bengal. J. Hum. Ergol. **32**, 17–22 (2003)
10. R. Borah, M. Kalita, Ergonomic evaluation of weaving activity and ergonomic intervention for drudgery reduction of weaver. Adv. Res. J. Soc. Sci. **7**(2), 239–244 (2016)
11. G. Li, P. Buckle, *Evaluating Change in Exposure to Risk for Musculoskeletal Disorders: A Practical Tool, HSE Contract Report 251/1999* (HSE books, Suffolk, 1999)
12. L. McAtamney, E.N. Corlett, RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**, 91–99 (1993)
13. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold l Limit Values and Biological Exposure Indices for 2001, Cincinnati, ACGIH (2001)
14. A. Nag, P.K. Nag, H. Desai, Hand anthropometry of Indian women. Indian J. Med. Res. **117**, 260–269 (2003)

Chapter 5
A Study on the Impact of Prolonged Sitting on Computer Workstation Users' Well-Being and Productivity: Punjab State Perspective

Daihrii Kholi and Lakhwinder Pal Singh

1 Introduction

A computer workstation/workplace is one where the majority of work is accomplished by using a computer, keeping a record in hard and soft copy and communicating over the telephone. Most computer workstation is sedentary in nature and often includes prolonged sitting without break. Studies have shown that prolonged sitting in the workplace often leads to discomforts and development of several health issues such as overweight, increased risk of Diabetes Mellitus, cardiovascular disease etc. Aside from overweight and Musculoskeletal Disorders (MSD), van Uffeln et al. (2010) noted in their review paper that occupational sitting is associated with higher risks of mortality [1].

Jakicic [2] shows that sedentary behaviours are positively associated with overweight and obesity [2]. Dunstan et al. [3], in their studies, concluded that the use of technology (computer) leading to prolonged sitting is associated with overweight [3]. In one study it is found that hours spend on watching television is positively associated with overweight in children [4]. Researchers had attributed the cause of overweight to physical inactivity and decrease in the rate of metabolism [5, 6]. However, studies also found no association between sitting time and overweight [7]. We, therefore, hypothesized that,

$H1_0$: There is no association between overweight and workplace sitting time.
$H1_a$: There is a significant association between overweight and workplace sitting time.

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US Bureau of Labor Statistic (www.bls.gov) reported that MSD is the single largest category of workplace injuries. MSD are injuries and disorders, which affect human body movement or musculoskeletal system, i.e. ligaments, nerves, muscles, tendons, blood vessels etc. Shariat et al. [8] found that prolonged standing and sitting induced MSD in worker's majority been back pain [8]. Moom et al. [9] pointed out there is a huge prevalence of MSD among computer bank employees in Punjab [9]. James et al. [10] showed that computer usage in university is linked with a higher risk of MSD [10]. The ill effect can be attributed to continuous static loading on the body parts and improper posture leading to unwanted stress in body parts [11]. We, therefore, hypothesized that,

$H2_0$: There is no association between MSD prevalence and workplace sitting time.
$H2_a$: There is a significant association between MSD prevalence and workplace sitting time.

Wennberg et al. [12] noted that working in a particular position for longer periods is known to induce stress and reduce concentration in workers [12]. Alkhajah et al. [13], Hall et al. [14], noted that given an option between enhanced flexible workstation and fixed workstation workers preferred working on the flexible workstation and reported significant improvement in comfort and productivity [13, 14]. Sitting for long periods can induce MSD in workers, which cause distraction and sometimes reduce mobility [13, 15].

$H3_0$: There is no association between workplace sitting time and user-perceived comforts and productivity.
$H3_a$: There is a significant association between workplace sitting time and user-perceived comforts and productivity.

Different workplace setting affects different parts of the body with different intensity, for example with adjustable monitor angles users can change according to their needs thus implying the ability to change neck posture. Michael Y Lin et al. [16] noted that different workstation setups induce different magnitudes and ranges of posture and muscle activity [16]. Kingma and van Dieen [17] noted that the removal of back support induces users to support their body weight by leaning forward and placing their forearms on the desks [17]. We, thus, hypothesized that,

$H4_0$: There are no differences in the degree of impact of different workstation setups on the prevalence of various discomfort.
$H4_a$: There is a significant difference in the degree of impact of different workstation setups on the prevalence of various discomfort.

Studies also have shown that the effect on health varies across socio-economic structure, the difference in food habits, ethnicity etc. [6, 15]. The aim of this paper was to study the impact of computer workstation on workers' well-being and productivity of Punjab State, and also study the impact of various workstation setups on the prevalence of various discomforts.

2 Methodologies

A. *Study Design*

Participants are selected from across the different regions of Punjab and across the different workplaces. A self-assessment questionnaire is designed, and data are collected physically on printed pages or through Google Form (Questionnaire is given in Appendix 1). Snowball sampling method was adopted and a total of 263 candidates submitted the feedback form within a period of September 18–January 19, the sample size was determined using the equation:

$$SS = \frac{Z^2 * P(1 - P)}{C^2} \quad (1)$$

where.

SS = Sample size.

Z = Standard normal deviation.

P = Proportion of the target population with a particular characteristic.

C = Confidence interval.

Snowball sampling methods were adopted so as to minimize the misreporting by the non-eligible person and also to target specified person across the different workplaces. Data analysis was carried out using a statistical tool package (SPSS v22) to test the hypothesis. The result is then used to recommend a suitable computer workstation.

B. *Inclusion and exclusion criteria of participants*

Inclusion criteria include any person who uses a computer to accomplish the majority part of their job are qualified for the study. Example: customer's attendee (calls centre) bankers, students or researchers, office staff and clerks etc. Exclusion criteria include mothers who are pregnant or in lactation periods, a person who has undergone major surgeries or sustained major injury recently.

C. *Measures*

For tabulation of body mass index (BMI), weight in kg and height in cm are collected. Continuous sitting time (CST) and daily sitting time (DST) are collected in graded range values. Perceived comfort level (PCL) and perceived levels of productivity (PLP), of the present workstation, are indicated in range 1–10, with 1 representing extremely uncomfortable/inefficient and 10 extremely comfortable/efficient, respectively. The prevalence of occurrence of various MSD or discomfort is graded accordingly as extremely frequent > very frequent > frequent > occasional > never. Information about the feature of a present workstation with respect to adjustability is graded as *Yes-Slightly-No.*

D. *Statistical Analysis*

Collected data are first exported to respective IBM SPSS (version 22) file format from both the physical forms and through Google Forms for further analysis. Descriptive statistical analysis was carried out to determine the nature of data. Spearman correlation analysis is carried out to determine the correlation between sitting time and overweight, the prevalence of MSD and perceived comfort and productivity. Next, linear regression analysis was conducted to see how well the association is explained. Furthermore, a multiple regression analysis was carried out to determine how the difference in workstation adjustability option affects the prevalence of various discomforts.

3 Results

Of the 263 participants, 179 are males and 84 are females with median ages of 25 years. Height and weight of participants range between 145–186 cm and 45–95 kg with medians of 165 cm and 66 kg, respectively. The average reported continuous and total daily sitting time is 1:30–2:00 and 5:00–6:00 h, respectively.

A. *Relationship between sitting time and overweight's*

A two-tailed Spearman's correlation yield correlation factor of 0.729, significant at 0.01 level (Table 1) indicating a strong association between daily sitting time and BMI. Linear regression analysis yielded R squared value of 0.537 significant at 95% confidence interval and linear model of:

$$BMI = 1.844DST + 0.238CST + 17.171 \tag{2}$$

Further part correlation gives 0.666 and 0.139 for daily sitting time and continuous sitting time indicating the prominent association between daily sitting time and overweight over continuous sitting time.

Table 1 Linear Regression analysis of CST and DST with BMI

Model	Unstandardized coefficients		Standardized coefficients	t	Sig	Correlations		
	B	Std. Error	Beta			Zero order	Partial	Part
Constant	17.171	0.424	–	40.524	000	–	–	–
Cont_time	0.238	0.105	0.107	2.260	0.025	0.417	0.139	0.095
Daily_sitting	1.844	0.128	0.680	14.394	0.000	0.729	0.666	0.605

Table 2 Spearman's correlation of CST with Prevalence of MSD

			Cont. time	Prevalence of (MSD)			
				Back	Shoulders	Hip/buttock	Neck
Spearman's rho	Cont. time	Correlation Coefficient	1.000	0.603**	0.567**	0.771**	0.389**
		Sig. (2-tailed)	–	0.000	0.000	0.000	0.000
		N	263	263	263	263	263

** correlation is significant at the 0.05 level (2-tailed)

B. Relationship between Continuous sitting time and prevalence of MSD

The Spearman's correlation for continuous sitting time and prevalence of various MSD is given in Table 2. The correlation factor for back, shoulders and hip/buttock pain yielded 0.603, 0.567 and 0.771, respectively, indicating a high significant strong association with continuous sitting time. However, the correlation factor for neck stiffness yielded 0.389 indicating a mild association with continuous sitting time. Further linear regression analysis of Back Pain (BP) with continuous sitting time and daily time gives Eq. (3) with R squared value of 0.371.

$$Prevalenceof\,BP = 0.478CST - 0.001DST + 1.789 \quad (3)$$

Similarly, for shoulders pain, it yielded Eq. (4) with R squared value of 0.339.

$$Prevalenceof\,SP = 0.485CST - 0.077DST + 1.177 \quad (4)$$

Also, linear regression analysis of hip/buttock (HP) gives Eq. (5) with R squared value of 0.601.

$$Prevalenceof\,HP = 0.569CST - 0.074DST + 0.856 \quad (5)$$

Thus, indicating a strong association of continuous sitting time with prevalence of back, shoulders, and hip/buttock pain and mild association with neck stiffness.

C. Relationship of sitting time with perceived comfort and productivity

Spearman's correlation of continuous sitting time with perceived Comfort and Productivity (Table 3) gives a correlation factor of −0.883 and −0.682, respectively indicating a strong negative association. Also, Spearman's correlation of daily sitting time (Table 3) yielded correlation factors −0.385 and −0.288, respectively. Moreover, Spearman's correlation of prevalence of Fatigue/Headaches (Table 3) gives correlation factors of 0.770, which also adds to the discomfort of users. Further linear regression analysis of perceived comfort with continuous sitting and daily sitting time gives Eq. (6) with an adjusted R square of 0.759

Table 3 Spearman's correlation of CST with PCL, PLP and prevalence of Fatigue

			Cont. time	Perceived		Prevalence
				Comfort	Productivity	Fatigue/Headaches
Spearman's rho	Cont. time	Correlation Coefficient	1.000	− 0.883**	− 0.682**	0.770**
		Sig. (two-tailed)	–	0.000	0.000	0.000
		N	263	263	263	263

** correlation is significant at the 0.05 level (2-tailed)

$$PCL = -1.228CST + 0.027DST + 10.654 \tag{6}$$

Similarly, perceived productivity yielded Eq. (7) with an adjusted R square of 0.515, respectively.

$$PLP = -1.040CST + 0.081DST + 9.926 \tag{7}$$

D. Degree of the impact of different workstation setup on the prevalence of various Discomforts

Spearman's correlation prevalence of various discomforts with workstation setups yields different correlation coefficient showing different degree of association. Back pain prevalence has the most degree of association with reclining chair adjustability, i.e. − 0.365, while Shoulders pain prevalence has most degree of association with chair back supports height. Similarly, hip/buttock has a high degree of association with monitor angles adjustability and table height of correlation coefficient of − 0.548 and − 0.524, respectively. Neck stiffness is highly associated with the adjustability of monitor angles with a correlation coefficient of − 0.626. However, eye strain shows little or no degree of association with the mentioned different workstation setups (Table 4).

4 Discussion

The goal of the current study is to study the impact of prolonged sitting on workers' well-being and perceived productivity. The result indicates that prolonged sitting has a negative impact on workers' well-being and productivity. The correlation coefficients range from −0.288 to as high as −0.883 indicating the variability in the association of various parameters.

The correlation coefficient of 0.740 between overweight and daily sitting time indicates a strong positive association between them, i.e. more time spent sitting at the workplace the more likely he/she will have higher BMI/overweight. Our result shows similarity with the finding of with finding of Mummery et al. [6] of 69.8%

Table 4 Spearman's correlation of various discomforts with different computer workstation setups

			Discomfort	Adjustability option for			
				Table height	Reclining chair	Monitor angle	Chair back support height
Spearman's rho	Prevalence back pain	Correlation Coefficient	1.000	–0.273**	–0.365**	–0.151**	–0.302**
		Sig. (two-tailed)	–	0.000	0.000	0.014	0.000
		N	263	263	263	263	263
	Shoulders pain	Correlation Coefficient	1.000	–0.371**	–0.305**	–0.369**	–0.591**
		Sig. (two-tailed)	–	0.000	0.000	0.000	0.000
		N	263	263	263	263	263
	Hip/buttock pain	Correlation Coefficient	1.000	–0.524**	–0.258**	–0.548**	–0.360**
		Sig. (two-tailed)	–	0.000	0.000	0.000	0.000
		N	263	263	263	263	263
	Neck stiffness	Correlation Coefficient	1.000	–0.166**	–0.626**	–0.397**	–0.394**
		Sig. (two-tailed)	–	0.007	0.000	0.000	0.000
		N	263	263	263	263	263
	Eye strain	Correlation Coefficient	1.000	–0.249**	–0.197**	–0.162**	–0.280**
		Sig. (two-tailed)	–	0.000	0.001	0.009	0.000
		N	263	263	263	263	263

** correlation is significant at the 0.05 level (2-tailed)

for workers with the daily sitting time of >6 h [6] The increased risk of overweight associated with sedentary behaviour can be attributed to the reduced metabolism rate while sitting as compared to physical workout/standing. Further Al-Ghamdi [4] found that children who spent more time watching television have a higher risk of being obese [4]. Bak et al. [7] found that there is no significant impact of occupational sitting time with obesity and rather bodyweight is a strong predictor of time spent in physical activity [7]. Our result also shows that continuous sitting time has not much a significant association with overweight. Also, as our result yielded an R square value of 0.537, which indicates that there is significant variation in overweight, which is not attributed by sitting time. These are in line with the previous finding that the risk of overweight depended on genetic makeup and lifestyle factor such as dietary intakes, cultural and social environment. Scharoun-Lee et al. [18] noted that the risk of obesity is higher in the case of historically underprivileged ethnic/racial minorities [18]. We, therefore, reject our null hypothesis that “there is no association between sitting time and overweight”, thus there is a strong positive significant association between daily sitting time and overweight. We further recommend in line with the previous finding that workplace sitting time should be minimized and that arrangement should be provided so that users can effectively work without loss of productivity [19].

The correlation coefficient for continuous sitting time and prevalence of various MSD shows that the association between them ranges from mild to strong. The association is strongest with hip/buttock pain of 0.771 correlation coefficient indicating that sitting for a longer period of time will result in the development of hi/buttock pain. Our result is in line with the previous finding that prolonged sitting leads to the development of MSD in user [20]. Fenety and Walker [21] noted that the development of MSD is due to continuous static loading on various body parts and recommend intermittent changes in postures [21]. Gallagher et al. [22] noted that continuous loading for 45 min is sufficient for onsets of MSD in users [22]. It may be noted here that our results yielded the lowest correlation between neck stiffness and sitting time while Moom et al. [9] found that among computer users of bank employees, it is predominantly prevalence after Back pain [9]. The difference in result may be explained by the adoption of an adjustable monitor angle, which promotes changes in neck posture. We, therefore, reject our null hypothesis that “Continuous sitting time has no association with prevalence of MSD”, thus from our study, we conclude “There is a varying association between continuous sitting time and prevalence of various MSD”.

The correlation coefficient shows that there is a significant negative association between users’ perceived comforts (−0.883) and productivity (−0.682) with continuous sitting time. However, there is a mild association between daily sitting time and perceived comforts (−0.385) and productivity (−0.288). The result is as expected from the previous finding that prolonged sitting leads to the development of MSD, which leads to discomforts and ultimately leads to reduced productivity. Users may forcibly sit for prolonged periods in the workplace due to organizational/business setups, which impact their perception of the workplace. Skyberg et al. [23] noted that users perceived control over their setup affect the satisfaction level of workers [23]. Furthermore, the correlation of prevalence of fatigue/headaches with continuous sitting time yielded a coefficient of 0.770, which is in agreement with the previous finding of McCrady and Levine [24] where they found that physically active workers are less vulnerable to stress [24]. Also, Thorp et al. found that users reported lesser fatigue while using sit-stand workstation [25]. Furthermore, our results have been corroborated by the finding of Kar and Hedge [26] that there is a significant reduction in short-term typing error in standing workstation without a significant reduction in speed [26]. We, therefore, reject our null hypothesis that “There is no significant association between sitting time and perceived comforts and productivity”. Thus, there is a significant negative association between continuous sitting time and users perceived comforts and productivity.

The result of correlation shows that there is a varying degree of association between various discomforts and different workstation setups. Our result is in line with the previous finding that different work setup affects different parts of users. Studies have shown that the specific placement of workstation affects different parts of the upper body [27]. Back pain is found to be mostly associated with the adjustability of the reclining chair, which may be explained as the ability of users to afford more range of motion with respect to spine motion. Studies have shown that the continuous change in the posture of the spine will enhance the flow of nutrition in the vertebral disc [28]. The association between shoulder pain and adjustability of chair back support could be attributed to the location of the support for shoulders while reclining on a chair. From the result, we find that there is a strong association between hip/buttock pain and adjustability of monitor angles and table height, the latter could be attributed to the ability to intermittently stand and work. The association between adjustability of monitor angles and hip/buttock pain could be mere coincidence and need further investigation. Furthermore, our results corroborate the finding of Young et al. [29] that viewing angles of computer monitors affect neck posture and its comfort levels [29]. The low association of eye strain with the above different setups may be due to the fact that eye strain is majorly due to the difference in intensity of the light source and also users may maintain a constant distance of viewing despite the changes in workstation setups. However, it may be noted that the majority of users, i.e. 68.45%, reported the occurrence of eye strain. Also, the correlation coefficient, i.e. 0.646 shows that prolonged continuous viewing of the computer screen is detrimental to eyes and leads to eye strain in users.

The strength of this study is that through a simple self-reported questionnaire feedback form, we are able to understand the various impact of computer workstation on users. However, the strength and result of this study should be viewed along with its limitation such as the inherent bias of respondents, limited parameters under consideration as various other office ergonomics like room temperature, amount of workload, illumination, noise level etc. can affect the comforts and productivity of workers. Future work could incorporate a larger sample size of the respondent for the study along with more parameters such as weekend leisure time activity, foods habits and other office dynamics. Also, a comparison study between the adjustable sit-stand workstation and sitting workstation could be undertaken. Furthermore, a quantitative measurement of productivity such as average words types etc. could be used to remove subjectivity and bias in reports.

5 Conclusion

In conclusion, we would recommend a reduction in prolonged sitting and daily sitting time through the addition of intermittent breaks and a means to work while standing. The majority of users reported that back pain starts developing between 1:00 and 1:30 h, we, therefore, strongly advised against continuous static posture for more than 1 h. We recommend that organizational and personal ergonomic training should be inculcated for reaping greater health and productivity benefits in tandem with previous studies [5]. Furthermore, the majority of users, i.e. 87.45%, reported that they would prefer an adjustable workstation over fixed workstation. In addition to the reduction of sitting time and adoption of adjustable workstation, we would recommend that care and emphasis should be taken so that prevalence of eye strain should be minimized. The study results provided insights into the various impact of computer workstation on users and also act as a guide for the proper design of computer workplaces.

References

1. J.G.Z. Van Uffelen et al., Occupational sitting and health risks: a systematic review. Am. J. Prev. Med. **39**(4), 379–388 (2010)
2. J.M. Jakicic, Physical_activity_and_weight_r.PDF, vol. 73, pp. 21–36 (2012)
3. D.W. Dunstan, G.N. Healy, T. Sugiyama, N. Owen, 'Too much sitting' and metabolic risk—has modern technology caught up with us? US Endocrinol. **5**, 29–33 (2009)
4. S. Al-, The association between watching television and obesity in children of school-age in Saudi Arabia. J. Fam. Community Med. **20**(2), 83 (2013)
5. G.N. Healy et al., Objectively measured sedentary time, physical activity, and metabolic risk. Diabetes Care **31**(2), 369–371 (2008)
6. W.K. Mummery, G.M. Schofield, R. Steele, E.G. Eakin, W.J. Brown, Occupational sitting time and overweight and obesity in Australian workers. Am. J. Prev. Med. **29**(2), 91–97 (2005)
7. H. Bak, L. Petersen, T.I.A. Sørensen, Physical activity in relation to development and maintenance of obesity in men with and without juvenile onset obesity. Int. J. Obes. **28**(1), 99–104 (2004)
8. A. Shariat, J.A. Cleland, M. Danaee, M. Kargarfard, B. Sangelaji, S.B.M. Tamrin, Effects of stretching exercise training and ergonomic modifications on musculoskeletal discomforts of office workers: a randomized controlled trial. Brazilian J. Phys. Ther. **22**(2), 144–153 (2018)
9. R.K. Moom, L.P. Sing, N. Moom, Prevalence of Musculoskeletal disorder among Computer Bank Office Employees in Punjab (India): a case study. Procedia Manuf. **3**, no. Ahfe, 6624–6631 (2015)
10. C. James et al., Musculoskeletal discomfort and use of computers in the university environment. Appl. Ergon. **69**(February), 128–135 (2018)
11. M.Y. Lin, A. Barbir, J.T. Dennerlein, Evaluating biomechanics of user-selected sitting and standing computer workstation. Appl. Ergon. **65**, 382–388 (2017)
12. P. Wennberg et al., Acute effects of breaking up prolonged sitting on fatigue and cognition: a pilot study. BMJ Open **6**(2), 1–9 (2016)
13. T.A. Alkhajah, M.M. Reeves, E.G. Eakin, E.A.H. Winkler, N. Owen, G.N. Healy, Sit-stand workstations: a pilot intervention to reduce office sitting time. Am. J. Prev. Med. **43**(3), 298–303 (2012)
14. J. Hall, L. Mansfield, T. Kay, A.K. McConnell, The effect of a sit-stand workstation intervention on daily sitting, standing and physical activity: protocol for a 12 month workplace randomised control trial. BMC Publ. Health **15**(1), 1–9 (2015)
15. K.I. Proper, E. Cerin, W.J. Brown, N. Owen, Sitting time and socio-economic differences in overweight and obesity. Int. J. Obes. **31**(1), 169–176 (2007)
16. M.Y. Lin, P. Catalano, H.T.H. Chan, P. Health, J.T. Dennerlein, A psychophysical protocol to develop ergonomic recommendations for sitting and standing workstations. Hum. Factors Ergon. Soc. **58**(4), 574–585 (2016)

17. I. Kingma, J.H. van Dieën, Static and dynamic postural loadings during computer work in females: sitting on an office chair versus sitting on an exercise ball. Appl. Ergon. **40**(2), 199–205 (2009)
18. M. Scharoun, J.S. Kaufman, B.M. Popkin, P. Gordon-Larsen, Obesity, race/ethnicity and life course socioeconomic status across the transition from adolescence to adulthood. J. Epidemiol. Community Health **63**(2), 133–139 (2009)
19. A. Hedge, E.J. Ray, Effects of an electronic height-adjustable worksurface on computer worker musculoskeletal discomfort and productivity. Proc. Hum. Factors Ergon. Soc. Annu. Meet. **48**(8), 1091–1095 (2004)
20. N. Gupta, C.S. Christiansen, D.M. Hallman, M. Korshøj, I.G. Carneiro, A. Holtermann, Is objectively measured sitting time associated with low back pain? A cross-sectional investigation in the NOMAD study. PLoS ONE **10**(3), 1–18 (2015)
21. A. Fenety, J.M. Walker, Short-Term effects of workstation exercises on musculoskeletal discomfort and postural changes in seated video display unit workers. Phys. Ther. **82**(6), 578–589 (2017)
22. K.M. Gallagher, T. Campbell, J.P. Callaghan, The influence of a seated break on prolonged standing induced low back pain development. Ergonomics **57**(4), 555–562 (2014)
23. K. Skyberg, K.R. Skulberg, W. Eduard, E. Skåret, F. Levy, H. Kjuus, Symptoms prevalence among office employees and associations to building characteristics. Indoor Air **13**(3), 246–252 (2003)
24. S.K. McCrady, J.A. Levine, Sedentariness at work: how much do we really sit. Obesity **17**(11), 2103–2105 (2009)
25. A.A. Thorp et al., Prolonged sedentary time and physical activity in workplace and non-work contexts. Int. J. Behav. Nutr. Phys. Act. **9**(1), 128 (2012)
26. G. Kar, A. Hedge, *Short-Term Typing Performance and Discomfort*, pp. 460–464 (2016)
27. D. Ankrum, K. Fraser, A. Plooy, R. Burgess-Limerick, The influence of computer monitor height on head and neck posture. Int. J. Ind. Ergon. **23**(3), 171–179 (1999)
28. L.L. Van Deursen, J. Patijn, J.R. Durinck, R. Brouwer, J.R. Van Erven-Sommers, B.J. Vortman, Sitting and low back pain: the positive effect of rotatory dynamic stimuli during prolonged sitting. Eur. Spine J. **8**(3), 187–193 (1999)
29. J.G. Young, M.B. Trudeau, D. Odell, K. Marinelli, J.T. Dennerlein, Wrist and shoulder posture and muscle activity during touch-screen tablet use: effects of usage configuration, tablet type, and interacting hand. Work **45**(1), 59–71 (2013)

Chapter 6
To Study the Stress Management of Women Police in Pune Urban Area

Nandini Patole, Shilpi Bora, Mahesh D. Goudar, and Abhijit Malge

1 Introduction

Stress underlies such various conditions as psychosomatic sickness, heart infections and can be a noteworthy supporter of appropriation in one's passionate social, mechanical, and family life. It occupies innovatively and individual adequacy and displays of life in a general fulfillment, so self-evident in our everyday lives. Policing is one of the most distressing occupations. Crafted by the police is to protect life what's more, property. It embraces examination of violations. Its job includes numerous difficulties, for example, experience with feared components while taking care of.

Women play an active role in the economic development of the country. Prior their job was just restricted to household exercises. However, presently, numerous ladies are selecting occupations so as to manufacture a decent vocation and give money-related help to their families. In twenty-first century, ladies enter criminal equity framework as a reaction to social powers for better assurance for ladies. Police resemble genuine saints; however, the vast majority of the general population are uninformed of the measure of pressure that police face each day. At the point when contrasted with other occupation, police employment is considered exceptionally upsetting and stress is an essential piece of the life of an expert cop. Police work includes assurance of life, protecting property through essential watch methods, implementation of laws in the spot for which the police headquarters is dependable. They are the primary line of security between the crooks and the general public.

Stress has turned into an unavoidable component of a people life in the present day world. Stress is the spin off effect of their work pressure. There is a budding preoccupation with stress as a problem within the workplace. According to Roy

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et al. [1], police occupational stress is a far-reaching issue as a result of its various negative consequences for people. Woman Police are overburdened due to irrational expectation of public. Long obligation hours, load from unrivaled officials, work under predicament and individual issues were brought up as significant purposes behind the pressure [2, 3].

Anxiety at work additionally gives a solemn hazard of lawsuit for all employers and associations conveying noteworthy liabilities for harms, terrible attention. In this way, there are unmistakably solid monetary and money-related explanations behind associations to oversee to lessen worry at work, beside the conspicuous helpful and moral contemplations. Study won't just help the investigator, but will also help the women police officials to improve their talents. Savitha [4] revealed that women police officials can identify what causes stress and accordingly take steps to prevent it. However will likewise enable the women police to improve their abilities. It has also been seen that women police can recognize what causes stress and accordingly find a way to counteract it.

Collins and Gibbs [5] discovered that the police authoritative culture and an official's workload at hand were the most elevated positioned stressors. Rossa [6] explores that women in policing have been consistently expanding and much exertion has been given to altering the workplace and making equivalent open doors in police work for women. However, law enforcement is still viewed as transcendently a male occupation. Naturally, the experience of female cops contrasts from those of their male partners and there is some proof that the working conditions are less conducive for women [7]. Women police experience certain degrees of provocation, threatening vibe, or other negative connections at work, alongside operational pressure [8].

Moreover, work of the police association between frequency of manifestation and the assessment of stressfulness is not accessible [9]. In this manner, it is sensible to scrutinize events that befall regularly, regardless of whether they are not profoundly appraised, alongside those that are exceptionally evaluated yet happen once in a while.

2 Methodology

The objective of the study was to recognize organizational stress experienced by women police personnel.

The study was conducted among police personnel in Pune city of India. There are about 17 Women Police Stations in Pune District. The sample of 50 respondents of women police officials with a total population of 11% (2017) working in Pune district of Maharashtra was chosen using random sampling method. Police Stations were randomly selected, and information were collected using questionnaire from available woman police personnels in the stations. The stress of the women police personnel is measured in a simple percentage.

3 Result

The socio-demographic data is presented in Table 1. Stress levels were further classified into low, moderate, and high though simple percentage as per the recommendation from the author who developed the questionnaire [10, 11] Table 2. The causes of organizational stress and their percentage of stress amid respondents are given in Table 2.

The information was first registered by including the scores of 25 parameters on causes of occupational stress to regulate the level of occupational stress. Each level had diverse scoring paradigm that was utilized to create a scope of all out scores. The total score ranged from 1 to 50. Using the total score, the levels of occupational stress were categorized into 3 levels as shown below

Table 1 Socio-demographic details of the respondents

Variables	Number (%)
Age (in years)	
21–25	9 (18)
26–30	18 (36)
31–35	7 (14)
36–40	5 (10)
41–45	3 (6)
46–50	6 (12)
50 and above	2 (4)
Education	
10th standard	15 (30)
HS	16 (32)
Graduation	9 (18)
Post-graduation and higher	7 (14)
Professional degree	3 (6)
Marital status	
Married	27 (54)
Unmarried/divorced/widowed	23 (46)
Family type	
Nuclear	37 (74)
Others	13 (26)
Designation (rank)	
Home guard	10 (20)
Constable	32 (64)
Assistant sub inspectors	5 (10)
Sub inspectors and grades above	3 (6)

Table 2 Causes of organizational stress with respondents

Serial no	Organisational stress	Number (%) of respondents who reported stress (Low, moderate and above)	Stress classification Low, Moderate, High
1	Staff shortages cause stress	24 (48)	Moderate
2	Lack of resources cause stress	32 (64)	Moderate
3	In equal sharing of work responsibilities cause stress	28 (56)	Moderate
4	Shift work causes stress for special cases like pregnancy, expecting mother, lactating mother, menstruation period	47 (94)	High
5	Traumatic events affects psychophysical health	38 (76)	High
6	Not finding time to stay in good physical condition	40 (80)	High
7	Working beyond working hours brings boredom	48 (96)	High
8	Noisy work area	31 (62)	Moderate
9	Inadequate or poor quality equipment/maintenance	43 (86)	High
10	Lack of a modern system/apparatus on duty	45 (90)	High
11	Occupational health issues (e.g., back pain, neck pain, joint pain)	50 (100)	High
12	Lack of training on new equipment	36 (72)	High
13	Dealing with supervisors	37 (74)	High
14	Too much computer work	22 (44)	Moderate
15	Dealing with co-workers	34 (68)	Moderate
16	Negative comments from the public	45 (90)	High
17	Not enough time available to spend with friends and family	50 (100)	High
18	Fatigue	50 (100)	High
19	Prolong standing affects physical health	50 (100)	High
20	Unequal sharing of work responsibilities	43 (86)	High

(continued)

Table 2 (continued)

Serial no	Organisational stress	Number (%) of respondents who reported stress (Low, moderate and above)	Stress classification Low, Moderate, High
21	Dealing with the court system	31 (62)	Moderate
22	Feeling like you always have to prove yourself to the organization	48 (96)	High
23	Working alone at night is risky and I don't feel good	50 (100)	High
24	I feel burn out at the end of the working day	50 (100)	High
25	My work is emotionally exhaustive	50 (100)	High

1. From score 35–50 designated High level of occupational stress
2. From 16–34 signified Moderate level of occupational stress
3. From 1–15 demonstrated low level of occupational stress.

The study initiated that the organizational stress was higher in the age group of 26–30 years as paralleled to added age groups. The organizational stress is higher among the women police personnel with designation of constable and Sub-Inspectors as compared to other posts. The respondent has also revealed that organizational stress is higher among the women police force as related to policemen (as per their individual opinion).

It can be noticed from Table 2 that higher number of women police are dealing with a problem like shift work causes stress for special cases like pregnancy, expecting mother, lactating mother, menstruation period. Due to lack of a modern system/apparatus, women police get exhausted. Around 100% stress of women police is due to occupational health issues, fatigue, night shift, inadequate equipment, negative comments from public, no time for friend and family, etc. Some of the causes for organizational stress are related to staff shortage, lack of resources, noisy work area, too much computer work, dealing with co-workers and court system to name a few where most of the women police suffering moderately dues to these reasons (Table 3).

4 Discussion

In India, there is a lack of literature on occupational stress and problems related to health among the women police personnel. The study revealed that the stress level is high in the police job for the women police force in India. It was seen that the organizational stress is more in married women working in law enforcement. This may

Table 3 Comparison of stress to socio-demographic characteristics

Variables	Number (%) on Organizational stress of the respondent
Age (in years)	
21–25	10 (20)
26–30	16 (32)
31–35	6 (12)
36–40	8 (16)
41–45	2 (4)
46–50	3 (6)
50 and above	5 (10)
Marital status	
Married	23 (46)
Unmarried/divorced/widowed	27 (54)
Designation (rank)	
Home Guard	7 (14)
Constable	23 (46)
Assistant sub inspectors	9 (18)
Sub inspectors and grades above	11 (22)

be due to that married women did not find time for their family. Particularly, female police work force face more pressure related to issues than their male partner as they deal with the family responsibilities and furthermore working in law requirement. Organizational stress was greater among the women constable it might be due to the reason that straight dealing with the community, and involved in crime enquiry and law and order maintenance [11]. According to Parashar et al. [12] and Collins and Gibbs [5], there were barely any investigations discovered that working Indian ladies face huge employment stress. Examination directed in the United Kingdom has also secured that job stress is higher among women police personnel. Occupational stress is the key sponsor of increased workloads, overtime, unfavorable work environment, and working capacity to name just a few of the many workplace hazards.

In the present study, amid the respondents, almost all the respondents have reported having physical illness such as urinary tract infection, tension, blood pressure, etc. The police job deems to levy a higher degree of stress, as well as an array of stressful circumstances, which can affect their physical, mental, and interpersonal relations [13]. The physical well-being concerns may be associated with the stressful job. In this case, there is a low productivity and low working condition among the women police personal. Police work tends to be regarded as inherently stressful because of the personal risk of exposure to confrontation and violence and the day-to-day involvement in a variety of traumatic incidents. As a result, high levels of stress-related symptoms are expected in this group of personnel. In relation to this, it has been found that sources of stress-related symptoms within police officers are significantly associated with mental ill-health. The psychological well-being, physical health, efficiency, and safety at work are important factors for any police agency to cogitate. It is essential to endorse scientific awareness and consequent conceivable interventions for the fatigued woman police.

Results specified that most recurrent stressors are dealing with family disputes, answering to a crime in progress, making life-threatening on-the-spot verdicts, and inadequate personnel were similar for both men and women [19]. Association with child crimes is a problematic charge (as by government policy women police to look into children's crimes) [14] for women police officers and it entails a superior capability and social support system in order to evade traumatization.

Manifestation of high work-related stress is a disturbing situation which desires to be addressed directly and has to be measured as a health issue. The stress may straightly distress their physical and psychological health which may result in absenteeism and poor working condition with less productivity. This may influence the crime deterrence and remedial amenities as well as their personal and familial life. Mental workouts such as yoga and meditation must be added to their (women police) day-to-day routine for at least one hour a day [4]. Savitha [4] has also added that women police officials may devote at least a few freed time every day with their families. Stress management programs, periodic health checkup, organizational elucidations to decrease stress in job, distinctive deliberations for females are few endorsements to address this solemn dispute.

5 Conclusion

Women police personnel experience significant occupational stress. Basically, women police itself and from lower post or rank suffers stress. Physical and psychological well-being issues are greater among them, which prerequisites instant consideration from the higher authorities. In this way, it's the obligation of these departments to set down arrangements for making a better workplace, both inside and outside the working spot.

References

1. B. Roy, K. Maheshkumar, A.K.I. Krishna, Assessment of psychological stress among female police personnel in Kerala **15**(10), 64–66 (2016) (Ver. VI). e-ISSN: 2279-0853, p-ISSN: 2279-0861
2. J. Brown, C. Cooper, B. Kirkcaldy, Occupational stress among senior police officers. Br. J. Psychol. **87**(1), 31–41 (1996)
3. R. Kaur, V.K. Chodagiri, N.K. Reddi, A psychological study of stress, personality and coping in police personnel. Indian J. Psychol. Med. **35**(2), 141 (2013)

4. M. Savitha, A study on stress management among women police officials. Law Order **26**, 26 (2016)
5. P.A. Collins, C.C. Gibbs, Stress in police officers: a study of origins, prevalence and severity of stress related symptoms within a county police force. Occup. Med. **53**, 256–264 (2003). https://doi.org/10.1093/occmed/kqg061 ([PubMed: 12815123])
6. I. Della-Rossa, Stress and coping in law enforcement (Doctoral dissertation, University of British Columbia) (2014)
7. C. Goto, C.J. Haney, PTSD and stressful events in police officers. (Master's Thesis) (2009)
8. J. Balkin, Why policemen don't like policewomen. J. Police Sci. Adm. **16**, 29–38 (1988)
9. J.M. Violanti, D. Fekedulegn, T.A. Hartley, L.E. Charles, M.E. Andrew, C.C. Ma, C.M. Burchfiel, Highly rated and most frequent stressors among police officers: gender differences. Am. J. Crim. Justice **41**(4), 645–662 (2016)
10. S. Bora, A. Chatterjee, S. Karmakar, D. Chakrabarti, Implementation of ergonomic design interventions to improve workplace amenities for Assam policewomen, in *International Conference on Research Into Design* (Springer, Singapore), pp. 219–229
11. G. Ragesh, H.M. Tharayil, M. Philip, A. Hamza, Occupational stress among police personnel in India. Open J. Psychiatry Allied Sci. **8**, 148–152 (2017)
12. M. Parashar, M. Singh, J. Kishore, R. Pathak, M. Panda, Prevalence and correlates of stress among working women of a tertiary health centre in Delhi, India [serial online]. Indian J. Med. Spec. (2017) 22 Feb 2017 [cited 2017 May]
13. M. Sekar, A. Subburaj, M.S. Sundaram, Policing the most stressful occupation: a study on Tamilnadu head constables. Int. J. Bus. Manag. Econ. Res. **4**(5) (2013)
14. Commonwealth Human Rights Initiative (CHRI), Rough Roads to Equality Women Police in South Asia (2015). http://www.humanrightsinitiative.org

Chapter 7
Effects of Different Types of Noise on Human Cognitive Performance

Deevesh Sharma, Monica Sharma, and Dileep Saini

1 Introduction

Noise can be defined as a subset of sound, especially when it is unpleasant or unwanted [1]. Since it is a psychological concept and subjective in nature, the perception of sound as noise may vary across individuals. Noise is pervasive in everyday life, and people are often exposed to it. With gradual industrialization, use of heavy machinery and transportation facilities at workplace, exposure to noise is growing rapidly. Prolonged exposure to noise at workplace has a substantial effect on worker's health and performance. There are several evidences of auditory and non-auditory effects of workplace noise. For example, partial or permanent hearing loss is one of the prevalent occupational disorders, often caused due to prolong exposure to noise. In non-auditory effects of noise, sleeping disturbance, annoyance, cardiovascular disease, and worker performance impairment are also well recognized. However, there are some other problems, such as communication difficulties, overexcitement and learning weakness, and lack of attention may arise at workplace due to exposure to noise [2]. Literature showed that exposure to noise at workplace significantly increased psychosocial stress and job dissatisfaction, which in turn, reduced worker's performance and productivity [3, 4]. Studies reported that exposure to noise adversely affected the ability to concentrate at work [5].

While considering the factors of noise, several studies showed that the type and the intensity level of noise play an important role in influencing human performance [5–11]. For example, intensity level of 45 dB was found better than higher intensities

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in case of reading activities and the performance of reader was found better when exposed to classical music in comparison to pop music. However, reading performance was found worst when exposed to factory noise [12]. Authors also reported that human performance in recall and recognition activities degraded with increasing noise intensity [13]. In a recent study, it has been reported that broadband noise at an intensity level of 80 dB deteriorated the recall performance of the participants [14]. In cognitive tasks, noise characteristics adversely affected human performance by increasing reaction time and/or number of errors [12, 15–17]. However, in a study of mental arithmetic task, noise intensity did not show any significant effect on the performance level, although it increased psychological fatigue [18, 19]. It was reported that exposure to high-intensity noise at work may lead the workers tired and less motivated [20]. Some authors suggested that noise intensity level did not affect human performance in visual attention tasks [21], while in contrast, a study of spatial visual attention task showed that noise at a level of 60 dB impaired performance of the participants by increasing the reaction time [8].

Furthermore, a study of inspection task reported that intermittent and random noise types had significantly affected the accuracy level in comparison to the same under continuous noise condition [22]. Authors reported that background music and office noise substantially reduced human performance in cognitive tasks [6]. In a study of cognitive tasks, including speech perception, short-term memory task, and sentence comprehension task, performance of the participants was significantly affected by the noise types, such as train noise and background speech noise [15]. In recent studies, moreover, the adverse effects of different types of noise on performance are well evident [16, 23].

Despite substantial impact of noise exposure on human performance, especially in cognitive tasks, and occupational health, there are limited studies that evaluated the effects of noise characteristics in this work setting. Only a successful empirical investigation of the effects of noise characteristics, including noise type and intensity level on human cognitive performance can lead to a valuable insight into elucidating which type of noise at what intensity level may influence human cognitive performance. The current study, therefore, is an attempt in that direction. The findings of this study may be helpful for the researchers and the ergonomists as well.

2 Methodology

A. *Materials*

(1) *Sound recorder*: In this study, a digital voice recorder (Sony corp., Japan) was used to record sound from different sources, including construction site, industry, road traffic, and railway. The present time of each sound recording was about 1 h.

(2) *Sound level meter*: The intensity of the noise generated for the experiment was assessed by a sound level meter (Smart Sensor corp., Dongguan, China).
(3) *Noise production set-up*: A personal computer (Lenovo corp.) connected with a 2.1 multimedia speakers system (Philips corp., Netherlands) was used to play the sound recordings during experiment. The intensity level of noise was controlled with the help of Sound Lock software (version 1.3.2). Sound Lock software enabled the generation of noise to maintain at a specific intensity level. The speakers were placed at a distance of 1.2 m from the ears (left and right) of the participants.
(4) *Workstation*: A 19.5 in. LED-backlit LCD display monitor (Dell corp., USA) with 497 mm diagonal screen provided an active viewing area of 435 mm horizontally and 240 mm vertically. The maximum display resolution was 1600 horizontally and 900 vertically. The screen images refreshed at a rate of 60 Hz and the response time was 5 ms. The image brightness and contrast ratio were 200 cd/m2 and 600:1, respectively. The screen display was coated with SiO2 polarize to reduce glare and reflection.
(5) *Participants*: Ten young healthy students of post-graduation program in engineering from a government institution were selected as participants by inviting through a general notice. The mean age of the participants was 27.2 (SD = 3.79) years. All the participants were male and had no history of visual or hearing problem. Before starting with the experiments, participants received theoretical as well as practical training about the experiment and became familiar with the equipment and the task requirements.

B. *Experimental design*

In this study, the experiment followed a 4 × 3 × 3 factorial design. Three independent variables, including noise type (construction noise, industrial noise, road traffic noise and railway noise), noise intensity (45, 65, and 85 dB), and task type (selective attention task, visual perception task, and concentration task) were evaluated. The combination of treatments was assigned randomly. The construction noise used in this study was a recording from a building construction site in Jaipur. The industrial noise was a recording from a bearing manufacturing industry in Jaipur. The road traffic and railway noise were recorded during rush hour from one of the busiest roads and railway junctions in Jaipur, respectively. The noise intensity levels were categorized according to the range between lowest intensity and the permissible exposure intensity for 8 h working shift in a day at a workplace.

(1) *Experimental set-up*: The experiment was conducted in a specially designed room in the laboratory. Figure 1 shows the experimental workplace configuration. The temperature and illumination level at the workplace were 23 °C and 1300–1400 lx, respectively. The monitor display

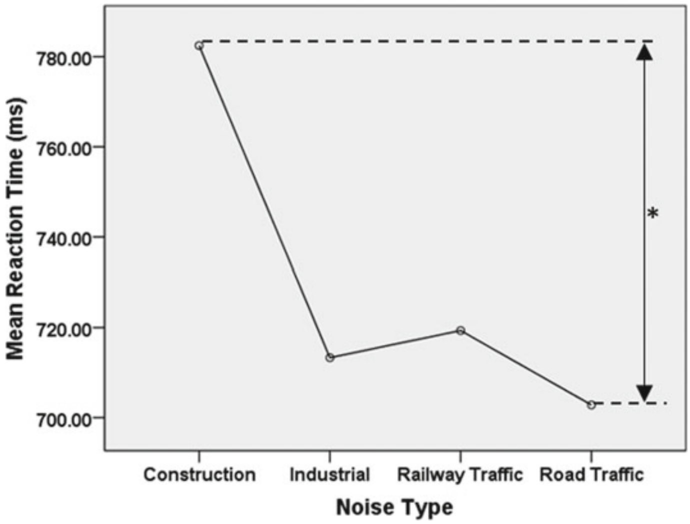

Fig. 1 Effect of noise type on mean reaction time (MRT) for stroop test

and keyboard were placed on a table 70 cm in height. The display monitor was adjusted as per the participant eye height in sitting position, in order to make the line of sight perpendicular to the display screen. A height-adjustable chair with back and arm rest was provided to the participants, and allowed to set the chair height according to their comfortable seating posture. There was no glare on the monitor screen.

(2) *Selective attention task*: Selective attention is the ability to respond to certain environmental stimuli while ignoring others, and in current research, for selective attention task the Stroop test [24] was employed. In this test, participants were provided with colored words on the monitor screen display. Looking at the display the participants had to identify the color of the font in which the text was displayed and respond accordingly, while completely ignoring the actual word meanings. For example, if the word "BLUE" in color RED is displayed on the monitor screen, the participant is expected to press the "R" button on the keyboard in order to submit a correct response. Each word was displayed on the monitor screen for 5 s and by the time participants had to submit their responses. Failing to do the same was considered as incorrect response. To complete this test each participant had to respond for 60 trails (60 colored words displayed on monitor screen) in roughly 5 min.

(3) *Visual perception task*: When objects are arranged in groups, there are always global features and individual features, and people are often faster in identifying the global features as compared to the individual features. In this study, to test the speed of visual perception of participants the Navon test [25] was employed. In the Navon test, participants had to look

at the figures, consisting of global and local features displayed on the monitor screen and respond based on the presence or absence of target letter ("H" or "O") at the local or global level. For example, if a figure made of many small letters "X" (local feature) looking like "H" (global feature), is displayed on the monitor screen; the participant is expected to press "B" button on keyboard in order to submit a correct response. Each figure was displayed on the monitor screen for 5 s during which the participant is supposed to submit the response, failing to which was considered as slow response. In this test, there were 60 trails (60 figures displayed on monitor screen) in roughly 5 min.

(4) *Divided attention task (multitasking)*: Multitasking refers to the tasks where the attention has to be rotated from one task to another, which is also called divided attention task. For experimentation purposes regarding multitasking test, shape and filling task was selected. In this task, the participant is supposed to differentiate between shapes of diamond and a square along with the number of dots filling the particular shape (two dots or three dots). The display is divided into two parts, the upper section is concerned with the shape and the bottom section is concerned with the shape filling. The shape target is a diamond shape for which the participant was expected to press "b" button on the keyboard and is a square shape is displayed the correct input would be "n" button on the keyboard. The shape filling target is two dots for which the participant was expected to press "b" button on the keyboard and if three dots are displayed the correct input would be "n" button on the keyboard. These targets are area specific on the display, for example, if a diamond shape filled with three dots was displayed on the upper section of the monitor, the correct input would be "b" button on the keyboard; if the same was displayed on the bottom section of the monitor, the correct input would be "n" as the lower section of the display is concerned with the shape filling and not the shape itself. Each figure was displayed on the monitor screen for 5 s during which the participant was supposed to submit the response, failing to which was considered slow response. In this test, there were 60 trails (60 figures displayed on monitor screen) in roughly 5 min.

(5) *Procedure*: The experiments were conducted in three consecutive days. On day one stroop test was conducted for four types of noise types and three levels of noise intensity. Ten participants were allowed to participate one at a time in random order for one experiment with first noise type and first level of noise intensity. Further again the similar procedure was used for next combination of noise type and intensity level. The experiments were kept apart by 5 min of time in order to rule out fatigue and monotony. Day two and three were conducted in same pattern for Navon test and multitasking test, respectively. The data was recorded for further study and analysis.

(6) *Study variables*: In this study, there are three independent variables which are noise intensity (dB), noise type, and task type. Here different kinds

of noises are studied on three levels of their intensities: 45 dB (low-level intensity), 65 (moderate level intensity), and 85 dB (high-level intensity), which ranged between the lowest intensity and permissible exposure intensity for working 8 h shift in a day at any workplace in India. Four type of noise types were included in the experimentation namely—construction noise, industrial noise, road traffic noise, and railway traffic noise. Three types of tasks were used in this study: Stroop task, Navon task, and multitasking task. The Stroop task is a measure of selective attention, the Navon task is a measure of visual attention or visual perception, and the Multitasking task is the measure of divided attention or rotating concentration. The dependent variables included, mean reaction time and percentage of errors. Mean reaction time was the mean of the proportion of total time taken to complete the task to the total number of trails. Percentage of error was computed by taking the percentage of the total number of incorrect response to the total number of trials.

C. *Statistical analysis*

In this study, statistical analysis was conducted using IBM SPSS 16.0. The effects of noise type and noise intensity level on the reaction time and errors under different cognitive tasks were evaluated using Analysis of Variance for repeated measures. Difference between sets of experimental conditions was tested using Bonnferroni's Multiple Comparison test. Mauchley's test was conducted to evaluate the assumption of sphercity and the Greenhouse–Geisser correction was used if the assumption was violated. Results were considered significant at $p \leq 0.05$. Effect size is reported as partial eta squared (η^2).

3 Results and Discussion

The performance of participants in terms of Mean Reaction Time (MRT) was influenced by the noise created intentionally for experimentation purposes. As seen in Tables 1, 2 and 3, there was a significant effect observed due to noise type during stroop test, Navon test, and multitasking test. The asterisk sign indicates the respective significant relationship between a factor and response. Whereas noise intensity and the interaction effect of both noise type and intensity was found to be significant only in multitasking test.

Table 1 Effects of study variables on Mean Reaction Time (MRT) for Stroop Test

Factor	F	P	η^2
Noise type	5.864	0.003*	0.394
Noise intensity	1.126	0.364	0.111
Noise type X noise intensity	1.871	0.103	0.172

Table 2 Effects of study variables on Mean Reaction Time (MRT) for Navon Test

Factor	F	P	η^2
Noise type	7.453	0.001*	0.453
Noise intensity	1.86	0.204	0.171
Noise type X noise intensity	1.541	0.183	0.146

Table 3 Effects of study variables on Mean Reaction Time (MRT) for Multitasking Test

Factor	F	P	η^2
Noise type	12.714	0*	0.586
Noise intensity	6.309	0.008*	0.412
Noise type X noise intensity	2.443	0.037*	0.214

The post-hoc analysis showed the significance within noise types or intensities for their respective significant cases as discussed previously. Figure 1, shows significance between construction noise type and road traffic ($p < 0.05$) for stroop test. In Fig. 2, the significance is even larger ($p < 0.01$) between construction noise and railway traffic noise for Navon test. Figures 3 and 4 show both low and high significance both in multitasking test. Interaction effect is highlighted in Fig. 5, for four noise types and three noise intensity levels which describes clear significance of interaction effect in the case of multitasking task.

The other indicator for performance used in this research was percentage error which was calculated after each experiment. Tables 4, 5, and 6 describe the significance of noise type only for stroop task and noise intensity proved significant for all three tasks. There was no significant interaction effect at all on errors (Fig. 6).

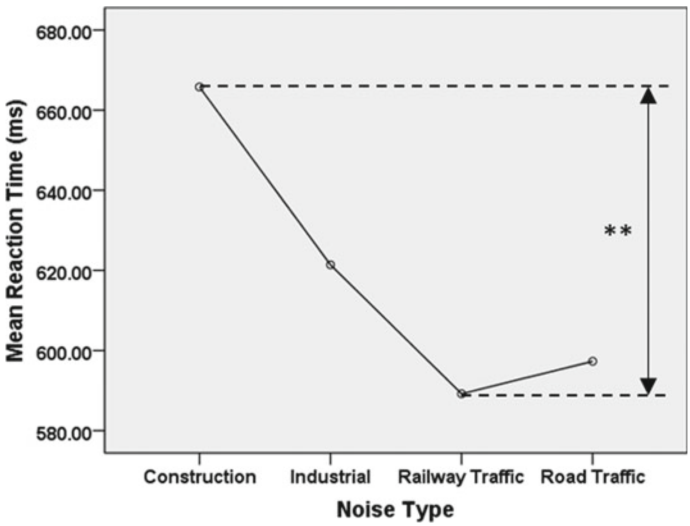

Fig. 2 Effect of noise type on mean reaction time (MRT) for navon test

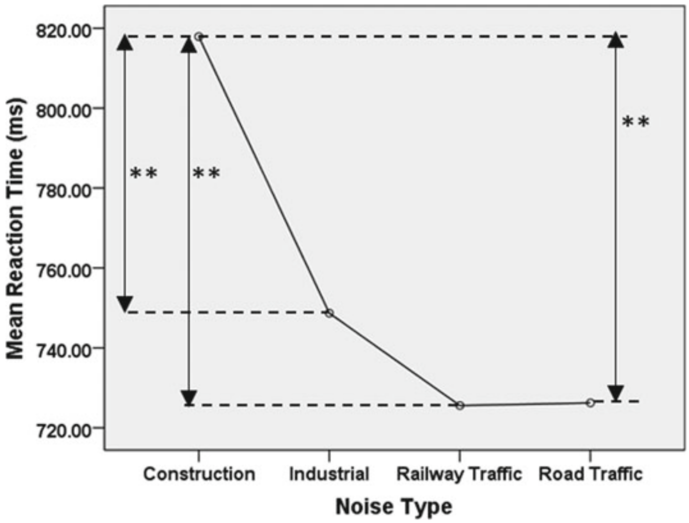

Fig. 3 Effect of noise type on mean reaction time (MRT) for multitasking test

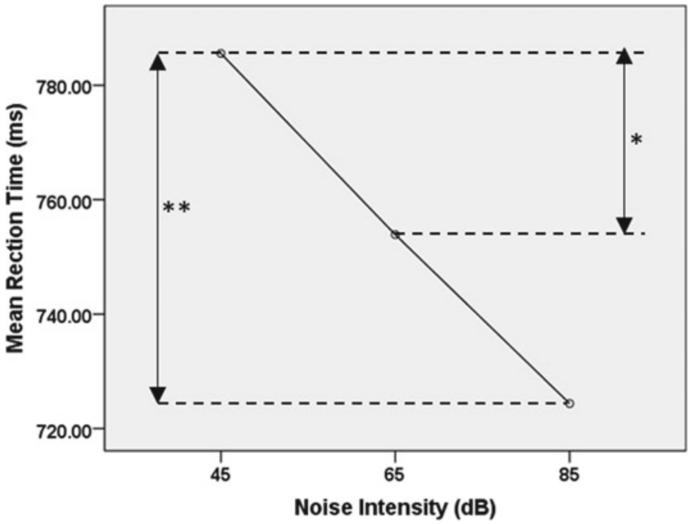

Fig. 4 Effect of noise intensity on mean reaction time (MRT) for multitasking test

Noise intensity has a significant effect on percentage of errors for all three tasks and as per Figs. 7, 8, and 9; there is significant difference between 45 and 85 dB intensity of noise. Whereas noise type was significant on errors only for the case of stroop test with maximum significant difference between construction and railway noise ($p < 0.01$).

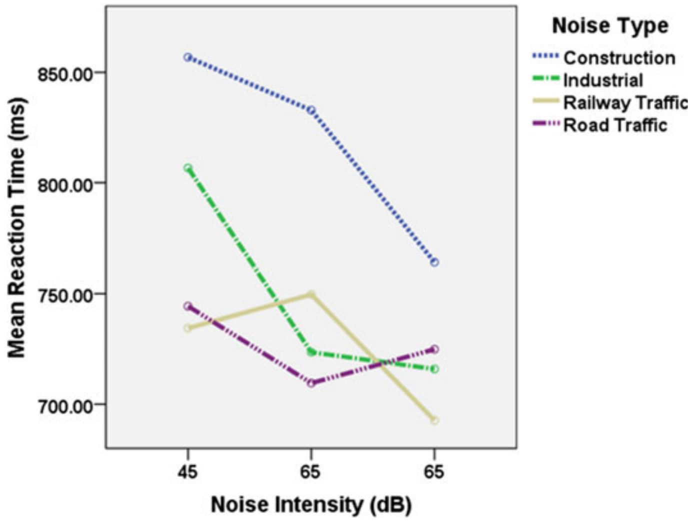

Fig. 5 Interaction effect on mean reaction time (MRT) for multitasking test

Table 4 Effects of study variables on percentage of errors for stroop test

Factor	F	P	η^2
Noise type	3.445	0.031*	0.277
Noise intensity	8.337	0.003*	0.481
Noise type X noise intensity	0.996	0.437	0.1

Table 5 Effects of study variables on percentage of errors for navon test

Factor	F	P	η^2
Noise type	0.7	0.56	0.072
Noise intensity	7.399	0.005*	0.451
Noise type X noise intensity	0.772	0.514	0.079

Table 6 Effects of study variables on percentage of errors for multitasking test

factor	F	P	η^2
noise type	0.913	0.448	0.092
noise intensity	9.708	0.001*	0.519
noise type X noise intensity	1.402	0.231	0.135

Noise type had more significant effect on MRT as compared to percentage error and railway construction noise was found to have the most negative influence on MRT. Noise intensity was found to have the most significant effect on percentage error as compared to MRT. Increased intensity of noise always showed increase in

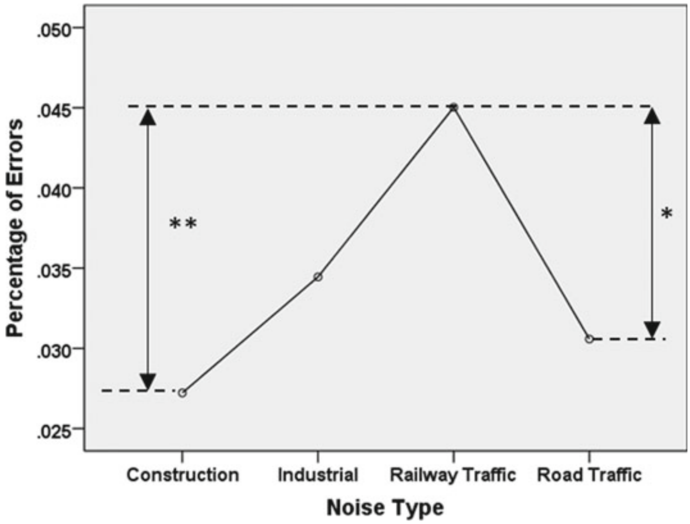

Fig. 6 Effect of noise type on percentage of error for stroop test

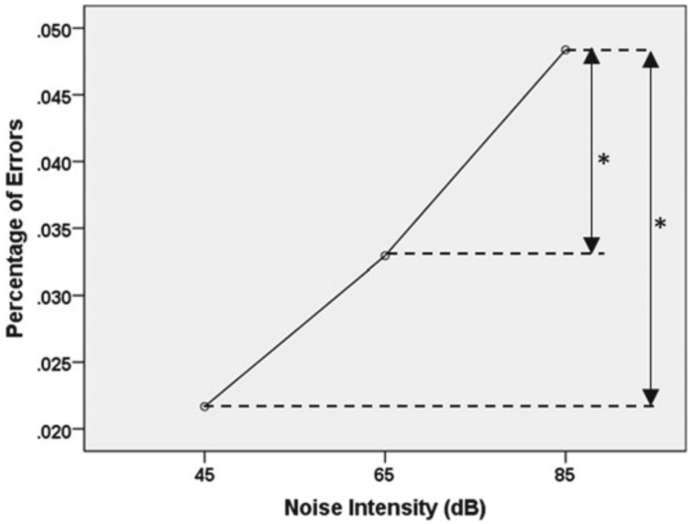

Fig. 7 Effect of noise Intensity on percentage of error for stroop test

errors in all three tasks. The interaction effect of both the factors was only found to be significant in multitasking task.

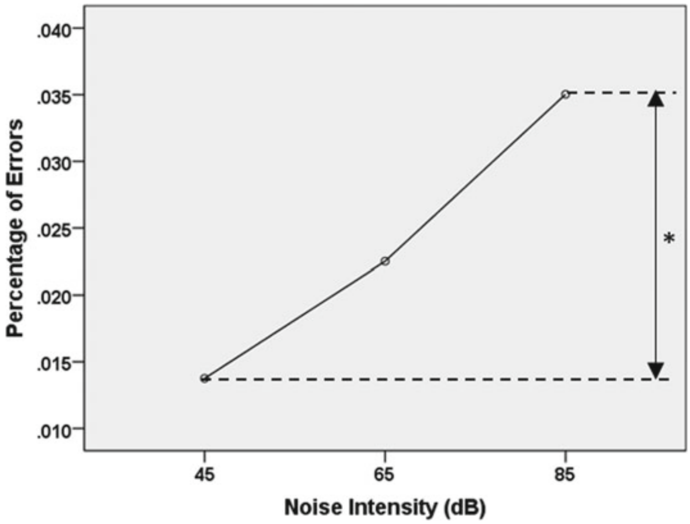

Fig. 8 Effect of noise intensity on percentage of error for Navon test

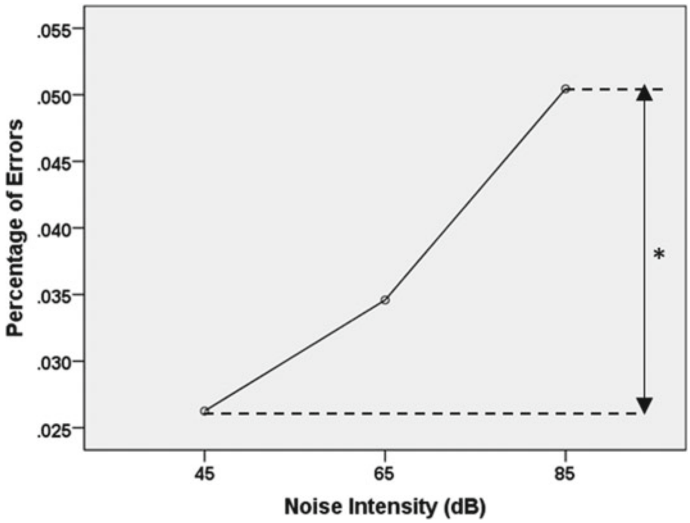

Fig. 9 Effect of noise intensity on percentage of error for multitasking test

4 Conclusion

Noise adversely affects human cognitive performance, and magnitude depends on both, type of noise and its intensity. Noise affects both changes in reaction time and errors made in cognitive performance. Noise increased reaction time for stroop task and Navon task, whereas it increased errors for all types of cognitive tasks. Some important conclusions from this study are as following:

A. Across all types of tasks including selective attention task, visual perception task, and divided attention task; type of noise played important role in influencing the mean reaction time.
B. Among four types of noise used in experimentation, construction noise was found to be contributing in maximum delay in reaction to the cognitive tasks.
C. Across all types of cognitive tasks, increasing intensity of noise proved to be the main reason behind increasing errors.
D. Only for the case of divided attention task, increasing intensity of noise reduced the mean reaction time making the subjects respond faster, but there was a very significant increase in errors. Also for this type of task, there was a significant interaction effect identified.

References

1. S. Cohen, N. Weinstein, Nonauditory effects of noise on behavior and health. J. Soc. Issues **37**(1), 36–70 (1981)
2. M. Basner et al., Auditory and non-auditory effects of noise on health. Lancet **383**(9925), 1325–1332 (2014)
3. P. Leather, D. Beale, L. Sullivan, Noise, psychosocial stress and their interaction in the workplace. J. Environ. Psychol. **23**(2), 213–222 (2003)
4. J. Akbari, H. Dehghan, H. Azmoon, F. Forouharmajd, Relationship between lighting and noise levels and productivity of the occupants in automotive assembly industry. J. Environ. Publ. Health 1–5 (2013)
5. K. Vassie, M. Richardson, Effect of self-adjustable masking noise on open-plan office worker's concentration, task performance and attitudes. Appl. Acoust. **119**, 119–127 (2017)
6. A. Furnham, L. Strbac, Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts. Ergonomics **45**(3), 203–217 (2002)
7. G. Cassidy, R.A.R. Macdonald, The effect of background music and background noise on the task performance of introverts and extraverts. Psychol. Music **35**(3), 517–537 (2007)
8. M. Trimmel, G. Poelzl, Impact of background noise on reaction time and brain DC potential changes of VDT-based spatial attention. Ergonomics **49**(2), 202–208 (2006)
9. S.P. Banbury, D.C. Berry, Office noise and employee concentration: identifying causes of disruption and potential improvements. Ergonomics **48**(1), 25–37 (2005)
10. P. Lercher, G.W. Evans, M. Meis, Ambient noise and cognitive processes among primary schoolchildren. Environ. Behav. **35**(6), 725–735 (2003)
11. L. Brocolini, E. Parizet, P. Chevret, Effect of masking noise on cognitive performance and annoyance in open plan offices. Appl. Acoust. **114**, 44–55 (2016)
12. T. Liu, C.C. Lin, K.C. Huang, Y.C. Chen, Effects of noise type, noise intensity, and illumination intensity on reading performance. Appl. Acoust. **120**, 70–74 (2017)
13. A. Kjellberg, R. Ljung, D. Hallman, Using route and survey information to generate cognitive maps. Appl. Cogn. Psychol. **22**, 1088–1098 (2008)
14. B.R.C. Molesworth, M. Burgess, S. Koh, The relationship between noise and mode of delivery on recognition memory and working memory. Appl. Acoust. **116**, 329–336 (2017)

15. M. Klatte, M. Meis, H. Sukowski, A. Schick, Effects of irrelevant speech and traffic noise on speech perception and cognitive performance in elementary school children. Noise Heal. **9**(36), 64–74 (2009)
16. S. Schlittmeier, A. Feil, A. Liebl, J. Hellbrück, The impact of road traffic noise on cognitive performance in attention-based tasks depends on noise level even within moderate-level ranges. Noise Heal. **17**(76), 148–157 (2015)
17. N. Marrone, M. Alt, G. DeDe, S. Olson, J. Shehorn, Effects of steady-state noise on verbal working memory in young adults. J. Speech, Lang. Hear. Res. **58**, no. Dec., 1793–1804 (2015)
18. G. Belojevic, E. Ohrstriim, R. Rylander, Effects of noise on mental performance with regard to subjective noise sensitivity. Int. Arch. Occup. Environ. Heal. **64**, 293–301 (1992)
19. G. Belojevic, V. Slepcevic, B. Jakovljevic, Mental performance in noise: the role of introversion. J. Environ. Psychol. **21**(2), 209–213 (2001)
20. H. Jahncke, S. Hygge, N. Halin, A.M. Green, K. Dimberg, Open-plan office noise: cognitive performance and restoration. J. Environ. Psychol. **31**(4), 373–382 (2011)
21. P. Nassiri et al., The interactive effect of industrial noise type, level and frequency characteristics on occupational skills. Perform. Enhanc. Heal. **3**(2), 61–65 (2014)
22. W. Taylor, B. Melloy, P. Dharwada, A. Gramopadhye, J. Toler, The effects of static multiple sources of noise on the visual search component of human inspection. Int. J. Ind. Ergon. **34**(3), 195–207 (2004)
23. P.J. Lee, J.Y. Jeon, Relating traffic, construction, and ventilation noise to cognitive performances and subjective perceptions. J. Acoust. Soc. Am. **134**(4), 2765–2772 (2013)
24. R. Stroop, Studies of interference in serial verbal reactions. J. Exp. Psychol. **18**(6), 643–661 (1935)
25. D. Navon, Forest before trees: the precedence of global features in visual perception. Cogn. Psychol. **9**, 353–383 (1977)

Chapter 8
Impact of Temperature on Recovery Heart Rate

Amol Mate, Shriram Sane, Varsha Karandikar, Dr. Suneeta Shriram Sane, and Vinayak Marathe

1 Introduction

In organized as well as in unorganized sector in India, the variations in thermal conditions are not adequately and accurately considered while determining standard output level for the labor and for determination of human resource requirement. Too tight allowances are unfair to the labor working in these extreme climatic conditions and too liberal allowances tend to be unfair to management and result in increasing costs. There are several environmental variables which may impact human energy consumption at workplace like temperature, noise, relative humidity, weight and others.

Considering the practical constraints of setting up of lab, equipment and severity impact of the different environmental variables, it was decided to consider one variable temperature in this research.

The experimental design itself was unique in the sense that every subject selected for the study had to undergo certain routines at different temperatures from 5 to 40 °C. It was a paired experimental design. Heart-rate of the subjects was continuously monitored at these different controlled temperatures at different levels of activity like rest, 3 miles per hour walking and 4 miles per hour walking. More than 50 volunteers undertook the arduous protocol and the data was scientifically collected.

It is well established that the speed at which heart-rate returns to normal after intense activity is a measure of the health of the subject including risk of certain diseases and fatigue. It is also considered a measure of cardiac efficiency. Typically, a recovery heart-rate of 12–15 heartbeats in one minute is considered normal for a

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normal human being. If it is lesser than 12 beats per minute, then the probability of cardiovascular diseases increases.

In this research work, heart-rate was monitored at various activity and temperature levels. The heart-rate recovery rates immediately after the exercise at the end of 1st and 2nd minute were also calculated. This paper presents the analysis of the experimental data generated during the experiments conducted in our laboratory and some initial insights from the same.

2 Literature Review

More than 50 papers were reviewed as part of the larger research. The research papers detailed below are relevant to the contents of this paper only.

Yildizel et al. [1] assessed the impact of heat stress on performance and worker health for a construction site in Moscow [1]. Temperatures were varied between 16 and 23 °C in two sets of experiments involving more than 193 workers. Impact of temperature on the current efficiency norms was also assessed. The temperature range considered was very narrow and the work severity or activity level was not controlled.

Priya Dutta et al. [2] assessed the impact of heat on health of construction workers in Ahmedabad, Gujarat [2]. Assessment was a combination of survey questionnaires, focused group discussion and onsite temperature measurements. This study highlighted high burden of heat-related discomfort and illness on the construction workers. Authors suggested that further studies estimating the exact nature of thermal loads experienced by construction workers were essential in the long-term benefit of these workers.

Sushil Kumar Dash et al. [3] did a comparative study of different heat indices in India's major metro regions based on observed and simulated data [3]. They also discuss the cyclic nature of these indices and their interannual variations. They indicated the importance of WBGT as an important heat index which needs to be developed in India. They mention about a need for further recording WBGT in different cities in India and co-relate with human comfort levels. This study did not involve experiments on actual human subjects to assess the amount of energy expended at different temperature levels.

Yanagida et al. [4] conducted experiments to monitor heart rate of professional race drivers during actual races. They found very strong positive correlation of average heart rate with speed of car and a negative correlation with temperature inside the cabin. As direct body cooling systems are deployed in professional racing, it was speculated that temperature was not positively strongly correlated with heart rate. In our setup, no special clothing is provided to subjects and hence we see significant impact on heart-rate with change in temperature levels.

KjellHausken, Sindre M Dyrstad compared heart-rate measurements and energy expenditures for four different training types [5]. Authors analyzed the exercise form Zumba and assessed how the heart-rates decrease during recovery periods. This study in 2016 validates the use of heart-rate as a measurement of energy expenditure which performing work.

Hernando et al. [6] undertook a study to validate the use of heart rate monitor RS 800 for heart rate variability analysis. This study validates our earlier assumption of using polar chest belt-based heart-rate monitor for monitoring heart-rates of the subjects during the experiments. This paper clearly suggests that the results from wearable heart-rate monitors like POLAR and ECG results are very much comparable and reliable especially when subjects are at rest, walking or low intensity exercise. As our experiments involve data collection at rest and walking, we can rely on the polar heart-rate monitor for required accuracy of measurement.

Bela Merkely, Attila Roka assessed heart-rate recovery [7] after exercise stress test and provided detailed insights into implications of cardiac therapy. Measurement of post-exercise heart rate recovery is a non-invasive method to assess parasympathetic function as heart rate deceleration during the first minute after peak exercise.

Literature review clearly indicated that impact of temperature on the recovery heart-rate after 1 and 2 min of exercise could be analyzed and any potential correlations could be explored. In this research work, heart-rate was monitored at various activity and temperature levels. The heart-rate recovery rate after 1st and 2nd^{d} minute after the exercise is also calculated. This paper helps us to validate our assumptions and our analysis approach on the experimental data generated during the experiments conducted in our lab.

3 Institutional Ethics Committee

As per the guidelines of Indian Council of Medical Research which is the apex body for the formulation, co-ordination and promotion of biomedical research funded by Government of India, an Institutional Ethics Committee was formed, as the experiments in this research work involved human participants. The ethics committee comprised of eminent Doctors, Social Workers and Researchers from Pune city along with faculty from the research institute who participated as the Chairman and Member Secretary of the committee.

Since the proposed research work involved testing of human subjects doing physical exercise like walking at various levels of temperature, a medical practitioner's guidance was availed to finalize the test protocol, during the initial stage of tests as well as during the total research period as and when required.

The ethics committee made field visits to the laboratory and laid down guidelines for experimentation on human subjects at varying temperatures.

4 Research Laboratory Design and Specifications

The research laboratory setup for this research work was called the Ergonomics and Environmental Engineering laboratory and was established at the research institute in the Department of Industrial and Production Engineering, Savitribai Phule Pune University.

The laboratory design was an insulated chamber where the human subjects could perform various experiments under homogeneous temperature conditions, with minimum loss of heat or cold air from the walls, flooring, doors and windows of the chamber.

The ambient temperature inside the laboratory could be set and controlled between −8 and +42 °C. Adequate capacity heaters and refrigeration system were installed to achieve the desired temperature setting inside the laboratory.

The laboratory had the following infrastructure.

- One treadmill
- One personal computer
- One mat for resting on floor
- One worktable
- Two chairs.

The laboratory was equipped with the following sensors and measuring equipment.

- One Polar H7 heart-rate sensor
- One Polar Watch
- Three temperature sensors
- Two relative humidity sensors
- One weighing scale
- One blood pressure monitoring apparatus.

The specifications of the laboratory are indicated in Table 1.

5 Experimental Design and Protocol

A comprehensive experimental design was finalized based on the guidelines of the institutional ethics committee, scope of research work, practical controllable factors in setting up the laboratory, safety and health of subjects involved.

The experimental design itself was unique in the sense that every subject selected for the study had to undergo certain activity routines at different temperatures from 5 to 40 °C. Throughout the temperature changes and activity routines (rest after acclimatization, walk at 3 miles per hour and walk at 4 miles per hour), a heart-rate sensor which was attached to the chest of the subject was recording the heartbeat at a sampling frequency of one second.

Table 1 Laboratory specifications

External size of chamber	14 Ft X 7.5 Ft X 8 Ft (Height)
Range of temperature	+2 to +48 °C
Refrigeration load	9,500 BTU/Chamber
Heating load	3 KW (For + 42 °C.)
Panel finish	Pre painted GI sheet on both sides
Panel thickness	60 mm
Insulation density	40 kg/cum
Floor insulation	PUF Slab
Floor finish	Aluminium chequered sheet with 6 mm marine ply backing
Door size	34″ × 72″ (Height) Inches
Door leaf thickness	60 mm thick
Exhaust fan size	8″ Dia, with side hung window
Refrigeration system	Hermetic compressor—emerson copland Condenser with fan motors Copper coils with Al fins Filter Drier Power supply—230 V, 1Ph, 50 Hz Refrigeration Capacity -10,000 BTUH Power Input—2 HP/Unit

The ambient temperature inside the laboratory was set and controlled across different predetermined set levels. Every subject was given 30 min for acclimatization to the individual temperature level (5, 10, 20, 25, 30, 40 °C) before recording heart-rate at rest. These 30 mins helped the subject's body to get used to the changed temperature setting and adjust.

The laboratory temperature and relative humidity levels from different sensors were averaged and recorded manually in a data sheet which was maintained for each subject. More than 50 human volunteers undertook the experiment.

Every subject went through the following process.

- Acclimatize at the first set temperature in the lab for 30 min
- Measure REST Heart Rate
- Walk on treadmill set at 3 Miles per hour walking speed for 3 min
- Transition to 4 Miles setting on treadmill
- Walk on treadmill set at 4 Miles per hour walking speed for 3 min
- Get down from treadmill and lie down on mat and give time to the subject to recover his heart-rate to its resting heart-rate level at that temperature
- Change the laboratory temperature setting to the next temperature level—The subject was laying on the mat and resting until the next set temperature was reached.

- After the set temperature was reached, additional 30 min of acclimatization time at rest were given to the subject to adjust the new temperature level
- Continue the same procedure at different temperature levels (5, 10, 20, 25, 30 and 40 °C)
- Refreshment break after approximately 2–2.5 h into the experiment
- At the end of experiment, data was downloaded from the chest heart rate sensor and uploaded online into the polar web-based application for further analysis
- The uploaded data was then downloaded into a defined template which contained all input data fields like age, temperature, relative humidity, heart-rate value, start and end time of the routine at different temperature levels
- The recovery heart-rate at the end of 1st and 2nd minute of end of activity were analyzed.

A dedicated research assistant was physically present in the laboratory when the experiment was being conducted and was continuously supervising the subjects and recording appropriate data.

A doctor was also arranged on call on all the days of the experiments, in case if there was any emergency and subjects needed immediate medical attention.

The rigorous experiment protocol was carried out on more than 50 human subjects during research work. The raw heart-rate and other experiment data were recorded for all these subjects.

6 Heartrate and Recovery Heart-Rate Analysis

Basic statistics of the heart-rate data like minimum, maximum, average and standard deviation across all subjects for different ambient temperature levels were established.

As seen in Table 2, average heart-rate at different work intensity levels significantly increased with increase in temperature and slightly increased at a temperature of 5

Table 2 Temperature level heart-rate data summary

Temperature (°C)	Average of average rest heart rate	Average of average heart rate during activity—3 miles per hour	Average of average heart rate during activity—4 miles per hour	Average of total heart beats—3 miles—transition—end of 4 miles
5	72	118	137	790
10	71	114	133	762
20	70	112	129	746
25	72	119	136	782
30	80	127	145	842
40	94	144	163	948

°C. The total heartbeats recorded during 3 miles per hour and 4 miles per hour activity also showed similar trends at temperature extremes (5 and 40 °C).

Total heartbeats are calculated as the sum of heartbeats recorded for all the activities of the exercise routine including walking at 3 miles per hour for 3 min, transition to 4 miles per hour and heartbeats consumed at 4 miles per hour for 3 min.

This table clearly indicated significant changes in heart-rate and total number of heartbeats at very low and high temperatures.

Table 3 shows the heart-rate recovery duration analysis. It is seen that heart-rate recovery time significantly increases with increase in temperature and slightly increases with decrease in temperature assuming baseline as 20 °C. Heart-rate recovery duration was calculated as the amount of time taken to recover to the base rest heart-rate before the experiment began at individual temperature level.

The analysis of the heart-rate recovery after 1st minute of activity at various temperature levels was analyzed and is presented in Table 4.

The table clearly indicates that average drop in heart-rate after 1st minute of activity is significantly lower at extreme temperatures like 5 and 40 °C, when compared with the average level at 20 °C. The percentage of volunteers whose heart-rate dropped less than 12 beats per minute after 1st minute was significantly high at these temperature extremes.

Table 3 Temperature Level Heart-rate Recovery Duration

Temperature (°C)	Min of heart rate recovery duration (secs)	Average of heart rate recovery duration (secs)	Max of heart rate recovery duration (secs)	StdDev of heart rate recovery duration (secs)	Rate of change of heart rate recovery with respect to base line of 20 °C
5	55	467	2169	483	1.4
10	46	385	2373	409	1.2
20	54	328	1537	328	1.0
25	59	478	2599	501	1.5
30	55	718	3214	654	2.2
40	127	1216	3073	740	3.7

Table 4 Recovery heart-rate analysis at the end of 1st minute

Temperature (°C)	Average drop in heart-rate 1st min after end of activity	% Volunteers with less than 12 heartbeats drop in heart-rate after 1st minute of exercise (%)
5	37	14
10	36	9
20	44	2
30	41	4
40	34	6

Table 5 Recovery heart-rate analysis at the end of 2nd minute

Temperature (°C)	Average drop in heart-rate 1 min after end of activity	Average drop in heart-rate 2 min after end of activity
5	37	39
10	36	31
20	44	38
30	41	14
40	34	6

Unpaired T tests performed on the above data also indicated significant impact of temperature on heart-rate recovery after 1st minute of activity compared to a comfortable temperature level of 20 °C.

The analysis of the heart-rate recovery after 2nd minute of activity at various temperature levels was also analyzed for some of the volunteers and is presented in Table 5.

As can be seen in Table 5, after 30 °C the drop in heart-rate significantly decreases at the end of 2nd minute. There were also some samples at these temperatures where the heart-rate actually started increasing in the 2nd minute after it dropped to a certain extent in the 1st minute.

The heart-rate recovery in bpm though does not vary significantly at different temperatures, the average heart-rates at higher temperatures being significantly higher at higher temperatures (refer Table 2) the total time duration for getting heart-rate back to resting heart rate are significantly higher at the higher temperatures (Refer Table 3).

7 Intial Insights from the Experiments

The raw data and basic statistical analysis of the heart-rate, number of heartbeats consumed, and heart-rate recovery clearly indicated that all these metrics significantly changed with increase in temperature toward 40 °C and slightly increased with decrease in temperature toward 5 °C.

Initial insights from the experimental data show that extreme temperatures do have significant impact on heart-rate recovery at the end of 1st and 2nd minute of activity or exercise.

There is also a likelihood that the heart-rate recovery may reverse after the 1st minute at temperatures above 30 °C which is clear indication of excess energy consumption and fatigue and stress on the cardiovascular system of the volunteers at these temperatures.

Researchers also used data collected during the experiments to estimate the heart-rate at various temperature levels using a non-linear mathematical model. An algorithm for estimating the energy consumption and allowances for various intensities of work has been established for Indian conditions across a wide alternative temperature range.

This data was used to arrive at rest allowance calculations at different temperatures and relative humidity, which were found to be significantly higher than those being used currently.

References

1. S.A. Yildizel, G. Kaplan, et al., A study on the effects of weather conditions on the worker health and performance in a construction site. J. Eng. Res. Appl. Sci. **4**(1), 291–295 (2015)
2. P. Dutta, A. Rajiva, et al., Perceived heat stress and health effects on construction workers. Indian J. Occup. Environ. Med. **19**(3), 151 (2015)
3. S.K. Dash, S. Dey et al., Comparative study of heat indices in india based on observed and model simulated data. Curr. World Environ. **12**(3), 504–520 (2017). ISSN: 0973-4929
4. R. Yanagida, K. Takahashi, M. Miura, M. Nomura, Y. Ogawa, K. Aoki, K. Iwasaki, Speed ratio but cabin temperature positively correlated with increased heart rates among professional drivers during car races. Environ. Health Prev. Med. **21**, 439–445 (2016)
5. K. Hausken, M.D. Sindre, Using heart rate monitors to assess energy expenditure in four training typesGazzetta Med. Ital. Arch. Sci. Mediche **175**,49–58 (2016)
6. D. Hernando, N. Garatachea, R. Almeida, J.A. Casajús, R. Bailón, Validation of heart rate monitor Polar RS800 for heart rate variability analysis during exercise. J. Strength Cond. Res. (2016) (Publish Ahead of Print())
7. B. Merkely, A. Roka, Assessment of heart rate recovery after exercise stress test: implications for cardiac resynchronization therapy. EP Europace **13**(4), 458–459 (2011)

Chapter 9
A Comparative Study on Health Status of Male and Female Agricultural Workers

Surabhi Singh, Santosh Ahlawat, and M. K. Chaudhary

Abbreviations

LBM-Lean Body Mass

MBF	Mass Body Fat
SLM	Soft Lean Mass
TBW	Total Body Water
PBF	Percent Body Fat
BMI	Body Mass Index
VFA	Visceral fat Area
WHR	Waist Hip Ratio
AC	Abdominal Circumference
WHR	Waist Hip Ratio
BMR	Basal Metabolic Rate

1 Introduction

The importance of agriculture in the context of the Indian economy is paramount. Not only is it a pivotal component in achieving several of India's goals—attaining food security, an 8% GDP growth rate and enhancing rural income but it is also the

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sector with the highest share of workers in the country. The average growth rate in the agriculture sector in the last five years has been 4.1% [2].

Though production in Indian agriculture has increased paramount over a decade, the health and nutritional status is still an unheeded area of concern. Researchers have indicated that farmworkers suffer from many health problems at their field due to many incongruous agents such as inappropriate working condition, dust, pesticides exposure, extreme weather and so on. Above and beyond, nutritional status of farmworkers also impacts their health condition. Top three morbidities reported in a study in south India amongst farmworkers were oral cavity, musculoskeletal system and respiratory system [7].

Few researchers stated that gender-sensitive approach to analyse health in agriculture may contribute more to inculcate advanced knowledge of gender-based health outcomes and help creating tailor future interventions and policies that meet the health needs of this diverse workforce [6]. Both genders may be affected by lack of food, still women are especially vulnerable due to their special needs associated with the biological processes of reproduction [5].

This paper examines the health of farmworkers in the Deesa Taluka of Gujarat state in India. Health of farmworkers is of special concern because of greater exposure to toxic chemicals, work-related injuries, poor working conditions and other occupational hazards. This paper makes two distinct contributions to the literature on the health of farmworkers. First, it provides a comprehensive look at farmworkers' health by using a large set of health indicators. Secondly, it will deal with various factors affecting health status of farmworkers.

Objectives of study:

- To measure body composition parameters, blood pressure and pulse rate of farmworkers
- To identify musculoskeletal disorders among farmworkers, respiratory diseases, traumatic injuries, skin diseases, infectious diseases and major illness of farmworkers
- To find out various factors affecting occupational health of farmworkers such as type of activity performed, working hours, working condition and their socio-economic characteristics.

2 Research Methodology

The research study was conducted in Deesa Taluka. Multistage random sampling was used for sample selection. Ten villages were selected randomly. From each selected village, ten male and ten female agricultural workers were selected by using simple random sampling procedure, who were actively involved in performing agricultural activities. The selected women were non-pregnant.

An interview schedule was developed to collect information on the type of agricultural activities performed by male and female agricultural workers, working hours, resting hours, type of disease and accidents they suffered from. Body fat analyzer was used to gauge BMI, MBF, PBF, VFA, WHR, etc. Digital blood pressure machine was used to measure diastolic and systolic blood pressure of agricultural workers. Pulse Oxymeter was used to measure their pulse rate.

Statistical Analysis

Statistical analysis was performed by SPSS 23 statistical software. Continuous variables are presented by mean and categorical variables as frequencies. Differences were tested using chi-square test or Fisher's exact test. The statistical significance level was set at $p = 0.05$ level of significance. Multiple Regression test was applied to investigate the effect of variables on health of agricultural workers. In multiple regression, stepwise regression technique was adopted for keeping the significant regression coefficients ($p < 0.05$) variables in the model. Because of the hierarchy principal, parameters in statistical significant interaction terms were retained in the model independently of their significance.

3 Results and Discussion

3.1 Personal Profile of Agricultural Workers

Distribution of agricultural workers according to their age indicates that more than half of the agricultural workers both male and female belonged to young age group, i.e. less than 40 years. On the contrary, 20% male and 13% female agricultural workers were from upper and old age.

Maximum agricultural workers (41%) had secondary education while maximum female agricultural workers (64%) were illiterate. Significant difference was found in educational level of male and female agricultural workers at secondary and high school levels. Maximum male and female agricultural workers, i.e. 42 and 45%, respectively, claimed that they earned ₹ 20,000–40,000 annually. Majority of the male and female agricultural workers were married. Likewise, majority of the male (74%) and female agricultural workers (83%) were living in joint family. Half of the male had more than eight members in their family while 44% female had 4–8 members in their family and 39% female had more than eight family members.

Cent per cent male and 99% female had agriculture as their main occupation while a few (13%) male workers had supporting occupation also such as dairy, shop, etc. which was significantly different in male and female (Table 1).

Table 1 Distribution of agricultural workers according to their personal profile

Age group	Male n = 100	Female n = 100	P value
	f (%)	f (%)	
Adolescent (<20yrs)	2.0	9.0	0.058
Younger (20–30yrs)	30.0	31.0	0.999
Young (30–40yrs)	25.0	30.0	0.526
Middle age (40–50yrs)	23.0	17.0	0.376
Upper age (50–60yrs)	11.0	10.0	0.999
Old age (>60yrs)	9.0	3.0	0.133
Education			
Illiterate	28.0	64.0	5.212
Primary	21.0	19.0	0.859
Secondary	41.0	15.0	**< 0.001**
High school	8.0	0.0	**0.006**
Intermediate	2.0	2.0	1.00
Income (in Rs)			
< 20,000	22.0	35.0	0.059
20,000–40,000	42.0	45.0	0.775
40,000–60,000	31.0	20.0	0.104
> 60,000	5.0	0.0	0.059
Marital status			
Unmarried	4.0	7.0	0.537
Married	96.0	93.0	0.537
Type of family			
Joint	74.0	83.0	0.168
Nuclear	26.0	17.0	0.168
Number of family members			
1–4	12.0	17.0	0.422
4–8	38.0	44.0	0.472
> 8	50.0	39.0	0.154
Occupation			
Agriculture	100.0	99.0	0.999
Supporting occupation	13.0	2.0	**0.005**

3.2 Body Composition Parameters, Blood Pressure and Pulse Rate of Farmworkers

As one of the objectives of this research is to assess various physiological parameters of agricultural workers to know their health status, BMI, LBM, MBF, PBF, protein, mineral, systolic and diastolic blood pressure and pulse rate were measured.

Table 2 points out that only 27% male and 28% female were in standard category and rest of them were either underweight or over weight. Surprisingly, more male agricultural workers were found low fat low weight as compared to female agricultural workers (27 and 16%, respectively) and significant difference (<0.001 p value) was observed between number of obese male and female (Table 3).

Mean weight of male and female agricultural workers was measured as 54.89 and 52.27 kg, respectively. Though, there was a wide difference between weights of respondents having minimum and maximum weight among both type of gender.

As far as lean body mass is concerned, mean LBM of male and female was found 44.03 and 36.49 kg, respectively. While minimum LBM of male and female agricultural workers was 15.8 and 22 kg, respectively. Similarly, maximum LBM of male agricultural workers was 64 kg and 55.5 kg for female agricultural workers.

Mean MBF of male agricultural workers was measured 10.06 kg and mean MBF of female agricultural workers was measured 15.31 kg. Mean SLM of male and female agricultural workers was 41.67 and 33.97 kg, respectively.

Mean of mineral content amongst male (3.178 kg) was little higher than mean of mineral content found amongst female agricultural workers (2.94 kg).

Mean VFA of male and female agricultural workers was measured as 78.096 cm^2 and 62.65 cm^2, respectively. The minimum VFA of male was 19.8 cm^2 which is too low than the normal range, while the maximum VFA of female was found very high than the normal one, i.e. 295 cm^2.

Mean of Abdominal circumference was found within normal range for both male and female agricultural workers. Again minimum waist hip ratio of male and female agricultural workers was 0.56 and 0.60, respectively, which is less than the normal range. Mean BMR of male, i.e. 1726 kcal was found more than the BMR of female agricultural workers, i.e. 1300 K cal.

Table 2 Distribution of agricultural workers according to their body type

S. No	Body type	Male n = 100	Female n = 100	P value
		f (%)	f (%)	
i.	Low weight	20.0	13.0	0.252
ii	Low fat low weight	27.0	16.0	**0.084**
iii	Standard	27.0	28.0	0.999
iv	Over weight	1.0	4.0	0.368
v	Obese	5.0	23.0	**< 0.001**
vi	Over fat	21.0	16.0	0.466

Table 3 Body Composition Parameters of agricultural workers

Body composition parameters	Male n = 100			Female n = 100			t-value	Sig
	Minimum	Maximum	Mean	Minimum	Maximum	Mean		
Weight (kg)	39.10	81.90	54.89	31.90	107.50	52.27	3.325	0.121
LBM (kg)	15.80	64.10	44.03	22.00	55.50	36.49	7.923	**0.000**
MBF (kg)	2.30	23.10	10.06	4.10	52.00	15.31	– 5.224	**0.000**
SLM (kg)	32.80	59.60	41.67	25.20	49.60	33.97	10.579	**0.000**
MINERAL (kg)	2.30	4.70	3.18	1.90	5.90	2.94	2.511	**0.013**
PROTEIN (kg)	6.00	13.40	9.29	5.10	9.90	7.30	12.896	**0.000**
TBW (kg)	23.50	46.20	32.09	19.60	40.00	26.69	9.141	**0.000**
PBF (%)	5.30	34.00	17.06	12.90	48.40	26.85	– 8.593	**0.000**
BMI (Kg/m^2)	15.50	27.20	19.79	14.40	45.70	22.18	– 4.049	**0.000**
VFA (Cm^2)	19.8	181.0	78.09	62.65	295	62.65	2.450	**0.015**
AC (Cm)	66.80	97.20	78.24	74.41	117.00	74.41	2.823	**0.005**
WHR	0.56	1.81	0.85	0.60	1.04	0.7806	3.175	**0.002**
BMR (K Cal)	953	1726	1246.13	850	1300.00	1114.75	6.260	**0.000**
AGE (yrs)	18	80	41.22	15	89	36.59	2.300	0.121

These findings are pointer to the fact that malnutrition occurs amongst agricultural workers. They need to be aware about balanced diet and nutrition. Temale agricultural workers were found having tendency of obtaining overweight in their upper age.

t value showed that all the body composition parameters of male agricultural workers were significantly different from female agricultural workers. It can be stated that women have different levels of body composition parameters in comparison to men (Table 4).

Blood pressure and pulse rate are important parameters to determine health of agricultural workers. Minimum systolic and diastolic blood pressure of male agricultural workers was found 103 mmHg and 58 mmHg, respectively, and for female agricultural workers 89 mmHg and 56 mmHg, respectively, which fell under the category of low blood pressure. Maximum systolic and diastolic blood pressure of

Table 4 Blood Pressure of agricultural workers

Parameters	Male n = 100			Female n = 100		
	Min	Max	Mean	Min	Max	Mean
Systolic BP (mmHg)	103	197	127.95	89	189	124.77
Diastolic BP (mmHg)	58	169	83.88	56	139	81.81
Pulse rate (BPM)	66	190	89.56	70	137	98.60

male agricultural workers and female agricultural workers were under the category of hypertension. Maximum pulse rate of male agricultural workers and female agricultural workers was found high which is an indicator of poor health. The findings are pointer to the fact that many agricultural workers were under the risk of heart diseases. High pulse rate is also associated with poor physical fitness and an independent risk factor of heart disease.

Table 5 sums up that majority of the male agricultural workers had body composition parameters below optimum level as compared to female agricultural workers. This is a sign that female agricultural workers were healthier compared to their male counterparts. Further, χ2 value signifies that there was a significant difference between parameters level of male and female agricultural workers (Table 6).

BMI is a good indicator of nutritional status of human, hence BMI of farmworkers was also measured. Findings indicate that more than half of the male agricultural

Table 5 Level of body composition parameters amongst agricultural workers

Parameters level	Male n = 100	Female n = 100	χ2 value
LBM	f (%)	f (%)	35.873**
Under	82.0	44.0	
Optimum	17.0	35.0	
Over	1.0	21.0	
MBF			11.318**
Under	52.0	30.0	
Optimum	23.0	26.0	
Over	25.0	44.0	
SLM			32.258**
Under	83.0	47.0	
Optimum	16.0	35.0	
Over	1.0	18.0	
Mineral			25.215**
Under	76.0	42.0	
Optimum	6.0	23.0	
Over	18.0	35.0	
Protein			24.772**
Under	75.0	44.0	
Optimum	24.0	41.0	
Over	1.0	15.0	
TBW level			24.728**
Under	81.0	50.0	
Optimum	17.0	32.0	
Over	2.0	18.0	

** shows that the value is highly significant at the level of .01%

Table 6 Distribution of agricultural workers according to their BMI

BMI (Kg/m^2)	Male n = 100	Female n = 100	**P value**
	f (%)	f (%)	
Under weight (<18.5)	42.0	27.0	**0.036**
Low weight (18.5–20)	23.0	15.0	0.206
Normal weight (20–25)	25.0	28.0	0.748
Obese I (25–30)	10.0	25.0	**0.008**
Obese II (>30)	0.0	5.0	0.059

workers were low and underweight and only one-fourth of them had normal weight. About 42% female were also under or low weight and only 28% were under normal category. More male were underweight in comparison to female at a significant level (P = 0.036) while female agricultural workers were observed significantly more in the obese category I than male agricultural workers (p = 0.008).

This is high time for agricultural workers to pay attention towards their health and nutritional status. Agricultural workers produce food for whole nation but they don't consume proper nutritive food (Table 7).

In accordance with Percent Body Fat, more than three-fourth of the male agricultural workers had low fat as compared to 36% female agricultural workers. Only 17% male and 26% female had normal PBF. Low PBF is the reason for poor energy level and fatigue. It may be increased by balanced diet. Per cent Body Fat was found significantly high in female agricultural workers in comparison to their male counterparts (Table 8).

The WHO states that abdominal obesity is defined as a waist–hip ratio above 0.90 for males and above 0.85 for females. Hence, 81% female and 73% male agricultural workers were normal on the basis of their WHR. While 27% male and 19% female agricultural workers were under risk of cropping up heart diseases or diabetes. In all categories of WHR, male and female agricultural workers were found significantly different.

Table 7 Distribution of agricultural workers according to their PBF

S.no	PBF (%)	Male n = 100	Female n = 100	P value
		f (%)	f (%)	
i	Very Low (<21)	74.0	29.0	2.431
ii	Low (21–23)	5.0	7.0	0.767
iii	Normal (24–30)	17.0	26.0	0.168
iv	High (31–36)	4.0	24.0	**< 0.01**
v	Very High > 36	0.0	14.0	**< 0.01**

Table 8 Distribution of agricultural workers according to their WHR

S. no	WHR	Male n = 100	Female n = 100	P Value
		f (%)	f (%)	
i	<0.85	52.0	81.0	< 0.01
ii	0.85–0.9	21.0	9.0	0.028
iii	>0.9	27.0	10.0	0.003

3.3 Musculoskeletal Disorders, Respiratory Diseases, Traumatic Injuries, Skin Diseases, Infectious Diseases and Major Illness of Agricultural Workers

Health risks in agriculture arise from various exposures, including organic and inorganic airborne dusts and gases, microbes and their toxins, chemicals including fertilisers, pesticides, physical and mechanical hazards, stress, and behavioural factors.

It is evident from Table 9 that injuries, falls, slips were reported by almost one-third of male and more than one-fourth of the female agricultural workers. Stress, hearing loss, headache and burning eyes were reported by 84, 56, 47 and 40% male agricultural workers, respectively. Highest percentage of female agricultural workers reported musculoskeletal disorders (58%) followed by chest pain 43%, abdominal pain (43%), dermatitis (43%), memory problems (40%) and vomiting (40%).

These problems may occur due to exposure to pesticides, working in extreme environment, heavy work in awkward posture, etc. Farmworkers face problems of stings and bites of various insects when they work at farm. Amongst them, mosquito, honeybee and scorpion bites were found very common reported by farmworkers. The stings and bites of insects not only cause irritation and pain while contain disease-spreading pathogens also.

Many agricultural workers reported chest pain, wheezing, shortness of breath and dry cough after getting exposed to pesticides for long hours. Moreover, 8% male and 17% female agricultural workers stated that they had asthma. Grain dust is also a cause of respiratory diseases because it is a complex substance composed of plant debris, insect parts, silica, chemical residues, molds, fungi and bacteria and their metabolites including endotoxins.

Fishers' exact test showed that some of the diseases were found statistically significantly more in female than their male counterpart such as abdominal pain ($p = 0.017$), nausea ($p = 0.024$), dermatitis ($p = < 0.01$), MSD's (p value <0.01) while wheezing was found highly significantly more in male workers (p value <0.01).

A survey of 141 agricultural workers in Texas and New Mexico found that men were 2.9 times more likely to report a back injury in the past 12 months compared to women, and were 3.0 times more likely to report a knee injury [2].

Table 9 Distribution of agricultural workers according to their health hazards

S. no	Health hazards	Male n = 100	Female n = 100	P value
		f (%)	f (%)	
1	Accidents	2.0	3.0	0.999
2	Injuries	28.0	28.0	1.00
3	Fall	33.0	26.0	0.352
4	Slip	30.0	24.0	0.425
5	Abdominal pain	26.0	43.0	**0.017**
6	Ataxia	5.0	11.0	0.191
7	Nausea	11.0	24.0	**0.024**
8	Dizziness	5.0	10.0	0.282
9	Vomiting	29.0	40.0	0.136
10	Skin or eye problems, such as rashes, inflammation or corneal ulceration	30.0	29.0	0.999
11	Dermatitis	10.0	43.0	**<0.01**
12	Fatigue	28.0	21.0	0.323
13	Headaches	47.0	57.0	0.202
14	Sleep disturbances	37.0	34.0	0.767
15	Anxiety	15.0	12.0	0.679
16	Memory problems	35.0	40.0	0.559
17	Musculoskeletal and Soft-Tissue Problems	19.0	58.0	**<0.01**
18	*Respiratory diseases*			
	Asthma	8.0	17.0	0.085
	Shortness of breath	16.0	17.0	0.99
	Wheezing	32.0	10.0	**<0.01**
	Burning eyes	**40.0**	30.0	0.181
	Chest pain	37.0	**43.0**	**0.470**
	Dry cough	34.0	36.0	0.8820
19	*Reproductive health problems*			
	Menstrual cycle disorders	–	21.0	–
	Infertility	4.0	15.0	–
	Spontaneous abortion	–	13.0	–
	Premature birth	–	2.0	–
	Pregnancy complications	–	12.0	–
20	Contact with electricity	16.0	12.0	0.541
21	Fever	6.0	32.0	**< 0.01**
23	*Stings and bites*			
	Snake	2.0	0.0	0.497

(continued)

Table 9 (continued)

S. no	Health hazards	Male n = 100	Female n = 100	P value
		f (%)	f (%)	
	Mosquito	60.0	52.0	0.318
	Honeybee	53.0	43.0	0.202
	Scorpion	52.0	18.0	**<0.01**
24	Stress	**84.0**	31.0	**<0.01**
25	Hearing loss	**56.0**	21.0	**<0.01**

3.4 Factors Affecting Occupational Health of Agricultural Workers Such as Type of Activity Performed, Working Hours, Working Condition and Their Personal, Socio-Economic Characteristics

It is apparent from the above Table 10 that majority of the male agricultural workers were involved in all types of agricultural and allied activities, whereas majority of the female agricultural workers were found indulge in harvesting (91%), livestock activities (82%) and sowing (72%). Significant difference was observed amongst types of activities performed by male and female agricultural workers (Table 11).

Table 10 Distribution of agricultural workers according to type of Activities they performed

Type of activities	Male n = 100	Female n = 100	P value
	f (%)	f (%)	
Levelling and making ridges	73.0	25.0	**<0.01**
Digging	69.0	10.0	**<0.01**
Transplanting	80.0	34.0	**<0.00**
Seed treatment	80.0	36.0	**<0.01**
Sowing	92.0	62.0	**<0.01**
Ploughing	89.0	00.0	**<0.01**
Manuring	89.0	32.0	**<0.01**
Irrigation	88.0	16.0	**<0.01**
Weeding	84.0	72.0	0.059
Harrowing	68.0	00.0	**<0.01**
Harvesting	95.0	91.0	0.406
Shelling	62.0	27.0	**<0.001**
Stripping	59.0	28.0	**<0.01**
Livestock activities	87.0	82.0	0.434

Table 11 Distribution of agricultural workers according to their working hours and resting hours

Resting hours	Male n = 100	Female n = 100	P value
	f (%)	f (%)	
1–3	72.0	59.0	**0.073**
3–5	20.0	36.0	**0.017**
5–7	6.0	3.0	0.497
>7	2.0	2.0	1
Working Hours	**f (%)**	**f (%)**	
1–3	9.0	10.0	0.999
3–5	11.0	15.0	0.528
5–7	23.0	25.0	0.868
7–9	26.0	17.0	0.168
>9	31.0	33.0	0.879

Resting hours and working hours are key factors of occupational health of agricultural workers. It was found that maximum male had 1–3 h resting period during day while more than half (59%) female had 1–3 h resting period during day.

As far as working hours are concerned, more than half of the male and half of the female worked more than 7 h during day. Almost one-third of male and female agricultural workers worked for more than 9 h a day. More working hours may cause many diseases such as sleep disturbance, weakness, fatigue, pain, etc.

Significant difference was found amongst resting hours of male and female, whereas male was taking less resting hours in comparison to female agricultural workers.

Table 12 envisages that maximum male agricultural workers had pesticide exposure of more than 10 years and majority of them were exposed to pesticides for 3–5 h in a day during working. Few of them, i.e. 18% male and 5% female agricultural workers used protective devices such as covering cloth on their mouth. 55% male and 66% female never used any protective device while spraying pesticide. This may cause severe health problems as they inhale pesticides directly into their lungs (Table 13).

It is noteworthy to know the working condition of agricultural workers as it may also affect their occupational health. More than half of the male agricultural workers reported the size, shape and weight of agricultural equipment appropriate to use. Maximum farmers (84%) performed agricultural activities under extreme outdoor environment, performed repetitive job (56%), worked with excessive noise (74%) and in bright or dim lighting (88%).

Likewise, less than half of the female agricultural workers found the size and shape of agricultural equipment appropriate and 53% female stated that weight of their equipment was appropriate. Majority of the female agricultural workers reported that they performed agricultural activities under extreme outdoor environment, with excessive noise and in bright or dim lighting. 59% female workers performed repetitive actions during their agricultural activities. Significant difference was not found

Table 12 Distribution of agricultural workers according to their Pesticide exposures

S. no	Total pesticide exposure years	Male n = 100	Female n = 100	P value
		f (%)	f (%)	
i	<1 year	0.0	19.0	**<0.01**
ii	1–10 years	39.0	50.0	0.154
iii	10–20 years	41.0	22.0	**0.005**
iv	20–30 years	20.0	9.0	**0.043**
v	>30 years	0.0	0.0	0
	Pesticide exposure hours/day	**f (%)**	**f (%)**	
i	<1 h	3.0	22.0	**<0.01**
ii	1–3 h	1.0	29.0	**<0.01**
iii	3–5 h	82.0	48.0	**<0.01**
iv	5–7 h	12.0	1.0	**0.002**
v	>7 h	2.0	0.0	0.497
vi	**Using protective device**	**f (%)**	**f (%)**	
vii	No	55.0	66.0	0.147
viii	Sometimes	27.0	29.0	0.874
ix	Always	18.0	5.0	**0.006**

in working conditions of male and female agricultural workers except for lighting. More female workers reported that they worked under extreme lighting condition.

All these factors show that agricultural workers performed their work under adverse working condition which indirectly affects their health such as risk of MSDs, poor vision, hearing loss, stress.

Multiple Regression Analysis

Multiple regression analysis was done to investigate the effect of various variables on health hazards of agricultural workers. Following models were formed separately for male and female agricultural workers (Table 14)

Male.

HH = 37.454 + 0.203 Pesticide exposure + 0.520 WC.

($R^2 = 0.175$).

The model shows that health hazards of male agricultural workers were affected by pesticide exposure and working condition in which they work. Another study conducted by Tarar (2016) is also in tune with these results. He concluded that significant association was found between pesticide exposure and health problems of agricultural workers. Other factors also affect health hazards of agricultural workers, namely type of activities performed by them, their Basal Metabolic Rate and their socio-economic status though non-significantly (Table 15).

Female.

HH = 32.705 + 0.207 BMI + 0.117 Age.

($R^2 = 0.185$).

Table 13 Distribution of agricultural workers according to their working condition

Size of equipment	Male n = 100	Female n = 100	P value
	f (%)	f (%)	
Appropriate	60.0	48.0	0.118
Not appropriate	40.0	52.0	0.118
Shape of equipment			
Appropriate	54.0	49.0	0.571
Not appropriate	46.0	51.0	0.571
Weight of equipment			
Appropriate	53.0	53.0	1
Not appropriate	47.0	47.0	1
Extreme outdoor environment			
Yes	84.0	81.0	0.710
No	16.0	19.0	0.710
Repetition of job			
Yes	56.0	59.0	0.774
No	44.90	41.0	0.774
Excessive noise generated by farm equipment			
Yes	74.0	80.0	0.401
No	26.0	20.0	0.401
Bright lighting or dim lighting			
Yes	88.0	98.0	**0.010**
No	12.0	2.0	**0.010**

Table 14 Rank of Factors affecting Health hazards of male agricultural workers

S.no	Factors	Coefficient	t	Sig.	Rank
i	Pesticide exposure	0.412	4.357	0.000	I
Ii	Working condition	0.210	2.221	0.029	II
Iii	Activities performed	−0.129	−1.297	0.198	IV
Iv	Alcohol	0.090	0.968	0.336	VII
V	SES	−0.102	−1.090	0.279	V
Vi	BMI	−0.036	−0.386	0.700	VIII
Vii	Age	0.011	0.083	0.934	X
Viii	VFA	−0.009	−0.092	0.927	IX
Ix	AC	−0.060	−0.640	0.524	VII
X	WHR	−0.095	−0.981	0.329	VI
Xi	BMR	0.191	1.770	0.080	III

Table 15 Rank of Factors affecting Health hazards of female agricultural workers

S. no	Factors	Coefficient	t	Sig	Rank
i	Working condition	– 0.042	– 0.418	0.677	VI
ii	Pesticide exposure	0.056	0.471	0.639	V
iii	Activities performed	– 0.011	– 0.108	0.914	IX
iv	SES	– 0.131	– 1.314	0.192	II
v	VFA	– 0.080	– 0.293	0.770	VII
vi	AC	– 0.028	– 0.142	0.888	VIII
vii	WHR	0.134	0.587	0.559	IV
viii	BMR	0.011	0.101	0.920	X
ix	Age	0.266	2.058	0.043	I
x	BMI	0.176	0.844	0.401	III

The model explains that health hazards of female agricultural workers were affected by their age and BMI. Socio-economic status, abdominal circumference, pesticide exposure and working condition also showed a trend to affect health hazards of female agricultural workers though non-significantly.

4 Conclusion

- The body composition parameters of farmworkers pointed out the fact that majority of them were either under nutritive or over nutritive. They need to have balanced diet and nutrition.
- Risk of heart diseases was found amongst farmworkers as the maximum and minimum value of blood pressure and pulse rate did not fall under normal range.
- Health hazards such as stress (84%), hearing loss (56%), headache (47%) and burning eyes (40%) were reported more by male agricultural workers while the highest percentage of female agricultural workers reported musculoskeletal disorders (58%) followed by chest pain, abdominal pain, dermatitis, memory problems and vomiting.
- Health Hazards of male agricultural workers were influenced highly by Pesticide exposure and working conditions and their counterpart was influenced by their age and BMI.

Recommendations for Policy Makers

1. Special policy should be developed to remove malnutrition problems amongst farmers. The research showed that male farmers were more malnutritive in comparison to their female counterpart.
2. Farmworkers toil under adverse working condition. Intervention programmes should be developed to create awareness amongst them to work under safe

condition as far as possible. Further modified agricultural equipment should be made available to the farmworkers.

3. Health camps should be organised for farmworkers to get an insight about their health condition and to give them preliminary treatment.

Conflict of Interest Author declares no conflict of interest.

References

1. Agricultural Worker Factsheets, published by the National Center for Farmworker Health, Feb 2015
2. FICCI report on Labour in Indian Agriculture: A Growing Challenge (2015). http://www.ncfh.org/uploads/3/8/6/8/38685499/menshealthfactsheet_bb_2.13.15.pdf
3. K. Demos, E. Sazakli, E. Jelastopulu, N. Charokopos, J. Ellul, M. Leotsinidis, Does farming have an effect on health status? A comparison study in West Greece. Int. J. Environ. Res. Publ. Health **10**(3), 776–792 (2013)
4. M.A. Tarar, T. Fatima, T. Sultan, F. Ahmad, I. Ahmed, S. Yasmin, Health problems faced by female farm workers in rural areas of Tehsil Dera Ghazi Khan: a sociological investigation. J. Dow Univ. Health Sci. **10**(1), 35–38 (2019)
5. K. Penny, D. Lorraine, *World Health Organization. Health Systems and Community Health Cluster. Global Commission on Women's Health* (1999). Women and occupational health: issues and policy paper for the Global Commission on Women's Health/editor: Penny Kane; project director: Lorraine Dennerstein. World Health Organization. https://apps.who.int/iris/handle/10665/65855
6. R.R. Habib, S. Hojeij, K. Elzein, Gender in occupational health research of farmworkers: a systematic review. Am. J. Ind. Med. **57**(12), 1344–1367 (2014)
7. R.R. Kulkarni, M.S. Shivaswamy, M.D. Mallapur, Health-seeking behavior of rural agricultural workers: a community-based cross-sectional study. Int. J. Med. Public Health **3**(1), 33–37 (2013)

Chapter 10
Exploring Correlation Between Linear and Non-linear Features of Short-Term Heart Rhythm Fluctuations During Internally and Externally Operative Attention

Mukesh Kumar, Dilbag Singh, and K. K. Deepak

1 Introduction

Neurocardiac response facilitate human attention as an ability to focus an entity over other entities in the external space [1–3]. Many research reports have been reported in order to distinguish the internal and external attention [4–6]. However, we are far from a complete and clear distinction of these two attention types [6]. Many researchers suggest that non-linear techniques are more robust to understand heart and brain interactions than traditional linear techniques [7]. This study investigates the correlation between linear and non-linear features of short-term heart rhythm fluctuations during internally and externally operative attention to extend the insight information of neurocardiac interactions for human attention states.

The heart rate variability (HRV) analysis is a principal tool to quantify autonomic nervous system activities in both physiological and psychological research [3, 8–10]. Several studies reported HRV as an index to diagnose disease associated with cardiovascular system such as myocardial infarction, congestive heart failure, and many more [11–13]. The most used linear measures of HRV are time and frequency-domain parameters, but unable to provide complete information about non-linear heart rate fluctuations [14]. Non-linear approaches outweigh these limitations and provide better assessment of heart health [10, 14, 15]. Poincare plot shows temporal correlations within the RR intervals, which is consider as promising tool for HRV data

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representation to measure randomness and autonomic modulation of heart rhythm [9, 14, 16]. The two prominent descriptors of Poincare plot are standard deviation across (SD1, represents short-term fluctuations of heart rhythm) and along (SD2, represents long-term fluctuations of heart rhythm) the identity line of dispersion points in plot for current RR interval (RR_n) against following RR interval (RR_{n+1}), i.e., RR_n versus RR_{n+1} [9, 10]. These descriptors reveal non-linear and dynamic functioning of heart and provide conclusive physiological interpretations [14]. To best of our information no study reported correlations between linear and non-linear features of HRV during internally and externally operative attention. Thus, this study may provide better insight understanding about complex heart systems functioning during internally and externally operative attention and may help us to design robust human–computer interface and accelerated learning programs.

2 Material and Methods

A. *Subjects*

Fourteen healthy volunteers (07 males, and 07 females; age 26.35 ± 2.15 years) are included in the study. All subjects are instructed to refrain from caffeinated beverages, alcohol, drug use, and rigorous physical activity for four hours prior to experiment. All volunteers were right handed, nonsmokers, and normal vision with 6/6 visual acuity. In addition, all volunteers have signed informed consent form to participate. The research protocol was approved by the institute-ethical committee.

B. *Data Acquisition*

The experimental data recording took place at rest in the sitting posture within a dim light room. A wireless headset B-Alert X10® of Advanced Brain Monitoring [17] was used to record ECG at a sampling rate of 256 Hz for minimum of 5-min segment for each experiment session. Subjects were not given with any specific breathing instructions.

C. *Methods*

Posner's spatial cueing paradigm [1] was used with internal and external peripheral cueing [6, 18], which provided comprehensive heart beat intervals for analysis. Similar task was employed by many researchers to study internal and external attention. Each subject participated for 5-min baseline session, six alternating sessions of computer-based internal and external attention task, and followed by 5-min recovery session.

D. *Data Analysis*

The initial automatic assessment of the recordings was performed by B-Alert X10® acquisition software, followed by visual inspection of ECG signal to ensure artifact free recording for further analysis. All recordings were with

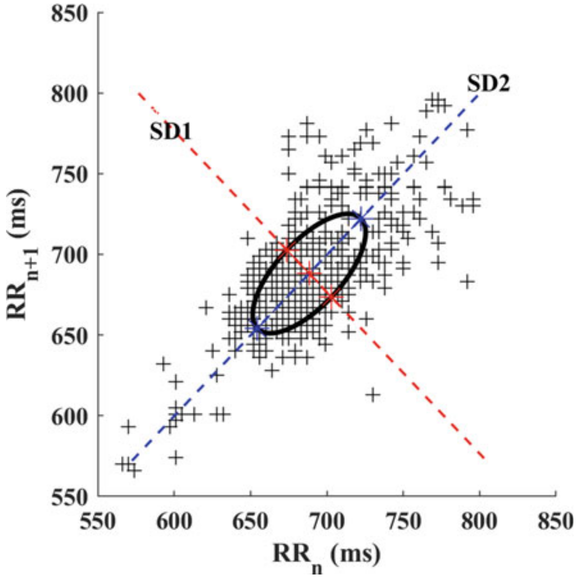

Fig. 1 Poincare plot of a 5-min ECG signal and representing parameters SD1 (represents short-term fluctuations of heart rhythm) and SD2 (represents long-term fluctuations of heart rhythm) measures the dispersion of RR-interval (RR_n) points across and along the identity line

93% artifact free epochs. RR intervals were retrieved from ECG signal for each session and used for further analysis.

Linear features of heart rhythm fluctuations were time and frequency-domain parameters and, non-linear features were the Poincare-plot parameters (SD1, SD2, SD2/SD1 ratio, and ellipse area as shown in Fig. 1), which were analyzed for each session using non-parametric Spearman correlation coefficient, and repeated measure ANOVA with post-test paired comparisons and Bonferroni correction for multiple comparisons. The significance value (p) with $p < 0.05$ for statistical tests was considered significant. Heart rate fluctuations were assessed using time and frequency-domain parameters [9, 10], which includes Mean_RR (represent mean of R-R interval), SDNN (standard deviation of R-R intervals), Mean_HR (mean heart rate), STD_HR (standard deviation of heart rate), RMSSD (root mean square of successive differences), NN50 (number of interval differences of successive R-R intervals greater than 50 ms of R-R intervals), pNN50 (percentage of successive normal sinus RR intervals). Mean RR, SDNN, RMSSD, and TINN intervals were expressed in milliseconds (msec); Mean HR and STD HR were expressed in beats per minute (BPM); NN50 was expressed in count; pNN50 was expressed in percentage (%) [9, 10]. Frequency-domain measures were LF (low frequency 0.04–0.15 Hz), HF (high frequency 0.15–0.4 Hz), TP (total power), LF/HF ratio (low frequencies/high frequencies ratio) [9]. LF is associated with baroreflex activity and is influenced by both parasympathetic and sympathetic activity. HF is believed to reflect respiratory sinus arrhythmia and is mainly associated with parasympathetic activity. The LF/HF ratio represents the balance between sympathetic and parasympathetic modulation and its use as an index of "sympathovagal balance" is argued by some researchers

[10, 19], however, we mentioned because it is widely used in heart rate variability research. The measurement of power spectral components of HRV is usually made in ms^2/Hz. Time and frequency-domain measures of HRV were obtained in accordance with Task Force 1996 guidelines [9].

3 Results

Observed correlations for HRV and Poincare plot of RR-intervals parameters are presented in Tables 1, 2, 3, and 4 for baseline, internally and externally operative attention condition, and recovery session. The values of SD1 were significantly correlated with mean inter-beat intervals ($r = 0.701$) and mean heart rate ($r = -0.701$) during internally operative attention, while there was no significant correlation during externally operative attention. The values of SD2 were found to be significantly correlated with SDNN ($r = 0.965$ and 0.890), low frequency ($r = 0.701$ and 0.640), and total power ($r = 0.543$ and 0.701) of heart rate variability (HRV) during both internally and externally operative attention, respectively. Moreover, the values of the SD2/SD1 ratio were significantly correlated with mean inter-beat intervals ($r = -0.618$) and mean heart rate ($r = 0.618$) during internally operative attention, while there was an insignificant correlation during externally operative attention. The values of ellipse area were significantly correlated with mean inter-beat intervals ($r = 0.6$), high frequency ($r = 0.670$), total power ($r = 0.727$) of HRV and were negatively correlated with mean heart rate ($r = -0.6$) during externally operative attention, while there was an insignificant correlation during internally operative

Table 1 Results of baseline session: spearman correlation analysis of the relationship between hrv and poincare-plot parameters

Parameter	SD1		SD2		SD2/SD1 ratio		Ellipse area (S)	
	r	p	r	p	r	p	r	p
Mean_RR	0.354	0.215	0.108	0.714	−0.310	0.281	0.231	0.427
SDNN	0.582	0.029*	0.991	0.000*	0.354	0.215	0.895	0.000*
Mean_HR	−0.354	0.215	−0.108	0.714	0.310	0.281	−0.231	0.427
STD_HR	0.341	0.233	0.771	0.001*	0.398	0.159	0.635	0.015*
RMSSD	1.000	0.000*	0.547	0.043*	−0.508	0.064	0.837	0.000*
NN50	0.771	0.001*	0.407	0.149	−0.402	0.154	0.578	0.030*
pNN50	0.938	0.000*	0.455	0.102	−0.556	0.039*	0.723	0.003*
HRV-LF	0.381	0.179	0.486	0.078	−0.055	0.852	0.634	0.015*
HRV-HF	0.772	0.001*	0.266	0.358	−0.601	0.023*	0.568	0.034*
HRV-TP	0.746	0.002*	0.495	0.072	−0.389	0.169	0.713	0.004*
LF/HF	−0.165	0.573	0.310	0.280	0.460	0.098	0.185	0.527

*indicates statistically significant at $p < 0.05$; for abbreviations see text

Table 2 Results of internally operative attention condition: spearman correlation analysis of the relationship between HRV and Poincare-plot parameters

Parameter	SD1		SD2		SD2/SD1 ratio		Ellipse area (S)	
	r	*p*	r	*p*	r	*p*	r	*p*
Mean_RR	0.701	0.005*	0.327	0.253	−0.618	0.019*	0.525	0.054
SDNN	0.631	0.016*	0.965	0.000*	−0.367	0.197	0.890	0.000*
Mean_HR	−0.701	0.005*	−0.327	0.253	0.618	0.019*	−0.525	0.054
STD_HR	0.046	0.876	0.578	0.030*	0.002	0.994	0.367	0.197
RMSSD	1.000	0.000*	0.495	0.072	−0.881	0.000*	0.829	0.000*
NN50	0.767	0.001*	0.609	0.021*	−0.745	0.002*	0.741	0.002*
pNN50	0.864	0.000*	0.389	0.169	−0.916	0.000*	0.635	0.015*
HRV-LF	0.165	0.573	0.701	0.005*	0.042	0.887	0.477	0.085
HRV-HF	0.767	0.001*	0.209	0.474	−0.881	0.000*	0.490	0.075
HRV-TP	0.398	0.159	0.543	0.044*	−0.363	0.203	0.481	0.081
LF/HF	−0.398	0.159	0.367	0.197	0.609	0.021*	−0.011	0.970

*indicates statistically significant at $p < 0.05$; For abbreviations see text

Table 3 Results of externally operative attention condition: spearman correlation analysis of the relationship between HRV and Poincare-plot parameters

Parameter	SD1		SD2		SD2/SD1 ratio		Ellipse area (S)	
	r	*p*	r	*p*	r	*p*	r	*p*
Mean_RR	0.516	0.059	0.336	0.240	– 0.380	0.180	0.600	0.023*
SDNN	0.666	0.009*	0.890	0.000*	−0.178	0.543	0.895	0.000*
Mean_HR	−0.516	0.059	−0.336	0.240	0.380	0.180	−0.600	0.023*
STD_HR	0.240	0.409	0.508	0.064	0.051	0.864	0.257	0.375
RMSSD	1.000	0.000*	0.437	0.118	−0.771	0.001*	0.895	0.000*
NN50	0.868	0.000*	0.402	0.154	−0.701	0.005*	0.767	0.001*
pNN50	0.974	0.000*	0.393	0.164	−0.793	0.001*	0.851	0.000*
HRV-LF	0.156	0.594	0.640	0.014*	0.288	0.318	0.349	0.221
HRV-HF	0.855	0.000*	0.332	0.246	−0.622	0.018*	0.670	0.009*
HRV-TP	0.666	0.009*	0.701	0.005*	−0.169	0.563	0.727	0.003*
LF/HF	−0.490	0.075	0.204	0.483	0.565	0.035*	−0.200	0.493

*indicates statistically significant at $p < 0.05$; For abbreviations see text

attention. The high frequency of HRV was significantly decreased during internally operative attention (529.39 ± 306.02) as compared to baseline (805.64 ± 477.26). However, the SD2 unfolding the long-term variations in heart rhythm were significantly reduced in both internally and externally operative attention (55.46 ± 11.83 and 58.17 ± 14.01, respectively) as compared to recovery sessions (68.43 ± 20.19).

Table 4 Results of recovery session: spearman correlation analysis of the relationship between HRV and Poincare-plot parameters

Parameter	SD1		SD2		SD2/SD1 ratio		Ellipse area (S)	
	r	*p*	r	*p*	r	*p*	r	*p*
Mean_RR	0.662	0.010*	0.174	0.553	−0.363	0.203	0.534	0.044*
SDNN	0.543	0.044*	0.965	0.000*	0.160	0.584	0.842	0.000*
Mean_HR	−0.662	0.010*	−0.174	0.553	0.363	0.203	−0.534	0.044*
STD_HR	0.169	0.563	0.793	0.001*	0.279	0.334	0.446	0.110
RMSSD	1.000	0.000*	0.393	0.164	−0.631	0.016*	0.895	0.000*
NN50	0.891	0.000*	0.282	0.329	−0.592	0.026*	0.735	0.003*
pNN50	0.978	0.000*	0.349	0.221	−0.666	0.009*	0.846	0.000*
HRV-LF	0.235	0.418	0.789	0.001*	0.481	0.081	0.499	0.069
HRV-HF	0.916	0.000*	0.231	0.427	−0.701	0.005*	0.749	0.002*
HRV-TP	0.648	0.012*	0.785	0.001*	0.020	0.946	0.864	0.000*
LF/HF	−0.543	0.044*	0.288	0.318	0.833	0.000*	−0.248	0.392

*indicates statistically significant at $p < 0.05$; For abbreviations see text

4 Discussion

An extremely high correlation of SD1 is observed with RMSSD, because mathematically the SD1 and RMSSD are equivalent [9, 10, 14], though their origin is different. Therefore, SD1 and RMSSD have same interpretation and accepted as a measure of short-term HRV [14]. The correlation between SD1 and HRV-HF is threefold large as compared with HRV-LF for all sessions, and strong alliance of SD1 to parasympathetic activity than to sympathetic activity, confirms that SD1 index parasympathetic control of heart rate. While SD1 is not significantly correlated with HRV-LF for any of the session, yet some dependence of SD1 to sympathetic activity cannot be ignored [10].

SD2 was best correlated with SDNN for all sessions. Also, the correlation between SD2 and HRV-LF is twice large as compared with HRV-HF for all sessions, which revealed that SD2 is strongly allied to sympathetic activity than to parasympathetic activity. Additionally, distinct relations observed for correlation between SD2 and TP during internally and externally operative attention. For externally operative attention condition correlation between SD2 and TP was higher (r = 0.701) as compared to internally operative attention (r = 0.543). Similarly, higher correlation, while of moderate strength, was observed between SD2 and HRV-LF during internally operative attention (r = 0.701) than externally operative attention (r = 0.640). Furthermore, the ellipse area best correlated with SDNN, RMSSD, NN50, and pNN50 for all sessions. Also, a strong correlation is observed between ellipse area and HF and TP for all sessions except for internally operative attention. The correlation between ellipse area and HRV-TP was different for internally operative attention (r = 0.481) and externally operative attention (r = 0.727). The correlation of ellipse area with other measures of HRV (HF, RMSSD, SDNN) interpreted as ellipse area is related to parasympathetic activity.

The SD2/SD1 ratio resembles to LF/HF ratio [14] and interpret as ratio of short-term fluctuations of heart rhythm to long-term fluctuations of heart rhythm [14, 16]. The SD2/SD1 ratio positively correlated with HRV-LF and negatively correlated with HRV-HF, which corresponds to interpretation that higher value of SD2/SD1 ratio may represent an increased sympathetic activity and/or reduced parasympathetic drive. Moreover, use of LF/HF ratio as measure of sympathovagal balance for short-term recordings is largely argued by the researchers [10, 19] and results reveal that SD2/SD1 ratio can be used as an alternative to LF/HF ratio [14]. The correlation between SD2/SD1 ratio and HRV-LF differentiates internally and externally operative attention with $r = 0.042$ and 0.288, respectively. Similarly, correlation between SD2/SD1 ratio and HRV-HF differentiates internally and externally operative attention with $r = 0.881$ and 0.622, respectively. However, few evidences reported reciprocal of SD2/SD1 ratio as measure of heart rate randomness rather than sympathovagal balance [14, 20, 21].

Furthermore, the merits of non-linear measures of HRV outweigh the limitations of linear measures of HRV, such as premature beats, technical artifacts, do not affect performance of Poincare plot [14, 16] as strongly affects conventional time and frequency-domain measures of HRV. The Poincare plot also provides prognostic information and utilized in pathological research such as chronic heart failure, sudden cardiac death, and myocardial infarction [14, 20, 21]. In this study, we demonstrate the use of Poincare plot descriptors to differentiate internally and externally operative attention conditions.

5 Conclusion

In the present study, we have investigated short-term heart rhythm fluctuations using linear and non-linear measures to provide distinction between internally and externally operative attention. The non-linear features of Poincare plot of inter-beat intervals are significantly correlated with linear features of short-term heart rhythm fluctuations and differentiate internally and externally operative attention. The correlation between SD1 and HRV-TP, Mean HR, SD2 and HRV-TP, SD2/SD1 ratio and HRV-LF, HRV-HF, ellipse area and HRV-HF, HRV-TP provided significant distinction between internally and externally operative attention. Thus, it is evident that the correlations between linear and non-linear features of heart rhythm fluctuations may further describe the underlying mechanisms of heart rhythm to mitigate human attention during internally and externally operative events, which may help us to design robust human–computer interfaces.

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References

1. M.I. Posner, Y. Cohen, R.D. Rafal, Neural systems control of spatial orienting. Philos. Trans. R. Soc. B Biol. Sci. **298**(1089), 187–198 (1982)
2. R. McCraty, M. Atkinson, W.A. Tiller, G. Rein, A.D. Watkins, The effects of emotions on short-term power spectrum analysis of heart rate variability. Am. J. Cardiol. **76**(14), 1089–1093 (1995)
3. J.F. Thayer, J.F. Brosschot, Psychosomatics and psychopathology: looking up and down from the brain. Psychoneuroendocrinology **30**(10), 1050–1058 (2005)
4. W. Prinzmetal, C. McCool, S. Park, Attention: reaction time and accuracy reveal different mechanisms. J. Exp. Psychol. Gen. **134**(1), 73–92 (2005)
5. W. Prinzmetal, A. Zvinyatskovskiy, P. Gutierrez, L. Dilem, Voluntary and involuntary attention have different consequences: the effect of perceptual difficulty. Q. J. Exp. Psychol. **62**(2), 352–369 (2009)
6. A.N. Landau, M. Esterman, L.C. Robertson, S. Bentin, W. Prinzmetal, Different effects of voluntary and involuntary attention on EEG activity in the Gamma Band. J. Neurosci. **27**(44), 11986–11990 (2007)
7. L. Faes, D. Marinazzo, F. Jurysta, G. Nollo, Linear and non-linear brain-heart and brain-brain interactions during sleep. Physiol. Meas. **36**(4), 683–698 (2015)
8. M.C. Helen Mary, D. Singh, K.K. Deepak, Identifying deep breath effect on cardiovascular signals using conditional entropy: an information domain approach. Biomed. Eng. Appl. Basis Commun. **30**(02), 1850012 (2018)
9. T. Force, Heart rate variability Standards: standards of measurement, physiological interpretation, and clinical use. Circulation **93**(5), 1043–1065 (1996)
10. G.G. Berntson et al., Heart rate variability: origins, methods, and interpretive caveats. Psychophysiology **34**(6), 623–648 (1997)
11. H.M. Mercy Cleetus, D. Singh, Multifractal application on electrocardiogram. J. Med. Eng. Technol. **38**(1), 55–61 (2014)
12. Z. Chen, P. Venkat, D. Seyfried, M. Chopp, T. Yan, J. Chen, Brain-Heart interaction: cardiac complications after stroke. Circ. Res. **121**(4), 451–468 (2017)
13. M.A. Samuels, The brain-heart connection. Circulation **116**(1), 77–84 (2007)
14. P. Guzik et al., Correlations between the Poincaré plot and conventional heart rate variability parameters assessed during paced breathing. J. Physiol. Sci. **57**(1), 63–71 (2007)
15. M.C. Helen Mary, D. Singh, K.K. Deepak, Impact of respiration on cardiovascular coupling using Granger causality analysis in healthy subjects. Biomed. Signal Process. Control **43**, 196–203 (2018)
16. B. Roy, S. Ghatak, Nonlinear methods to assess changes in heart rate variability in type 2 diabetic patients. Arq. Bras. Cardiol 317–327 (2013)
17. C. Berka et al., EEG correlates of task engagement and mental workload in vigilance, learning, and memory tasks. Aviat. Space. Environ. Med. **78**(5 Suppl), B231–B244 (2007)
18. W. Prinzmetal, K.L. Whiteford, J.L. Austerweil, A.N. Landau, Spatial attention and environmental information. J. Exp. Psychol. Hum. Percept. Perform. **41**(5), 1396–1408 (2015)
19. G.E. Billman, The LF / HF ratio does not accurately measure cardiac sympatho-vagal balance vol. 4, no. February, pp. 1–5 (2013)
20. H.V. Huikuri et al., Abnormalities in beat-to-beat dynamics of heart rate before the spontaneous onset of life-threatening ventricular tachyarrhythmias in patients with prior myocardial infarction. Circulation **93**(10), 1836–1844 (1996)
21. P.K. Stein, P.P. Domitrovich, H.V. Huikuri, R.E. Kleiger, Traditional and nonlinear heart rate variability are each independently associated with mortality after myocardial infarction. J. Cardiovasc. Electrophysiol. **16**(1), 13–20 (2005)

Chapter 11
Determination of Lifting Index for Paddy Storage Activity in the Use of Modified Bamboo Basket by Farm Women

M. Kalita, R. Borah, and N. Bhattacharyya

1 Introduction

Storage of paddy grains is performed by more than 70% of the rural Assamese women and is one of the most drudgery prone post harvest activities of Assam. *Bamboo basket* is a conventional tool used for carrying the grains from yard to the place of storage structures after proper sun-drying of paddy grain. The storage activity comprises of three sub-activities which are performed in sequence. This includes loading grains (Fig. 1), carrying grains (Fig. 2) and unloading the grains (Fig. 3) in the storage structures. The farm woman usually carried more than 16 kg of grains at a time by adopting an awkward posture which is above the permissible limits (ILO). The load lifted may be fixed or variable at times and forces produced during various processes of material handling, e.g., pulling, pushing, lifting, carrying, etc. may sometimes be much above the normal tolerance level of the worker [2]. The *bamboo basket* used by farm women for paddy storage activity was not in conformity to the body types and anthropometric measurements. There is no provision of base and grip for handling the tool which increases the grip fatigue of the farm women. For farm women recomended weight limit is not determined and thereby increses the risk of musculo skeletal disorders. Musculoskeletal disorders (MSDs) are important causes of work incapacity and loss of workdays, in such cases, determination of weight limit for farm women is very essential. Lifting of loads above recommended weight limit (RWL) produces backward bending of the back during lifting and imposed maximum postural stress on the low back and increased the risk of lifting-related low back pain and disorder [1].

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Fig. 1 Loading paddy gains

Fig. 2 Carrying paddy grains

Fig. 3 Unloading paddy grains to the storage place

There is a need to develop tool or technology for farm women for increasing productivity, comfort, enhance work efficiency and wellbeing of health status and reducing drudgery. Effective ergonomic interventions can lower the physical demands of manual material handling (MMH) tasks, thereby lowering the incidence and severity of the musculoskeletal injuries. An ergonomic intervention is a useful tool for improving productivity and product quality. In the present study for preventing and controlling of ergonomic risk factors and enhancing comfort and efficiency of farm women in paddy storage activity, engineering controls was applied for modification of conventional basket and a modified bamboo basket was designed. Keeping this in mind the study was carried out to assess the recommended weight limit (RWL) and lifting index (LI) of farm women in storing paddy grains by using modified paddy carryings bamboo basket.

2 Methodology

The present study was conducted on Jorhat sub-division of Jorhat district of Assam. Thirty farm women in the age group of 25–35 years who had been involved in paddy storage activity since last 10 years were selected for the present study. Lifting index (LI) is used for determining acceptable weights for storage activity by farm women. Engineering control was applied for design modification of conventional bamboo basket for storing paddy grains.

For assessing lifting index in paddy storage activity by using modified bamboo basket, tasks variables, multipliers and recommended weight limit (RWL) were worked out.

The revised NIOSH lifting equation was applied for evaluating acceptable weights limit of farm women in storing of paddy grains.

Lifting index (LI) is the ratio between the load actually lifted and the recommended weight limit (RWL). It is defined by the relationship of the weight of load lifted (L) and the recommended weight limit (RWL) [5]. A lifting index less than 1 is believed not to increase the risk of injury. An index of more than 1 indicates that many workers are at increased risk and the task should be redesigned. The goal of NIOSH in developing the equation is to protect workers by setting limits on manual lifting [5].

Recommended weight limit (RWL) = (LC) (HM) (VM) (DM) (AM) (FM) (CM). [5]

Equation in Metric.

- LC = load constant = 23 kgs
- HM = horizontal multiplier = 25/H
- VM = vertical multiplier = [1−(0.003 |V-75|)]
- DM = distance multiplier = [0.82 + (4.5/D)]
- AM = asymmetric multiplier = [1−(0.0032A)]
- FM = frequency multiplier
- CM = coupling multiplier

There are four different steps for using NIOSH lifting equation for manual material handling tasks [5]. These are as follows:

Step 1: Measure and record lifting task variables:

Lifting Tasks	NIOSH lifting variables							
	H Horizontal Location (10-25”)	**V** Vertical location (0-70”)	**D** Travel Distance (10-70”)	**A** Angle of asymmetry (0-135°)	**C** Coupling (1=Good, 2=Fair, 3=Poor)	**F** Frequency (0.2-15lifts/min)	**L** Avg. Load lifted(lbs.)	**L** Maximum Load lifted(lbs.)	Duration (1,2,8 hours)

Step 2: To determine the multipliers to use in the NIOSH equation:

Lifting Tasks	Multipliers (in Metric)					
	HM = horizontal multiplier = (25/H)	VM = vertical multiplier = [1 - (0.003 |V - 75|)]	DM = distance multiplier = [0.82 + (4.5/D)]	AM = asymmetric multiplier = [1-(0.0032A)]	FM = frequency multiplier (from Table 5 in Appendix A)	CM = coupling multiplier (from Table 7 in Appendix A)

Step 3: To calculate the NIOSH recommended weight limit (RWL)

$$RWL = (51)(HM)(VM)(DM)(AM)(FM)(CM)$$

$$\text{Or } (23)(HM)(VM)(DM)(AM)(FM)(CM).$$

Step 4: The final step is to calculate the lifting index (LI)

$$LI = \frac{\text{Object weight}}{RWL}$$

3 Results and Discussion

Personal and demographic characteristics of farm women revealed that cent percent respondents were literate and sixty-six percent respondents belonged to nuclear families. Majority of the respondents (82%) belonged to marginal farmers having 1 acre of land for paddy cultivation. As regards to age of the respondents, 88% falls in the age group of 30–40 years.

4 Design Modification of Conventional Bamboo Basket for Enhancing Comfort and Efficiency

Musculoskeletal disorders (MSDs) can be controlled through proper design and implementation of ergonomic intervention. The ergonomic intervention under engineering control may be job redesign, workplace redesign, automation, workplace/work accessories redesign, tool design, etc. In the present study for preventing and controlling of ergonomic risk factors and enhancing comfort and efficiency of farm women in paddy storage activity, engineering controls was applied for design modification of conventional basket.

5 Design Criteria or Features and Specification of Modified Paddy Carrying Basket

The design criteria selected for modifying conventional basket were load capacity, frontal length, depth, weight, base and grip of the basket in terms of length, height and weight of the handle. Load capacity of the modified basket was 10 kg., frontal length was 16 inches and weight of the modified basket was 800 gm. The size of the bases was 1 cm in height. Circumference of the handles was 2 inches, length of the handle was 6.2 and height of the handle 2 inches (Fig. 4). Depth or height of the basket has direct relationships with the load capacity. For reducing the capacity, depth or height of the conventional basket was reduced in modified basket for maintaining balance between physical capacity of the farm women and physical load carried by them. According to NIOSH lifting Eq. (1981) for optimal design, the height should not exceed more than 12 inches [4]. For proper gripping, handle was provided which is an additional feature in modified baskets. The use of handle eliminates hand grip discomfort and increases handgrip strength. In modified basket, handle was provided by following revised NIOSH lifting Eq. (1994) to minimize the bending posture while carrying grains. According to revised NIOSH lifting Eq. (1994), the handle

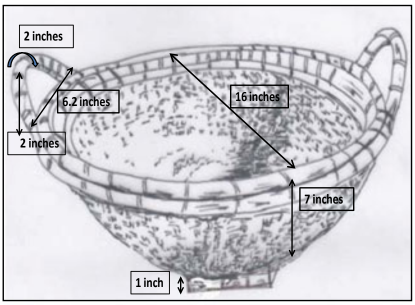

Fig. 4 Dimensions of modified basket

of a container for manual material handling has 0.75 to 2.5 inches diameter, more than 4.5 inches length and more than 1.5-inch height, cylindrical shape, a smooth and non-slip surface [4]. The farm women have to lift the load of paddy grains from floor to 67.52 inches height.

6 Determination of Lifting Tasks Variables in the Use of Modified Basket

Lifting task variables

Measurement of lifting task variables in the use of modified basket is presented in Table 1. The horizontal location of the hands of farm women in the paddy storage activity in the use of modified basket was found to be 42.67 cm. The horizontal location was reduced in modified basket for reducing the load capacity of the basket. The values were ranged from 33–51 cm. The vertical location was 79.56 cm.

The maximum value was found 93 cm and minimum 63 cm. The vertical travel distance of the lift was 89.26 cm. The maximum value was 140 cm and minimum was 38 cm. The differences were more in vertical travel distance is due to the fact that height of the storage structures (*bhoral*, *mer, duly,* etc.) is different for different farmers. Asymmetric angle (A) is the amount of degree to which the body is required to twist or turn during the storage activity (lifting task). The asymmetric angle is the amount (in degrees) of trunk and shoulder rotation required by the farm women and which was found 0° in the paddy storage activity while using modified basket. This is due to the fact that for the provision of handle in the modified basket bending or turning during paddy storage was eliminated and hence angle was found to be nil. A good coupling (1) was provided in modified basket to reduce the grasp forces required and to increase the acceptable weight for paddy storage activity. The lifting frequency of storage of paddy grains (lifting tasks) was analyzed by using the average number of lifts per minute during an average 15 min sampling period (Table 1). The frequency was found to be 1.26 lift/min means a farm woman can complete 1.26 lift in one minute period of time with a load of 10 kg in front of the body. For carrying heavy loads in conventional basket farm women were walking slowly and thereby decreasing their frequency of lift per minute. The average weight of the filled up basket was found 10 kg. The lifting duration was found to be moderate duration (2 = moderate duration).

Multipliers

Determination of six multipliers values of paddy storage activity (lifting task) to use in the NIOSH lifting equation for calculating the RWL is the second step evaluated for paddy storage activity. Data on Table 2 showed that horizontal multipliers of storage activity by using modified basket were found 0.60. The Vertical multipliers values were found 0.98 by using modified basket in paddy storage activity. The value of vertical multipliers was found 0.88 in paddy storage activity by the farm women.

Table 1 NIOSH lifting variables of farm women in the use of modified basket for paddy storage activity

Lifting Tasks-Paddy storage	NIOSH Lifting Variables (in Metric)								
	H Horizontal Location (25–63 cm)	V Vertical location (0–175 cm)	D Travel Distance (25–175 cm)	A Angle of asymmetry (0–135°)	C Coupling (1 = Good,2 = Fair, 3 = Poor)	F Frequency (0.2–15 lifts/min)	L Avg. Load lifted (kg.)	L Maximum Load lifted(lbs.)	Dur Duration (1,2,8 h)
Total	42.67	79.56	89.26	0°	1	1.26	**10**	**10**	1–2

Table 2 Multipliers of farm women respondents in the use of modified basket for paddy storage activity

Lifting Tasks-Paddy storage	Multipliers (in Metric)					
	HM = horizontal multiplier = (25/H)	VM = vertical multiplier = [1 − (0.003 |V−75|)]	DM = distance multiplier = [0.82 + (4.5/D)]	AM = asymmetric multiplier = [1 − (0.0032A)]	FM = frequency multiplier (from Table 5 in Appendix A)	CM = coupling multiplier (from Table 7 in Appendix A)
Total	0.60	0.98	0.88	1	0.87	1

The values of asymmetric multipliers in paddy storage activity by the farm women were found 1. The values of frequency multipliers of paddy storage activity by the farm women were found 0.87. The values of coupling multipliers of paddy storage activity by the farm women were found 1(Table 2).

Recommended weight limit (RWL)

An observation from Table 3 revealed that the recommended weight limit (RWL) of paddy storage activity by using modified basket was found to be 10.28 kg. Farm women should carry 10.28 kg of paddy grains in one lift. The load capacity of the paddy carrying basket should not exceed more than 10.28 kg. Physiological workload of farm women in paddy storage activity was assessed on the basis of heart rates (beat.min^{-1}) and energy expenditures (kJ. min^{-1}) which indicated that storage of paddy grains with modified baskets was categorized as 'moderately heavy' activity while with conventional basket, it was categorized as 'heavy' activity.

The lifting index (LI) of storage of paddy grains in the use of modified basket was found to be 0.97 (Table 3 and Fig. 5) which indicates that all the healthy farm women can carry this amount of load without any work-related musculoskeletal disorders (WMSDs) or injury and design modification is very effective for reducing health injury of farm women for storage activity or any lifting tasks. These results suggest that storage of paddy grains by the new tool and techniques is highly beneficial in postharvest activities (as indicated by the LI of less than 1.0) (Table 3 and Fig. 5).

The whole process of paddy storage activity such as loading the grains, carrying grains and unloading grains were simplified by using modified basket. Use of modified basket for paddy storage activity can increase output, enhance efficiency, comfort, wellbeing of health status, workable life and reduce ergonomic cost,

Table 3 Recommended weight limit (RWL) and lifting index (LI) for paddy storage in the use of modified basket

Sl. No	RWL = (23) (HM) (VM) (DM) (AM) (FM) (CM)	RWL	Avg. Load Lifted (kg.)	Lifting index (LI) = Weight lifted/RWL
Total		10.28	10	0.97

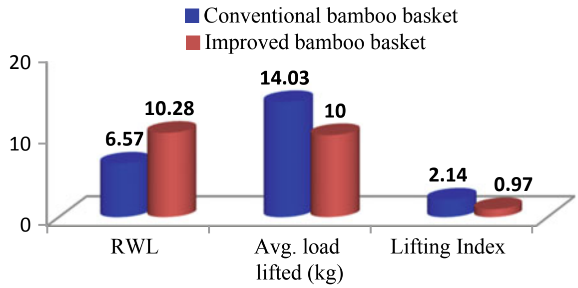

Fig. 5 RWL, average load lifted (kg.) and lifting index for paddy storage activity in the use of conventional and modified basket

drudgery and health hazards of farm women. Similar research study conducted by Gupta, et al [3] suggested that the improved equipments were found to be economical in terms of time and energy and also improved the health and efficiency of the farmwomen and best for Indian workers.

7 Conclusion

The primary product of the NIOSH lifting equation is the recommended weight limit (RWL) or permissible weight limit, which defines the maximum acceptable weight (load) for all healthy workers. Determination of maximum acceptable weight can be an appropriate base for planning and implementing interventional ergonomics programs. The recommended weight limit (RWL) and lifting index (LI) for storage activity by the use of modified basket were found to be 10 kg and 0.97, which indicates that all the healthy farm women could carry 10 kg of paddy grains without any risk of work-related musculoskeletal disorders (WMSDs). The paddy storage activity performed by farm women was simplified and reduces drudgery with the use of modified basket.

References

1. S. Chattopadhyay, K. Basu, S. Sahu, G. Paul, Ergonomic evaluation of postural stress of male and female construction laborers' employed in unorganized sectors in West Bengals. Ergonomics for Everyone. Edited by Somnath Gangupadhyay. Occupational Ergonomic Laboratory. Department of Physiology. University of Calcutta, pp. 131–135(2009)
2. S. Gangopadhyay, T. Das, G. Ghoshal, B. Das, An ergonomic study on the development of musculoskeletal disorders among the fixed load and variable load handling workers of Kolkata. Indian J. Biolog. Sci. **9**, 37–45 (2003)
3. P. Gupta, A. Singhala, S. Sing, P. Sharma, S. Jain, Drudgery Faced by farm women in Agriculture. Published in the proceedings of National Seminar on Dynamic of women in Agriculture for National Development, M.P. University of Agriculture and technology, Udaipur, India, pp. 230–236 (2002)

4. National Institute for Occupational Safety and Health (NIOSH). Work Practices, guide for manual lifting, no. 81–122, Washington D.C. (1981, 1994)
5. G.S. Nelson, H. Wickes, J.T. English, Manual lifting: the NIOSH Work Practices Guide for Manual Lifting Determining Acceptable Weights of Lift. Nelson and Associates (1994, 2010)

Chapter 12
Recent Advancement in Human–Computer Interface and Ergonomic Design: A Review

Yogesh Mishra, M. L. Meena, and G. S. Dangayach

1 Introduction

Enhancing employee productivity, work-related wellbeing and safety are significant worries of industry these days. The workplace concerns like awkward system design, antagonistic ambiance, amorphous jobs, discordance between employee competence and task requirements lead to developing musculoskeletal disorders, the existence of injuries and accidents. The work-related portion of the injuries and ensuing disability is probably preventable, and there's a proof base to feature interventions for diminishing work-related disorders [1–6]. There is a necessity for evaluating various methodological facets of interventions for workplace design.

In the past few years, there have been engaged endeavors toward incorporating ergonomic standards into product development and workplace design [7–10]. The incorporation of ergonomics into workplace design comes into existence by the advancement in domains like epidemiology, ergonomic evaluation and intervention. Virtual Ergonomics and Digital Human Model (DHM) are pace-raising technologies that enable system design, ergonomic analysis and disorder assessment [11]. There is expanding participation among designers and ergonomists toward the incorporation of sensible human models and computer-aided design. It is quite challenging to embrace significant advancement in design procedure and computer automation and implement it in the actual manufacturing domain.

The paper aims to analyze the advancement in the last ten years in the field of applications of Human–Computer Interface and computer-aided ergonomic design.

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2 Research Methodology

The literature was preferred from the SCOPUS indexed database. To identify the literature, keywords like: ‘ergonomic design’, ‘ergonomic intervention’, ‘ergonomic evaluation’, ‘virtual reality’ and ‘digital human model’ were used. A few original articles out of the last ten-year database were preferred from reckoned ergonomics journals like: Ergonomics, International Journal of Production Research, International Journal of Industrial Ergonomics, Applied Ergonomics, Human Factors, and Theoretical Issues in Ergonomics Science, Human Factors and Ergonomics in Manufacturing, International Journal of Productivity and Performance Management to conduct the review. More than 200 articles were found and by analyzing the abstracts and findings the 44 articles have been preferred for this review. The wellspring of literature is essentially from the ergonomics area and enhanced from the design area. The classification of literature is done in three categories, i.e., and Ergonomic Design and Ergonomic Intervention, Ergonomic Tools and Analysis, and Virtual Ergonomics and Digital Human Model.

2.1 Ergonomic Design and Ergonomic Intervention

Work station issues that influence the health and safety of the workforce cause non-appearance and decreased profitability. To address this issue focused on ergonomic interventions are vital. The ergonomic intervention approaches are: manufacturing and organizational interventions that emphasis on proposed actions and work routine, engineering interventions which emphasis on routes and layouts, behavioral interventions which emphasis on personal employee’s attitude by way of training. There is a substantial group of writing which demonstrates contextual analysis of interventions in the fields such as wellness program [12], automotive [13], farming [14] and information technology [15] which have utilized various intervention methods at macro and micro levels. The ergonomic intervention benefit includes incorporating diminished pay costs, improved profitability and quality, comfort-health-safety and ease of use [16–18]. So the advantages of intervention should be assessed toward composing business case for intervention purpose.

The effects of the intervention are determined by the adopted strategies and participatory approach role must be highlighted here [19, 20]. Ergonomists, architects, health specialists, engineers, administrators and employees are associated with the participatory approach. The aim has presently switched from micro-level intervention to ergonomic design results by efforts to merge human factors and ergonomics concepts into design. A framework has been proposed by Village and his colleagues [21] and Neumann and Village [22] to merge work system design with ergonomic factors through a participatory approach of ergonomic intervention which includes the merger of the design process with human factors.

Even though there are various kinds of literature related to ergonomic interventions but two substantial issues that need to be discussed are (i) issues related to adopted methodology for attempting intervention (ii) analysis of cost estimation and benefits for adaptability of intervention by organizations. Sound ergonomics assumptions are used to provide inputs for effective intervention implementation. Gambatese [23] has addressed the barriers related to 'cost designing', 'vigilance models', 'design methods and tools' and 'interacting work system models'. Human factors and ergonomics unified design structure along distinct aim on risk measurement is addressed by Village and his colleagues [21, 24]. Productivity, quality, ergonomic stress and safety would be included in the performance matrix of a multivariate work system [21, 24–27]. A variety of ergonomic tools and approaches are used for the ergonomic assessment of work systems and products. However, for improved incorporation, human factors and ergonomics with the design process the appropriate design approach and tools are vital for multiple performance criteria. Literature specifies various design approaches used for the ergonomic assessment of work systems and products that include Behavioural design approach [28], TRIZ [29], Focus groups [30], Axiomatic design [31, 32], Functional analysis [33], Quality function deployment [34], Virtual Reality [35, 36], Expert system [15], between other methods and approaches. The design approaches and tools need to justify the ergonomic, quality and productivity criterion. The specified design results acquired from any of the selected approaches would give the inputs toward the intervention module. Therefore the choice of design approach plays an important role in the human factors and ergonomics intervention framework.

2.2 *Ergonomic Tools and Analysis*

A substantial amount of tools have been developed to conduct ergonomic analysis which is used to assess physiological requirements, working posture, psychological demand and man–machine productivity analysis. A lot of techniques have been used as module merged into design software. Table 1 represents a few of important ergonomic methods and their classification. Dempsey and his colleagues [37] surveyed the deployment of different types of tools, measurement approaches, and software, and found that 50.6% of them utilized some software tools. For example, RULA, Psychophysical databases and NIOSH lifting equation are integrated into design software like ProE and CATIA, OWAS in winOWAS, Three-Dimensional Static Strength Prediction Program (3DSSPP), etc. Some video-based ergonomic assessment tools such as ErgoSAM, MVTA VIDAR are used for analysis of motion and initial musculoskeletal disorder risk assessment. Various authors [25, 27, 38, 39] have addressed the use of computer-aided ergonomic assessment. The input of ergonomic analysis depends upon the employment surveillance or risk assessment approach. Therefore, the type of ergonomic analysis depends upon the available resources, characteristics of the work system and ergonomist expertise.

Table 1 Classification of ergonomic methods [11]

Types of tool and approaches	Name of method
Observational tools and integrated tools	RULA; REBA; OWAS; QEC; MVTA; PLIBEL; Cube Model; ACGIH HAL and lifting TLV; Cube model; NIOSH equation; EWS; Ergo Toolkit
Physiological models	Energy Expenditure equation; Oxygen consumption models
Biomechanical models	WATBAK; LMM risk assessment model; Three-Dimensional Static Strength Prediction Program; Continuous Assessment of Back Stress, Muscle effort
Cognitive models	Critical incident technique; NASA Task Load Index; Cognitive Task Load Analysis; Cognitive Work Analysis; Critical Decision Method; Team Cognitive Task Analysis Techniques; Hierarchical Task Analysis; Verbal Protocol Analysis; Subjective Workload Assessment Technique
Psychophysical scales and models	Psychophysical Databases; Borgs scale of perceived exertion; Body Part Discomfort Scale
Productivity analysis	ErgoSAM; ErgoMOST; DMSP; EMA

Note RULA: Rapid Upper Limb Assessment; REBA: Rapid Entire Body Assessment; OWAS: Ovako Working Posture Assessment System; QEC: Quick Exposure Checklist;
MVTA: Multimedia Video Task Analysis; PLIBEL: Checklist Tool Developed by Kemmlert; ACGIH HAL: American Conference of Governmental Industrial
Hygienists (ACGIH) threshold limit value for hand activity level; NIOSH: The National Institute for Occupational Safety and Health; LMM: Lumbar Motion Monitor

Due to the multi-dimensional nature of ergonomic issues, a broad ergonomic analysis incorporates the adoption of various tools. Over the past few years, the improvements have been made to merge various ergonomic tools into an individual analysis domain. Digital human modeling is the equivalent approach of integration which is reviewed in the Virtual Ergonomics and Digital Human Model section. Besides up-gradation in ergonomic and modeling tools, there is a requirement to merge costing analysis with productivity [15, 40].

2.3 *Virtual Ergonomics and Digital Human Model*

Digital Human Models and computer-assisted simulation tools are acknowledged to be auspicious in the assistance of intense ergonomic analysis. Simulation and Digital Human Modeling is a biomechanical description of the human body including design estimations which set up the model to generate moves or stance. The combination of DHM and simulation can be used to upgrade the product as per individual convenience and safety, to determine chaos and destructions and to analyze the conduction of healing and surgeries. The employment of the digital human modeling approach acknowledges smooth and prior recognition of ergonomic-related issues and diminishes the requirement of real prototypes and their evaluation [35, 41]. A few software which uses human models are RAMSIS, SANTOS, SAMMIE, JACK, BOEMAN, HumanCAD, SAFEWORK and Anybody [42]. These are applied specifically in areas such as aviation and automotive manufacturing. Laring and his colleagues [43] and Vilas and his colleagues [27] have addressed the tools for simulation such as MTM-UAS, ErgoSAM, and ErgoMOST, which are based on Methods-Time Measurement (MTM). Cimino and his colleagues [44] focus on the use of simulation to merge ergonomic results in the virtual domain. By growing virtual manufacturing (VM) and virtual reality (VR), Virtual ergonomics authorize designers to form and shape virtual humans and to explore the communication among individual and the product [8, 21, 24, 27]. For instance, human aspects like relocation, perceptibility, embracing, grasping may be assessed by giving an early response to designers in the product development phase. An example of VR and VM utilization such as Hu and his colleagues [33] addressed the ergonomic assessment of drilling job which is performed in virtual domain.

2.4 Conventional Design Versus HFE Integrated Design

This review highlights the application of a few computer-aided design concepts in the field of conventional design. The conventional design does not include ergonomic investigation while HFE integrated design encompasses the combination of hardware and design software for the analysis of human capabilities. Ample use of HFE in the initial design phase may rise the development cost but at the same time, it benefits in various fields, i.e. productivity and quality improvement, claims lower compensation, etc.

Figure 1 shows the relationship between the product life cycle and work system cost. A combination of digital human models and product life cycle tools raises the efficiency to achieve the required engineering design along with its analysis, better ergonomics of the product and avail savings in cost and time. Multiple confront are faced by the designers during HFE incorporation. The integration of the manikin in recent software should show the potential and performance of the human body. To use the available functions in the manikin group digital human model system is required for the user.

3 Conclusion

The review has shown that HFE integrated design is the most innovative and intuitive concept that earns interest of the user as well as facilitates the global design process. It is also helpful in time as well as cost-saving to the user. This concept

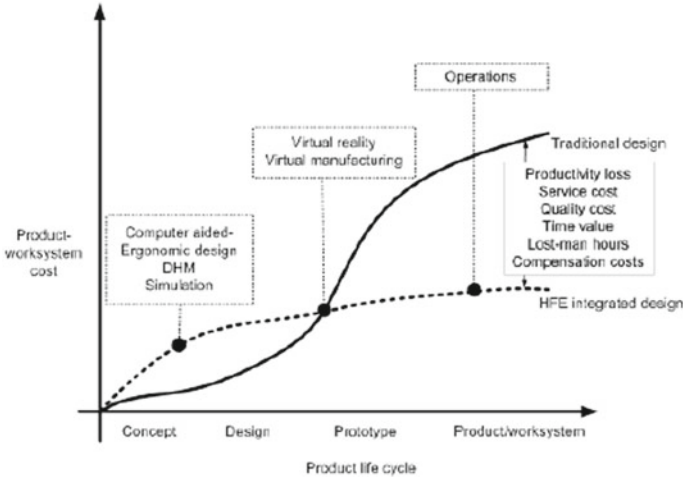

Fig. 1 Product-work system cost versus product life cycle [41]

provides the opportunity to proactively assess different variables in the work environment to optimize the key ergonomic factors associated with the job of manual work. There is a requirement for new research plans which are applicable to complicated systems. Individuals associated with work system design and interventions need to improve their learning of effective operation and implementation of dimensions of advance processes. For product design and workplace design, concepts like virtual reality and virtual manufacturing are generating routes for the integration of ergonomic design tools into computer applications. The occurrence of virtual reality and virtual manufacturing promotes the opportunity for ergonomic design systems and framework.

References

1. M. Isler, M. Kucuk, M. Guner, Ergonomic assessment of working postures in clothing sector with scientific observation methods. Int. J. Clothing Sci. Technol. **30**(6), 757–771 (2018)
2. P. Pillastrini, R. Mugnai, L. Bertozzi, S. Costi, S. Curti, Effectiveness of an ergonomic intervention on work-related posture and low back pain in video display terminal operators: a 3 year cross-over trial. Appl. Ergon. **41**, 436–443 (2012)
3. I.V. Rivilis, K. Cullen, D.C. Cole, E. Irvin, J. Tyson, Effectiveness of participatory ergonomic interventions on health outcomes: a systematic review. Appl. Ergon. **39**, 342–358 (2008)
4. M.K. Sain, M.L. Meena, Exploring the musculoskeletal problems and associated risk-factors among brick kiln workers. Int. J. Workplace Health Manag. **11**(6), 395–410 (2018)
5. E. Tompa, R. Dolinschi, C. de Olivera, B.C. Amick III., E. Irvin, A systematic review of workplace ergonomic interventions with economic analyse. J. Occup. Rehabil. **20**, 220–234 (2010)
6. R.H. Westgaard, J. Winkel, Ergonomic intervention research for improved musculoskeletal health: a critical review. Int. J. Ind. Ergon. **20**, 463–500 (1997)

7. G. Di. Gironimo, R. Mozzillo, A. Tarallo, From virtual reality to webbased multimedia maintenance manuals. Int. J. Interact. Design Manuf. **7**, 183–190
8. G. Lawson, D. Salanitri, B. Waterfield, Future directions for the development of virtual reality within an automotive manufacturer. Appl. Ergon. **53**, 323–330 (2016)
9. W.P. Neumann, M. Medbo, Ergonomic and technical aspects in the redesign of material supply systems: big boxes versus narrow bins. Int. J. Ind. Ergon. **40**, 541–548 (2010)
10. J. Santos, J.M. Sarriegi, N. Serrano, J.M. Torres, Using ergonomic software in non-repetitive manufacturing processes: a case study. Int. J. Ind. Ergon. **37**, 267–275 (2007)
11. R. Rajesh, R. Srinath, Review of recent developments in ergonomic design and digital human models. Ind. Eng. Manage **5**(186), 2169–2316 (2016)
12. P. Buckle, P.J. Clarkson, R. Coleman, J. Ward, J. Anderson, Patient safety, systems design and ergonomics. Appl. Ergon. **37**, 491–500 (2006)
13. M. Vitello, L.G. Galante, M. Capoccia, G. Caragnano, Ergonomics and workplace design: application of Ergo-UAS system in fiat group automobiles. Work **41**, 4445–4449 (2012)
14. T.R. Waters, Ergonomics in design: interventions for youth working in the agricultural industry. Theor. Issues Ergon. Sci. **13**, 270–285 (2012)
15. A. Azadeh, I.M. Fam, M. Khoshnoud, M. Nikafrouz, Design and implementation of a fuzzy expert system for performance assessment of an integrated health, safety, environment (HSE) and ergonomics system: the case of a gas refinery. Inf. Sci. **178**, 4280–4300 (2008)
16. H.W. Hendrick, Applying ergonomics to systems: Some documented 'lessons learned". Appl. Ergon. **39**, 418–426 (2008)
17. W.P. Neumann, J. Eklund, B. Hansson, L. Lindbeck, Effect assessment in work environment interventions: a methodological reflection. Ergonomics **53**, 130–137 (2010)
18. A.S. Tavares, F.N. Da Silva, Ergonomics and design: its principles applied in the industry. Work **41**, 5981–5986 (2012)
19. K. Kogi, Participatory methods effective for ergonomic workplace improvement. Appl. Ergon. **37**, 547–554 (2006)
20. S. Lahiri, P. Markkanen, C. Levenstein, The cost effectiveness of occupational health interventions: preventing occupational back pain. Am. J. Ind. Med. **48**(6), 515–529 (2005)
21. J. Village, C. Searcy, F. Salustri, P.W. Neumann, Design for human factors (DfHF): a grounded theory for integrating human factors into production design processes. Ergonomics **58**, 1529–1546 (2015)
22. W.P. Neumann, J. Village, Ergonomics action research II: a framework for integrating HF into work system design. Ergonomics **55**, 1140–1156 (2010)
23. J.A. Gambatese, Research issues in prevention through design. J. Safety Res. **39**(2), 153–156 (2008)
24. J. Village, M. Greig, S. Zolfaghari, F. Salustri, W.P. Neumann, adapting engineering design tools to include human factors. IIE Trans. Occupat. Ergon. Human Factors **2**, 1–14 (2014)
25. D. Battini, M. Faccio, A. Persona, F. Sgarbossa, New methodological framework to improve productivity and ergonomics in assembly system design. Int. J. Ind. Ergon. **41**, 30–42 (2011)
26. D. Lamkull, L. Hanson, R. Ortengren, A comparative study of digital human modelling simulation results and their outcomes in reality: A case study within manual assembly of automobiles. Int. J. Ind. Ergon. **39**, 428–441 (2009)
27. D.R.D. Vilas, F. Longo, N.R. Monteil, A general framework for the manufacturing workstation design optimization: a combined ergonomic and operational approach. SIMULATION **89**, 306–329 (2013)
28. H. Sun, H. Houssin, M. Gardonni, F. de Bauvrond, Integration of user behaviour and product behaviour during the design phase: Software for behavioural design approach. Int. J. Ind. Ergon. **43**, 100–114 (2013)
29. T. Tosetto, A.J. Camarotto, Ergonomics and design in the Brazilian agricultural sector: a proposal to build matrix of contradictions. Work **41**, 5339–5346 (2012)
30. F. Bruno, M. Muzzupappa, Product interface design: A participatory approach based on virtual reality. Int. J. Human-Comput. Studies **68**, 254–269 (2010)

31. W. Karwowski, Ergonomics and human factors: The paradigms for science, engineering, design, technology and management of human compatible systems. Ergonomics **48**, 436–463 (2005)
32. Z. Taha, H. Soewardi, S.Z.M. Dawal, Axiomatic design principles in analysing the ergonomics design parameter of a virtual environment. Int. J. Ind. Ergon. **44**, 368–373 (2014)
33. B. Hu, W. Zhang, G. Salvendy, Impact of Multimodal Feedback on Simulated Ergonomic Measurements in a Virtual Environment: A Case Study with Manufacturing Workers. Human Fact. Ergon. Manuf. Serv. Indust. **22**, 145–155 (2012)
34. J. Marsot, QFD: a methodological tool for integration of ergonomics at the design stage. Appl. Ergon. **36**, 185–192 (2005)
35. D.B. Chaffin, Improving digital human modelling for proactive ergonomics in design. Ergonomics **48**, 478–491 (2005)
36. G. Colombo, D. Regazzoni, C. Rizzi, Markerless motion capture integrated with human modeling for virtual ergonomics, in *Digital Human Modelling-Part II*, pp. 314–323 (2013)
37. P.G. Dempsey, R.W. McGorry, W.S. Maynard, A survey of tools and methods used by certified professional ergonomists. Appl. Ergon. **36**, 489–503 (2005)
38. T. Binay, R. Rajesh, Maiti J, Ergonomic evaluation of billet mould maintenance using hierarchical task analysis, biomechanical modeling and digital human modeling. Comput.-Aided Desig. Appl. **12**, 256–269 (2014)
39. R. Rajesh, J. Maiti, B. Samanta, Application of the cube model for Biomechanical exposure assessment of combined manual material handling tasks in a manufacturing plant in India. IIE Trans. Occupat. Ergon. Human Factors **2**, 1–13 (2014)
40. M. Garcia, A. Sanchez, R. Domingo, M.A. Sebastián, A cost-benefit ergonomics methodology applied to service industry with digital human modeling. Europ. J. Industr. Eng. **8**(4), 533–553 (2014)
41. D.B. Chaffin, Human motion simulation for vehicle and workplace design. Human Factors Ergon. Manuf. Serv. Indust. **17**, 475–484 (2007)
42. C. Berlin, T. Kajaks, Time-related ergonomics evaluation for DHMs: a literature review. Int. J. Human Factors Model. Simul. **1**, 356–379 (2010)
43. J. Laring, M. Christmansson, R. Kadefors, R. Ortengren, ErgoSAM: A preproduction risk identification tool. Human Factors Ergon. Manuf. Serv. Indust. **15**, 309–325 (2005)
44. A. Cimino, F. Longo, G. Mirabelli, A multimeasure-based methodology for the ergonomic effective design of manufacturing system workstations. Int. J. Ind. Ergon. **39**, 447–455 (2009)

Chapter 13
Identification and Classification of Parameters for Woodworking Chisel Design

Dhananjay Singh Bisht and Mohammed Rajik Khan

1 Introduction

In today's competitive globalized market and socio-economic paradigm, manufacturers are increasingly interested in continuously monitoring market competition in order to keep their product lines updated with the current trends. The study of product competition has become an important preliminary exercise for any design project. Important insights about what manufacturers consider as important attributes of the product experience such as—unique/special features, value additions and specific/special customer needs are assessed by comparative benchmarking performed traditionally in the physical world, and today very often using online resources.

Collecting product-specific data physically from marketplace could be a tedious, time-consuming, and highly subjective process. Researchers often take help of manufacturer descriptions about products using online resources (outside of the formal scientific literature) to gain more practical, holistic and contemporary/historical insights about them [1]. With growing digitalization and web access, online mode of primary and secondary research is gaining popularity [2]. Commonly today, it is seen that most professional brand manufacturers and traders maintain official websites which provide holistic product descriptions and the latest product information.

Product design and research methodologies frequently adopt linguistic approaches inspired by the research traditions in the social sciences for gaining qualitative insights about user requirements necessary to make decisions regarding product features. Therefore, verbal description-based surveys are often conducted during

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user-centred research studies [3]. To cite specific instances of applications in the past, verbal descriptors have been studied in the context of hand tools [4], seats [5], etc.

A popular technique of meaningfully organizing verbal descriptors is card sorting. Card sorting is technique of organizing multiple pieces of information (e.g. verbal descriptors, user perceptions, etc.) into fewer meaningful categories composed of similar items [6]. Categories are proposed by survey participants and are generally similar in name or in concept. A research team analyses and combines similar categories to form higher order labels. Open card sorting is used to understand the patterns of how users classify information. Closed card sorting makes use of pre-defined categories supplied to users for assigning cards to them [7].

The product in focus in this study is woodworking chisel. A chisel is a tool of simplicity [8]. The construction is that of a sharpened steel blade attached to a handle. Chisels can be used to split, slice, scrape, chop and pare wood. They can be held in one hand and driven with a mallet, or be used by two hands for controlled paring cuts. They work equally well with hard or soft wood, almost indifferent to whether they are worked with the grain, across the grain or on end grain. Bench chisel is one of the most versatile tools inside a woodworking workshop. It is frequently used for dovetailing, mortise-and-tenoning, paring, installing hinges, chamfering edges, and even clean-up of workpieces. Suggestions for chisel selection can be found in various printed and online resources (e.g. [8, 9]). However, in order to understand essential factors underlying the buying decisions of consumers, and design decisions of manufacturers, it makes good sense that representative opinions regarding chisels from different manufacturers be formally examined. Currently, product reviews, discussion forums, product descriptions available on manufacturers' websites or on e-stores are some good sources to gather contextual information about any product. One of the reliable sources to gain updated information on the design concerns of manufacturers is the data available through product brochures and information available on manufacturer websites.

The aim of this study is to compile verbal descriptions about woodworking chisel designs from the websites of popular chisel manufacturers and reduce them into meaningful higher order factors. Such classification schemes could be employed for purposes such as developing information architecture of websites, new product development, developing marketing and organizational strategies, etc.

2 Procedure

This study was conducted in accordance to the principles and rules laid out for user research by the Institute Ethical Committee at National Institute of Technology, Rourkela.

2.1 Online Information on Chisel Designs

An online market research exercise was conducted to explore and understand popular literature on woodworking chisels developed by reputed brands. The list of manufacturers was decided based on inputs from three sources.

The first source was a study conducted in [8] where a comparison of 23 bench chisels was conducted based on the parameters of—(a) the amount of work required to get an out-of-the-box chisel ready for cutting; (b) performance of chisels in paring and dovetail and mortise and tenon joints; and (c) duration the edge held when chopping end grain. 23 brands were compared in this work, namely—*Ashley Isles, Ashley Iles American, Barr, Blue Spruce, C.I. Fall, Crown, Footprint, GarrettWade, Grizzly, Hirsh, Irwin, Lee-Valley, Lie Nielsen, MHG, Narex, Sorby, Pfeil, Two Cherries, Iyoroi, Grizzly (Japanese), Matsumura (White), Matsumura (Blue)* and *Nomikatsu.*

The second source for information on popular brands was [9] which provided a comparison of 10 brands of woodworking tools on the basis of their—(a) country of origin; (b) edge-holding; (c) slenderness; (d) price; (e) width of range; and (f) availability. The following ten brands were considered—*Pfeil*, *Stubai, Carl Heidtmann*, *Mifer*, *Auriou, Bristol Design, Robert Sorby, Ashley Iles, Henry Taylor (Acorn)* and *Marples.*

As a final source of information regarding popular chisel brands, the authors interviewed four woodworking experts employed as technical workshop staff in their department. Suggestion from 8 hardware store owners was also gathered. References to 8 additional chisel brands came up, namely—*Stanley, Dewalt, Eastman, Venus, Deeps, Taparia, Ajay Industries* and *Black Jack Tools.*

2.2 Analysis of Content

Based on a cumulative list of brands compiled from the 3 sources previously, product descriptions were extracted from the official websites of their manufacturers. This list of verbal descriptors was printed and provided to a team of experts constituted of 4 academic researchers (experienced Design faculty). Formally signed consent forms regarding voluntary participation were collected from the experts. The experts as a team were requested to analyse the descriptors and retain only the most meaningful and relevant ones. Redundant descriptions were singularized. A reliable list of concise and meaningful product descriptors was created.

A basic classification exercise was then conducted by the experts to identify descriptions specific to—(a) handle; (b) the blade; and (c) the chisel as an entire unit. An additional analysis of the descriptors was conducted to identify a design-centred classification of these items which the experts suggested could be useful for the purposes of new product development.

2.3 Card Sorting

An open card sorting exercise was conducted to identify functionality-centred categories underlying the verbal descriptors set. Chisel descriptors were examined by the 4 experts individually. Each expert was provided a deck of cards with one chisel descriptor listed in each card. The expert had to examine each card and stack functionally related items together in distinct piles. There were no restrictions regarding the minimum or maximum number of items that each pile could consist of. At the end of this process, each expert also had to propose a suitable label for each functional group resulting from this exercise. Later, the experts worked as a team to identify those group labels which were conceptually similar and combined them together under a single category label.

A closed card sorting was performed using 16 postgraduate students studying Design. Formal signed consent regarding voluntary participation was collected from the participants. Each of the participants had to analyse every chisel descriptor printed on a card and categorize it under one of the functional groups identified by the experts earlier. The conceptual nature of a typical item to be included within each functional group was clearly described to the participants. The cards were organized randomly during card sorting to eliminate perceptual biases. Since the participants were all postgraduate design students having spent at least 6 years in higher technical education, they had a fairly mature sense of design, manufacturing and marketing-related concepts. At the same time, the participants were being offered special assistance by the experts when they faced any conceptual concerns associated with the task. Later, a mapping exercise was performed to document the frequency of recommendations for placing different chisel descriptors under specific functional groups. This information was analysed by the 4 experts who then finalized assigning of different descriptor items to specific functional groups.

3 Results

38 chisel brands were identified for online research. Some of these brands did not have an official webpage. Descriptions on such chisels were collected from reliable alternative web sources, such as the websites of reputed retailers. From the different web sources, it was observed that the following categories of wood chisels were offered by the 38 brands—*bench chisels, firmer chisels, framing chisels, butt chisels, carpenter chisels, mortise chisels,* and *dovetail chisels.* However, many brands did not manufacture all these varieties of chisels. In order to standardize the context of data collection, product literature was collected for the single most common category of chisel manufactured by most brands which was found to be the ‘bench chisel’.

The different descriptors extracted for the 38 brands have been provided in Tables 1, 2 and 3. These descriptors were categorized by the 4 design experts into descriptions regarding the blade (Table 1), the handle (Table 2) and the complete chisel.

Table 1 Blade descriptors

Code	Descriptor
B01	Access to undercuts like dovetails
B02	Accurate in corners
B03	Bevel edge
B04	Blade guard
B05	Corrosion protection
B06	Cryogenically treated
B07	Cuts straight
B08	Diamond hardness tested
B09	Doubly tempered
B10	Easy to sharpen
B11	Extended life
B12	Extra long
B13	Fine polished
B14	Finely ground
B15	Finely honed
B16	Finished by hand
B17	Flat backs
B18	Flat grounded
B19	Flat tang
B20	Folds into handle
B21	For dovetailing
B22	For easy cutting of harder woods
B23	For manipulations in tight and difficult to access places
B24	Forged by hand
B25	Forged by new unique procedure
B26	Fully forged
B27	Fully grinded
B28	Gets into tight places
B29	Good edge retention
B30	Good rigidity
B31	Good strength
B32	Hardened
B33	High quality
B34	High-holding edge
B35	Highly polished
B36	Lacquered
B37	Laminated

(continued)

Table 1 (continued)

Code	Descriptor
B38	Large tang
B39	Long life
B40	Micro-precise grinding
B41	Minimal friction
B42	Mirror like sheen
B43	Optimum clearance
B44	Parallel sides
B45	Provides sidewall clearance
B46	Provides security
B47	Razor sharp
B48	Reduced risk of blade binding in the cut
B49	Robust forged
B50	Rolling on work surface prevented
B51	Rust resistant
B52	Shaft with through tang
B53	Sharp edge
B54	Sharpened using common abrasive such as water stones
B55	Short
B56	Sides sharpened
B57	Smooth cutting
B58	Smooth face
B59	Superior sharpness
B60	Tang seated deeply
B61	Tapered bevel
B62	Tapered from shoulder to tip
B63	Thin section
B64	Thin sides
B65	Tough
B66	True bevel
B67	Ultra-fine finishing
B68	Unbeatable durability
B69	Unbeatable strength
B70	Wear resistant
B71	Workable in angled corner or tight recess

Table 2 Handle descriptors

Code	Descriptor
H01	2-part component/bi-material
H02	Asymmetrical profile
H03	Brushed surface
H04	Bulky handle
H05	Cap
H06	Cap withstands repetitive impact/strikes
H07	Comfort in hand
H08	Comfortable gripping
H09	Contoured
H10	Domed end
H11	Durable
H12	Easily replaced
H13	Easy grip
H14	Easy re-seating
H15	Easy to use mallet on end
H16	Easy to use in palm
H17	Elasticity in handle
H18	Ergonomic in hand
H19	Excellent control
H20	Experiencing resurgence in popularity
H21	Extra strength
H22	Extra-large cap
H23	Fatigue free handling
H24	Firm grip
H25	Fits hand nicely
H26	Flat surface
H27	Flats on the top and bottom
H28	For heavy slugging
H29	For paring tools
H30	Hammer button/impact button/strike cap
H31	Handle holds in place
H32	Hardwood handle
H33	Hardwood socket-type handle
H34	High strength
H35	Hole for wall mounting/hanging/suspension
H36	Hornbeam/ Ash/Elm handle
H37	Interchangeable colors

(continued)

Table 2 (continued)

Code	Descriptor
H38	Large striking ring
H39	Longer handle
H40	Loose/not-loose
H41	Natural variation in color
H42	Non-slip handle
H43	Non-slip inserts
H44	Oiled wood
H45	Opening for storage
H46	Precise control
H47	Preferred grip
H48	Refined paring
H49	Resistant to heavy chopping cuts
H50	Resistant to impact
H51	Resists chipping from glancing mallet blows
H52	Robust
H53	Rubber inserts
H54	Shallow flats parallel to the blade back on handle
H55	Shatter resistant
H56	Shorter handle
H57	Simple tap removal
H58	Sits nicely in palm
H59	Socket type handle
H60	Stained handle
H61	Steel striking ring
H62	Strength lies between timber and steel
H63	Tactile cues for finger placement
H64	Tapered version
H65	Toughness
H66	Unbeatable tensile strength
H67	Waxed
H68	Withstands heavy blows from mallet/high impact
H69	Wood from sustainable source
H70	Wood wedged into tapered socket

Table 3 Complete chisel descriptors

Code	Descriptor
C01	"Hallmark" of guarantee
C02	Accessible packaging
C03	Accurate
C04	Added control
C05	Balances well
C06	Best-in-class
C07	Blade guard
C08	Branded
C09	Brass/steel ferrule
C10	Carpenter's chisel
C11	Centre of gravity below tang-socket connection
C12	Centre of gravity close to the tang-socket connection
C13	Comfortable
C14	Controlled use
C15	Design for craftsmen
C16	Designed by craftsmen
C17	Drop forged
C18	EAN code provided
C19	Easy for customers to evaluate product in store
C20	Easy identification
C21	Elegant gilt-edge taper bolster and ferrule
C22	Ergonomic design
C23	Ever popular style
C24	Expensive
C25	Expensive to make
C26	Favorite of woodworkers around the world
C27	Fine balance
C28	Firmer chisel
C29	Follows DIN 5139 requirements
C30	For carving out a recess with ease
C31	For cleaning up the job
C32	For fine woodworking
C33	For finishing work
C34	For fitting joints
C35	For gentle paring

(continued)

Table 3 (continued)

Code	Descriptor
C36	For guiding with precision and care
C37	For heavy blows
C38	For on-site/jobsite work
C39	For professional construction
C40	For rough jobs
C41	For the most demanding tasks
C42	For traditional cutting
C43	Framing chisel
C44	Free-hand use
C45	Fulfills user need
C46	Handle and blade aligned accurately
C47	Handles are less likely to break
C48	Handles can be replaced easily
C49	Heavy-duty
C50	High/finest quality
C51	Highest standards
C52	Indented mark of brand identity
C53	Innovated design
C54	Integral part of woodworker's toolkit
C55	Leather washer
C56	Light pattern
C57	Made from solid bar stock/blank
C58	Made in Japan
C59	Made in own machine shop
C60	Made of craftsmanship
C61	Manages in restricted working space
C62	Marked with size
C63	Milled
C64	Name you can trust
C65	Not common these days
C66	Once produced in a vast array
C67	Optimal precision as with hand-forged
C68	Popular product/design
C69	Precision made
C70	Professional woodworking
C71	Protects working edges of blade when not in use
C72	Reputed
C73	Resurgence in popularity

(continued)

Table 3 (continued)

Code	Descriptor
C74	Revolving ferrule
C75	Ring ferrule
C76	Short
C77	Should be your first set
C78	Socket chisel
C79	Socket-like stainless-steel ferrule that seats directly onto the shoulder
C80	Solid steel ring for years of dependable use
C81	Strong ferrule
C82	Superb/Excellent balance
C83	Superior performance
C84	Supports light mallet strokes
C85	Tapered version
C86	Traditional
C87	Turned
C88	Unique
C89	Universally used
C90	Versatile
C91	Withstands abuse

3.1 Design-Centred Descriptors

On preliminary examination of descriptors by the team of experts, a tripartite design-centred typology was realized. 3 design-specific categories of chisel descriptors were proposed by the team, namely—(a) objective descriptions; (b) subjective descriptions; and (c) descriptions about the performance, benefits and value.

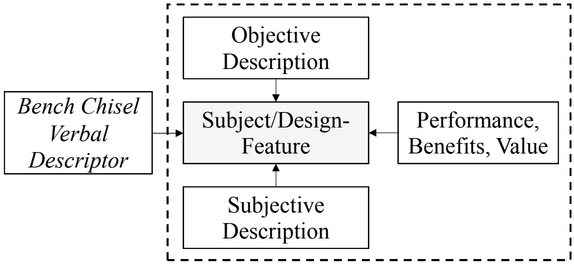
The following explanations were provided by the experts in support of this decision.

Expert 1: *"A good design could be articulated well and finally implemented to satisfaction if we have information regarding both the objective descriptions of the design as well as a multi-perspective subjective understanding of its usefulness."*

Expert 2: *"A designed artifact serves a specific utility. It makes sense to describe an artifact in terms of its performance during intended use. Also, in terms of the benefits offered with its adoption and use."*

A block diagram to illustrate the conceptual understanding of this classification scheme is provided in Fig. 1. The nature of the three categories proposed is limited to design-specific concerns which typically include objective and subjective details, as well as the descriptions regarding performance, benefit and value offerings.

Fig. 1 Deconstruction of a standard descriptor phrase



The first category of descriptors includes those terms and phrases which provided a fairly objective description of the chisel design. These include information which is not ambiguous, i.e. clear technical descriptions, as well as undisputed facts about the design. Descriptors in this category include phrases such as ‘drop forged’, ‘follows DIN 5139 requirements’, ‘turned from solid blank’, etc.

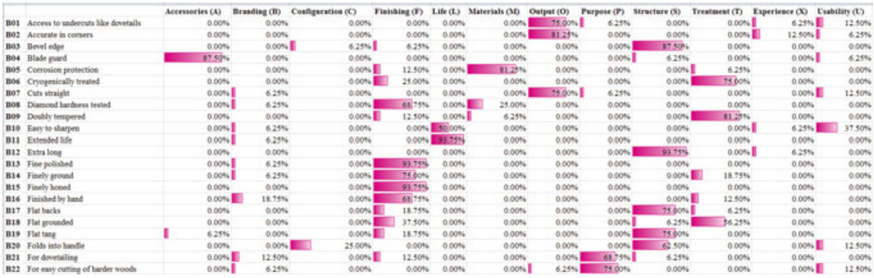
The second category of descriptors includes terms and phrases which are subjective in nature, i.e. hard-to-quantify, perceived qualities of the subject, or its description. Such descriptors also include phrases with multiple or unclear interpretations. The items include descriptors such as ‘light pattern’, ‘ergonomic design’, ‘shorter handle’, etc.

Several descriptors provided by chisel manufacturers were provided in the form of claims of existence of certain qualities or features in the product. Such descriptors were often provided in the form of a pure subject, i.e. a kind of a checkbox item. Such items were treated as value additions as a consequence of their presence as a product feature—e.g. items like ‘blade guard’ and ‘corrosion protection’ (Table 1). Such descriptors also include terms and phrases that provided performance descriptions or benefits offered by the product. This category includes terms such as ‘durable’, ‘free hand use’, ‘fulfills user needs’, etc.

3.2 Functionality-Centred Descriptors

The tripartite design-centred categorization scheme for classifying chisel design descriptors (Fig. 1) faces the limitation of not being functionality-specific. To overcome this limitation, the 4 experts conducted an open card sorting and found 12 different functional factors that describe the entire set of chisel descriptors from Tables 1, 2 and 3. The following categories were suggested by the 4 experts, respectively –

Expert 1: *Human-centered concerns; Components of chisel; Branding of chisel; Construction details; Fabrication details; Performance of chisel; Structure specific details (7 factors).*



		Accessories (A)	Branding (B)	Configuration (C)	Finishing (F)	Life (L)	Materials (M)	Output (O)	Purpose (P)	Structure (S)	Treatment (T)	Experience (X)	Usability (U)
B01	Access to undercuts like dovetails	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	6.25%	0.00%	0.00%	6.25%	12.50%
B02	Accurate in corners	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	81.25%	0.00%	0.00%	0.00%	12.50%	6.25%
B03	Bevel edge	0.00%	0.00%	6.25%	6.25%	0.00%	0.00%	0.00%	0.00%	87.50%	0.00%	0.00%	0.00%
B04	Blade guard	87.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.25%	0.00%	0.00%	6.25%
B05	Corrosion protection	0.00%	0.00%	0.00%	12.50%	0.00%	81.25%	0.00%	0.00%	0.00%	6.25%	0.00%	0.00%
B06	Cryogenically treated	0.00%	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%	0.00%
B07	Cuts straight	0.00%	6.25%	0.00%	0.00%	0.00%	0.00%	75.00%	6.25%	0.00%	0.00%	0.00%	12.50%
B08	Diamond hardness tested	0.00%	6.25%	0.00%	68.75%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
B09	Doubly tempered	0.00%	0.00%	0.00%	12.50%	0.00%	6.25%	0.00%	0.00%	0.00%	81.25%	0.00%	0.00%
B10	Easy to sharpen	0.00%	6.25%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.25%	37.50%
B11	Extended life	0.00%	6.25%	0.00%	0.00%	93.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
B12	Extra long	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	93.75%	0.00%	6.25%	0.00%
B13	Fine polished	0.00%	6.25%	0.00%	93.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
B14	Finely ground	0.00%	6.25%	0.00%	75.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.75%	0.00%	0.00%
B15	Finely honed	0.00%	0.00%	0.00%	93.75%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
B16	Finished by hand	0.00%	18.75%	0.00%	68.75%	0.00%	0.00%	0.00%	0.00%	0.00%	12.50%	0.00%	0.00%
B17	Flat backs	0.00%	0.00%	0.00%	18.75%	0.00%	0.00%	0.00%	0.00%	75.00%	6.25%	0.00%	0.00%
B18	Flat grounded	0.00%	0.00%	0.00%	37.50%	0.00%	0.00%	0.00%	0.00%	6.25%	56.25%	0.00%	0.00%
B19	Flat tang	6.25%	0.00%	0.00%	18.75%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%	0.00%	0.00%
B20	Folds into handle	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%	0.00%	62.50%	0.00%	0.00%	12.50%
B21	For dovetailing	0.00%	12.50%	0.00%	12.50%	0.00%	0.00%	0.00%	68.75%	6.25%	0.00%	0.00%	0.00%
B22	For easy cutting of harder woods	0.00%	6.25%	0.00%	0.00%	0.00%	0.00%	6.25%	75.00%	0.00%	0.00%	0.00%	12.50%

Fig. 2 Screenshot of a table developed for frequency analysis of participant responses during closed card sorting (n = 16)

Expert 2: *User experience; Tool usability; Chisel assembly; Value offered; Manufacturing information; Material details; Chisel features; Maintenance details; Operation-related information; Tool purpose; Form-related information (11 factors).*

Expert 3: *Aesthetics, sensing and feeling; Design; Accessories; Information; Finishing and processing; Properties; Working and output; Shape (8 factors).*

Expert 4: *Subjective information; Configuration-related descriptions; Parts and features of chisel; Advantages of the tool; Fabrication details; Material specifications; Maintenance-related descriptors; Performance of the tool; Built of the chisel (9 factors).*

A total of 35 categories (factors) were proposed by the 4 experts. It was seen that many of these categories conceptually overlapped with each other. Therefore, the experts as a team analysed and resolved the 35 unresolved functional categories into 12 relatively distinct ones. Then, based on the responses from 16 student participants using a closed card sorting exercise, each descriptor item was assigned to a unique functional category if a majority of the participants recommended this assignment during sorting (see Fig. 2). In Table 4, a list of the 12 categories has been provided with a unique reference code for each category. Also provided are the corresponding descriptions about the factor (label) and the mapping of the different verbal descriptor items from Tables 1, 2 and 3 against these factors.

4 Discussion

From the sorting results, it can be observed that within the chisel literature accessed, greatest numbers of descriptions (39) were about *branding and information (B)*. The factor of *branding and information* includes details specific to market positioning of the brand and information associated with the product including value propositions. In their online literature, manufacturers place a special focus on advertising the product and in highlighting their value offerings. This should explain the presence

Table 4 Twelve technical factors describing the functional space of bench chisel design

Functional factor name and reference code	Brief and detailed description of the factor	Codes of descriptors within the group (ref. Tables 1, 2 and 3)
Accessories (A)	*Accessories, parts and features.* Details about different features and parts of the product	B04, 38; H05, 22, 30, 38, 43, 53, 61, 63; C07, 09, 55, 74–75 (15 items)
Branding (B)	*Branding and information.* Advertising pitches and descriptions about special information, quality and value statements	B24, 33; H18, 20, 47, 69; C01, 06, 08, 15–16, 18, 22–26, 29, 45, 47, 50–54, 58–60, 62, 64–66, 68, 70, 72–73, 77, 86, 88–89 (39 items)
Configuration (C)	*Assembly of parts and their configuration.* Information on how different parts are fit together, configured and interact with each other	B60; H40, 70; C46, 79 (5 items)
Finishing (F)	*Finishing and construction details.* Specific details about the finishing details and special qualities offered due to the construction	B08, 13–16, 35, 43, 56, 59, 66–67; H03, 21, 31, 60; C11-12, 69, 82 (19 items)
Life (L)	*Maintenance and life of the product.* Maintenance related information and benefits, and descriptions about life of the product	B10-11, 39, 54, 68; H06, 11–12, 14, 49–51, 51, 55, 57, 68; C48-49, 71, 80–81, 91 (22 items)
Materials (M)	*Materials used and associated properties.* Descriptions of materials used, their composition and their properties	B05, 29–31, 34, 51, 65, 69–70; H01, 17, 32, 34, 36, 62, 65–66 (17 items)
Output (O)	*Performance and output.* Performance of the product and the output observed on use of the product	B01-02, 07, 28, 41, 45, 48, 50, 57, 71; H19, 46; C03-05, 14, 30, 61, 67, 83, 90 (21 items)
Purpose (P)	*Purpose and context of use suggested.* Descriptions or prescriptions about the context of use	B21, 22–23; H28-29, 48; C10, 30–43, 84 (22 items)
Structure (S)	*Structure, shape and size.* Details about the physical shape, form and structure of the product	B03, 12, 17, 19–20, 44, 47, 52–53, 55, 58, 61–64; H02, 04, 09–10, 26–27, 33, 35, 39, 45, 54, 56, 59, 64; C76, 78, 85 (32 items)

(continued)

Table 4 (continued)

Functional factor name and reference code	Brief and detailed description of the factor	Codes of descriptors within the group (ref. Tables 1, 2 and 3)
Treatment (T)	*Processing, treatment and manufacturing.* Manufacturing details and information about specific treatment met to the product	B06, 09, 18, 25–27, 32, 36–37, 40, 49; H44, 67; C17, 57, 63, 87 (17 items)
Experience (X)	*Aesthetics and user experience.* Descriptions regarding subjective feeling and experiences of users	B42; H07-08, 23–25, 37, 41, 47, 58; C13, 21, 27, 56 (14 items)
Usability (U)	*Product usability.* Descriptions about usability-centered design features, and superiority of product during use	B46; H13, 15–16, 42; C02, 19–20, 44 (9 items)

of a majority of such descriptors in the data set. Also, a high number of descriptors (32) were related to the *structure, shape and size (S)* of chisels. The s*tructure, shape and size* factor constitutes a more utilitarian concern than that of branding. Structure-based considerations are probably the most fundamental for any consumer to rationalize the buying decision, which explains the reason for a large number of such descriptions available on manufacturers' websites. The lowest number of descriptors (5) were found for the categories of *assembly of parts and their configuration (C)*, and then for *product usability (U)* (9). Descriptors regarding *assembly, parts and configurations* were the lowest in numbers probably because the bench chisel typically has very few components. Another reason could be that a significant number of descriptors regarding chisel components were considered under conceptually close categories such as *accessories, parts and features (A).* Another factor constitutive of only a few descriptors was *product usability*. Here again, the reason for few members could be the assigning of some usability-related descriptors under other more contextually relevant factors such as *performance and output (O)*, or *aesthetics and user experience (X).*

5 Conclusion

In this paper, a detailed list of verbal descriptors regarding bench chisels was compiled using information published online by manufacturers of 38 popular brands. Then, using direct observation accounts of 4 design experts, separate lists of descriptors were identified for the blade, the handle and the chisel as a whole. These experts later helped in classifying these descriptors on the basis of 3 design-centred categories namely objective, subjective and value-specific descriptions. Finally, using open and closed card sorting techniques, 12 functionality-specific factors were identified by the experts and the 232 descriptors captured from online literature were mapped against these factors.

The authors admit to the use of only a limited number of contexts within which the chisel descriptors were examined and the categories established. However, it was always felt that other kinds of contextual categorization schemes for the bench chisel descriptors may be explored in the future. Also, categorical schemes proposed in this study could be further examined for their validity across various populations and in different contexts. From this paper, the descriptors and the categories developed using them can also be employed as the conceptual basis for different real-life applications, e.g. designing better hardware tools for consumers, developing superior information architecture for manufacturer websites, setting-up specialized functional divisions within an organization that deals with woodworking tools, etc.

References

1. M. Vergara, S. Mondragón, J.L. Sancho-, M.J. Agost, Perception of products by progressive multisensory integration. A study on hammers. Appl. Ergon. **42**(5), 652–664 (2011)
2. J.E. Pitkow, M.M. Recker, Using the Web as a survey tool: Results from the second WWW user survey. Comput. Netw. ISDN Syst. **27**(6), 809–822 (1995)
3. D. Kee, I. Lee, Relationships between subjective and objective measures in assessing postural stresses. Appl. Ergon. **43**(2), 277–282 (2012)
4. L.F.M. Kuijt, J. Twisk, L. Groenesteijn, M.P. De Looze, P. Vink, Identifying predictors of comfort and discomfort in using hand tools. Ergonomics **48**(6), 692–702 (2005)
5. K. Ebe, M.J. Griffin, Factors affecting static seat cushion comfort. Ergonomics **44**(10), 901–921 (2001)
6. W. Hudson, Playing your cards right: getting the most from card sorting for navigation design. Interactions **12**(5), 56–58 (2005)
7. T. Warfel, D. Maurer, *Card sorting: a definitive guide. Boxes and arrows* (2004). Available: http://boxesandarrows.com/card-sorting-a-definitive-guide/
8. C. Gochnour (2008). Available: http://www.startwoodworking.com/sites/default/files/tool-test-bench-chisels.pdf
9. D. Onians, *Essential woodcarving techniques.* Guild of Master Craftsman Publications Limited (1997)

Chapter 14
Evaluation of Driving Postures of Electric Loco Goods Pilots Using Muscle Fatigue Assessment in WAG7 Locomotives

Subir Danda, Soumya Sarkar, Bikash Bepari, Kalyanbrata Saha, and Balendra Nath Lahiri

1 Introduction

Indian Railways (IR) is a government-owned and operated fourth-largest rail network in the world. It connects far away areas of the country by route length of about 67,000 km. It carried an average of 26 million passengers and around 2.8 million tonnes of freight daily. The revenue earning of freight traffic in Indian railways is escalating with increasing movement in coal, fertilizer, iron-ore and cement; and by which it adds score to the India's Gross Domestic Product (GDP). This is only been possible due to the efforts of about 1.3 million employees working round the clock [1–3]. In Railway, thousand kinds of job are being performed by the specialized and segmented team of workers. The loco pilots (locomotive drivers) represent a unique segment of their own kind.

Drivers, whatever be the mode of transport, have a great responsibility, any mistake may toll severely by bringing irreversible loss of lives and property.

But if the focus is concentrated on their life, it has been noted that the professional electric loco pilots (electric engine drivers) are susceptible to musculoskeletal disorders, which often lead to de-categorization and low retirement age. The electric loco pilot's working ambiance, i.e. driving cabin, exposure to vibrations, noise and

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electromagnetic radiation, climatic conditions, driving posture, irregular and against the nature job condition, affect their life adversely.

Katsis et al. (2015) used several metrics of surface electromyograms to found out muscle fatigue of the drivers during actual driving conditions [4].

Etemadinezhad et al. (2018) found that Muscle Fatigue Assessment (MFA) is a more suitable tool to predict workers' musculoskeletal discomfort compare to few other ergonomic evaluation methods [5].

Wibisono et al. (2016) conducted an ergonomic study on carpenter by using MFA tool and as per outcome; few suggestion has been made [6].

Nusantara et al. (2017) conducted a study on influence of working posture of packing workers and MFA score suggests low level of fatigue on all of body segment with new packing desks [7].

Damayanti et al. (2018) used Rodgers Muscle Fatigue Analysis Method (MFA) to assess the physical risks of elderly workers, and the result confirms that all elderly workers have musculoskeletal complaints in the lower back, legs and neck [8].

A sample of 29 electric goods loco pilots, working in standing/sitting postures (driving postures) was studied. The study is conducted on few specific frequently adopted postures, which are broadly classified into two categories, (i) Primary Functions, essential to operate the moving giant; and (ii) Secondary Functions, additional activity to smoothen the running of train.

The primary function is further sub-divided into five elementary activities, e.g. Notching (to accelerate the train), Braking (to decelerate or stop the train), etc. Similarly the secondary functions are sub-divided as Talking in walky-talky, Signal Exchange, etc.

The results are finally evaluated by using Rodgers Muscle Fatigue Assessment method. The Rodgers Muscle Fatigue Assessment is a tool, which assesses the amount of fatigue that accumulates in muscles during various work patterns [9–11].

The objective of the study is to identify the region of the body segment, which is susceptible to injury and inflammation due to fatigued muscle and suggest the preventive measures.

2 Methodology

The WAG_7 is the most economical, affordable and successful class of goods locomotive with 6000 hp hauling capacity. It is an indigenous design by RDSO and built by CLW and BHEL. All BHEL built WAG_7 locomotives have Tiger Face colours, i.e. Red or Dark Blue on white. But CLW built WAG_7 locomotives have yellow stripe on blue colour.

On 3 August 1992, the first WAG_7 locomotive was inaugurated and named *Shantidan* in honor of *Mother Teresa*. In the 2015–16 financial year, this type of loco production was totally stopped in CLW [13, 14].

Only WAG_7 old variant type electric locomotives were considered for the present study.

In general, the WAG_7 old variant locomotives have a wooden driving seat with Rexene/ cloth cover and a small backrest. The space between the driving desk and the chair is in-sufficient. Hence the driving posture is quite constrained. For footrest a rod is only provided. The size of the engine's cab room is quite small. The position of sanding paddle switch, vigilance switch, and brake paddle is quite awkward, and needs to be operated by legs only.

A circular notch is provided on the driving desk. The elevation of A-9 valve is higher than driving desk. The SA-9 valve is situated higher than this, and both are on the left side. The horn lever is situated approximately at the same height as the driving desk (Figs. 1 and 2).

About 29 male electric goods loco pilots were considered for the present study and all of them participated voluntarily. To collect the raw data, a Canon compact camera was used for videography in situ in running train.

The study is focused on few frequently adopted postures and activities, which are broadly classified as primary functions and secondary functions.

The primary functions are those activities, which are essential to operate the moving giant and the secondary functions are additional activities and assist for smoother control of train.

Fig. 1 CLW make WAG_7 old variant electric locomotive

Fig. 2 BHEL make WAG_7 old variant electric locomotive

The primary function is sub-divided into five elementary activities

(i) Notching—to accelerate or decelerate the train,
(ii) Brake application—to decelerate or stop the train,
(iii) Operating Breaker & switches—to on/off the various controls, e.g. blower, compressor, head light, etc.
(iv) Driving—overall monitoring, and
(v) Looking at Gauges—to monitor the various parameters.

Similarly the secondary functions are sub-divided as

(i) Application of horn—to alert all about moving giant,
(ii) Operating vigilance switch—to feed anti-sleep signal to the locomotive control,
(iii) Talking in walky-talky—to exchange verbal communication,
(iv) Signal exchange—to exchange speech-less communication, and
(v) Leaning out—to observe the following train attached at the rear end.

Lot of physical activities are performed by the loco pilots during their duty. These tasks are separated into numbers of elementary activities using Therbligs as suggested by Gilbreth and then analysed.

Therbligs is mainly used to simplify work. It comprises a system to analyse the motions involved in performing a task. The identification of individual motions, as well as moments of delay in the process, are used to find out the unnecessary or inefficient motions and thus helps to utilize or eliminate even split-seconds of wasted time.

The presently used Therbligs are a combination of those assigned by the Gilbreths, Alan Mogensen and Dr. Ralph Barnes [15].

During analysis, the worst postures were identified and evaluated by using Muscle Fatigue Assessment (MFA). This indexing method is utilized to identify the tasks and body segments associated with highest potential of risk.

The Muscle Fatigue Analysis was proposed by Rodgers as a means to assess the amount of fatigue that accumulates in muscles during various work patterns within 5 min of work. The hypothesis was that a rapidly fatiguing muscle is more susceptible to injury and inflammation. With this in mind, if fatigue can be minimized, so should injuries and illnesses of the active muscles can be minimized. This method for job analysis is most appropriate to evaluate the risk for fatigue accumulation in tasks that are performed for an hour or more and where awkward postures or frequent exertions are present. Based on the risk of fatigue, a Priority for Change can be assigned to the task [9].

Effort levels description for the different body segments, continuous (single) effort duration and effort frequency are provided on MFA data collection form. Within a body region, once an Effort Level is chosen to represent the task, the assignment of Continuous Effort Time and Efforts per Minute should be associated with the chosen effort. The Priority for Change is found by locating the combination of scores in the various categories in the table on task identification data sheet. The table provides an indication of relative risk for fatigue within a category [10, 11].

To carry out appropriate statistics on collected data and unbiased analysis of outcomes, excel software was utilized. The results are also verified by using basic formulations available in standard textbook [17].

3 Results

The driving posture of 29 male electric loco goods pilots was considered for the present study. All of them were chosen randomly and they had participated voluntarily.

The maximum MFA score in any of the body segment during above said primary activities are listed below (Table 1).

The graphical representations of primary activities are as below (Fig. 3).

Result indicates that none of the body segment is under fatigue condition during notching activity. But during application of brake, above 70% population is suffering from muscle fatigue in any of their body segment. The reason for the same may be revealed by elaboration of the MFA scoring system, which is listed as under.

Table 1 Priority for change on primary activities

Change priority	Notching	Brake aapplication	Operating breaker	Driving	Looking gauges
Low	29	8	21	22	21
Medium	0	21	0	7	8
High	0	0	3	0	0
V/ High	0	0	0	0	0

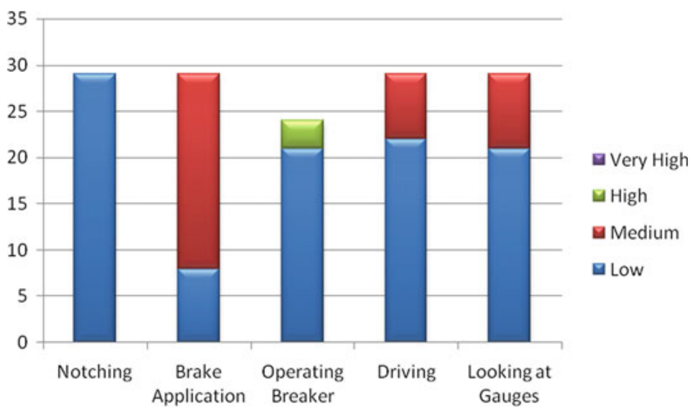

Fig. 3 Graphical representation of Priority for Change on Primary Activities

Table 2 Elaboration of braking posture

Change priority	Back	Leg		Feet		Left shoulder	Left Arm	Left wrist
		Lt.	Rt.	Lt	Rt			
Medium	1	1	21	1	21	5	7	8

Table 3 Elaboration of breaker and switch operating posture

Change priority	Left wrist	Right wrist
High	1	2

Table 4 Elaboration of driving posture

Change		Leg		Feet		Shoulder		Arm		Wrist	
Priority	Back	L	R	L	R	L	R	L	R	L	R
Medium	2	3	6	3	6	2	1	2	1	2	1

Table 5 Elaboration of gauge reading posture

Change priority	Neck
Medium	8

Table 2 indicates that the braking posture is deteriorating mostly due to fatigue accumulation in right leg and feet. In few other cases, the fatigued muscles have also been observed in left shoulder, arm and wrist region.

Operating breaker and switches scores indicate 12.5% population have high change priority, the elaboration of the same is as depicted below.

Table 3 indicates that for the above posture, cases muscle fatigue is in the region of operating wrist.

Driving scores indicates 24% population havechange priority of medium category and elastration of the same is as below.

Table 4 indicates that the driving posture is worsening mainly due to fatigued muscle in the right lower limb.

Scores for looking at gauges indicate above 27% population have medium change priority, the elastration of the same is as under.

Table 5 indicates that the driving posture is weakening only due to fatigue in the neck region.

As previous, the maximum MFA score in any of the body segment during the above said secondary activities are listed below (Table 6 and Fig. 4).

The graphical representations of secondary activities are as below.

Result indicates that few population showed fatigue body segment in each of the above-mentioned secondary activity. Similarly the reason for the same may be revealed by elaboration of the MFA scoring system as previous. As it contains five sub-section, hence one by one elaboration is made as under.

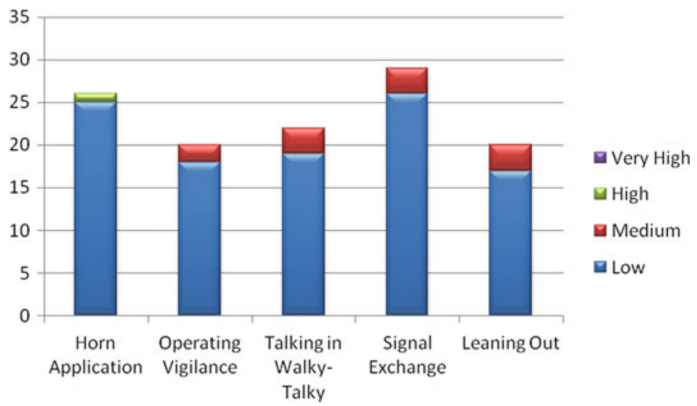

Fig. 4 Graphical representation of Priority for Change on Secondary Activities

Table 6 Priority for change on secondary activity

Change priority	Horn application	Operating vigilance	Walky- talky	Signal exchange	Leaning out
Low	25	18	19	26	17
Medium	0	2	3	3	3
High	1	0	0	0	0
V. High	0	0	0	0	0

During application of horn, only one person is showing high priority in MFA score.

Table 7 shows the same is in the left wrist region.

About 10% of populations are having medium change priority during operating vigilance switch as shown below.

Table 8 discloses the same is on the right lower limb region only.

Using of walky-talky scores indicates that above 13% population have priority for change of medium category as shown below.

Table 9 specifies that the stress is on the upper limb region only.

Table 7 Elaboration of honking activity

Change priority	Left wrist
High	1

Table 8 Elaboration of vigilance switch operating posture

Change priority	Right leg	Right feet
Medium	2	2

Table 9 Elaboration of walky-talky using posture

Change priority	Left shoulder	Left arm	Right arm	Left wrist	Right wrist
Medium	1	2	1	2	1

Table 10 Elaboration of signal exchange posture

Change priority	Left shoulder	Left arm	Left wrist	Right wrist
Medium	2	2	2	1

Table 11 Elaboration of leaning out posture

Change	Leg			Feet		Right	Right	Right
Priority	Neck	Lt	Rt	Lt	Rt	Shoulder	Arm	Wrist
Medium	1	1	1	1	1	1	3	2

Signal exchange scores indicate, above 11% population have priority for change of medium category as shown below (Table 10).

Table 11 revealed that the stress is also in the upper limb region.

Scores of leaning out identify that 15% population belongto medium change priority category as shown below.

Table 11 shows that the fatigue is also in the upper limb region mainly.

4 Discussion

In WAG_7 locomotive, notch is a steering wheel shaped horizontal circular wheel, rotates about its axis by application of torque by hand. By rotating this notching wheel in clockwise direction the train is accelerated or vice versa. Therefore the notching activity includes—notching, de-notching, application of dynamic braking, etc. This task is needed to be performed frequently by using a jerk produced by right hand mainly. The Therbligs of this posture is *Use*. As per MFA scoring system, the change priority of notching activity is low, which means it is a safe task.

By operating the A—9 valve, the brake in train is applied. For that, the loco pilot needs to pull a horizontal lever in anti-clockwise direction by left hand. Simultaneously, the right leg needs to push a brake lever for its effective and smooth application. The Therbligs of this posture is *Use*. Results shows, above 70% population is having fatigue in right lower limb of the body and about 25% population in left upper limb region. In all the above cases, the MFA change priority score is 231, where score 2 indicates moderate effort level, 3—continuous effort duration for 20 to 30 s, and 1—effort frequencies less than one per minute. So, by reducing the engagement duration on brake paddle and brake lever, the effort duration can be minimized, which simultaneously reduce the MFA change priority score.

Breaker and switches are required to operate to put on/off blower, compressor, headlight and other control switches. The Therbligs of this posture is *Use*. In above activity, about 12.5% populations are having high change priority score of 321 in the operating wrist region. Here also score 3 indicates heavy effort level, 2—continuous effort duration for 6 to 20 s and 1—effort frequencies less than one per minute. The above result indicates the holding of breaker/switch with pinch grip for moderate duration of time need to be prevented to make the posture comfortable.

Driving is mainly a cognitive task, in which the body posture remains static most of the time and the loco pilots mainly search for any abnormality in the track or not. The Therbligs of this posture is also *Search*. About 24% of populations are having various MFA scores with medium change priority at various body segments. But holding the notch wheel or brake lever with deviated wrist need to be prevented; also the legs and feet need to be supported properly. These two adaptations and proper training certainly bring down the MFA score.

The various parameters of locomotive are displayed on various gauges located at various regions of driving cab. The loco pilots need to follow the reading by rotating their eye and head at regular interval for smooth operation of train. The Therbligs of this posture is *Inspect*. MFA suggest above 27% population have medium change priority score in the neck region with score value of 213, where 2 means moderate effort level, 1 is continuous effort duration less than 6 s, and 3—effort frequencies more than 5 to 15 per minute. By reducing the frequency of neck movement, the MFA scores can be minimized.

Blowing horn is a secondary activity with Therbligs *Use*. By using left hand (mainly), the loco pilots need to press horn lever in vertically downward direction. It is a safety device and is used to draw the attention of all nearby. Only one person is showing high priority scoring 321 in the left wrist region during the above-said posture. Obviously here also 3 stand for high effort level, 2 for continuous effort duration of 6 to 20 s, and 1—effort frequency less than one per minute. Therefore the result indicates that the person was holding horn lever with pinch grip for moderate duration of time.

The vigilance is a foot switch, need to operate minimum of once in a minute during loco running, otherwise, the loco brake will operate automatically. It is also a safety device; feeds the engine control about awakening condition of loco pilots. The loco pilots generally operate this switch by their right foot and the posture Therbligs is *Use*. Only two persons are having medium change priority score of 213 at right lower body segment, where 2 stand for moderate effort level, 1 for continuous effort duration less than 6 s and 3 for effort frequencies more than 5 to 15 per minute. In the present case, instead of operating once in a minute, 5 or more numbers of times the vigilance switch is operated, which is the main cause of increased MFA scores.

Walky-talky is used for verbal communications with other railway employees engaged with the rail movement, and the Therbligs is *Use*. Three persons are having MFA score of 231 in operating hand upper limb portion, where 2 stand for moderate effort level, 3 for continuous effort duration for 20 to 30 s and 1 for effort frequency less than one per minute. The result clearly indicates that the continuous effort duration is responsible for these increased MFA scores.

Signal exchange is a speechless communication with the railway employees engaged with the rail movement, and the Therbligs is *Search*. Here also three persons are having MFA scores of 231 in the upper limb area. The reduction of continuous effort duration certainly improves the situation.

To watch the following train attached to the rear end of the locomotive, leaning out activity is performed and its Therbligs is *Search*. Same as the previous two, three persons are having MFA scores of 231 mainly in their right upper limb. Here also the reduction of continuous effort duration needs to be reduced.

5 Conclusion

Train driving is a complex task with higher level of decision-making and dynamic control operation [19]. The information of surroundings needs to be identified, processed and used to take appropriate actions.

Muscle Fatigue Assessment (MFA) is utilized to identify the tasks and body segment associated with highest potential of risk with the hypothesis that rapidly fatiguing muscle is susceptible to injury and inflammation. Based on the risk of fatigue, MFA offers level of change priority directly for any particular body posture [9].

The present study is conducted on few frequently adopted postures, broadly classified into two groups; which are further sub-divided into five elementary activities. These ten sets of activities of the loco pilots are evaluated by MFA method.

Results revealed that notching operation and application of horn does not cause any accumulation of fatigue in most of the subjects as per MFA suggestion.

The case is worse in case of braking operation, as more than 70% of population showed moderate level of change priority. The main cause of these results is due to prolonged application of brake paddle. About 25% of populations showed moderate level of change priority during static driving posture and during inspecting various gauges. These are due to keeping the same posture for prolonged duration of time and increased frequency, respectively. For rest activities, moderate level of change priority is observed only in 10% of population or less, which may possibly be reduced by proper training. Only in very few cases, high-level change priority had been observed.

In the above scenario, the following modifications are suggested:

(i) Instead of horizontally operated brake lever (A—9 valve), vertically operated brake lever is suggested, which certainly improve the effort score by preventing wrist deviation.

(ii) A platform of 2 to 3 inch height is needed to be provided for driving and the brake paddle needs to be located exactly in front of that platform, so that the operation does not require any awkward posture.

(iii) Proper maintenance of goods rake and schedule change of brake block is suggested to prevent poor brake power, which certainly reduce the braking time.

(iv) The cab room needs to be re-designed ergonomically, so that the frequently used breaker and switches are re-located near loco pilot, also frequently vision gauges need to be re-located in exact front.
(v) The gauges and breakers should be re-located in the identical place for all similar types of locomotive.
(vi) During training, the driving mistake of each loco pilot needs to be corrected by showing their own driving video.
(vii) It has been noted that the loco pilots are continuously keeping their hand on notch wheel. It is therefore suggested to re-locate the horn button in centre of the notch wheel, as commonly used in cars. This certainly reduces the fatigue score, as well as reaction time (as it is a safety device).
(viii) Instead of vigilance, a camera with eyeball detector sensor and buzzer need to be installed in front of loco pilots, so that the distraction during driving may be reduced.
(ix) Instead of providing walky-talky, the inbuilt communication system in locomotive, as used in EMU cab, may make the situation more crew friendly.
(x) The signal exchange with green or red flag and light is quite outdated. Instead of that, a few coloured LED lamps need to be installed at locomotives corner wall (same as indicator lamp) and need to be operated by a switch, located near loco pilot, which will certainly improve the speechless communication.
(xi) Leaning out is not at all permissible, as the moving giant is travelling front and the loco pilot is looking at rear end, any obstruction or flying object coming from the front is not visible. In that high speed, even if a small flying bird strikes, it may cause fatal by striking like a bullet. Thus installation of surveillance camera at critical points of the train with a display unit under control of train's guard is suggested.

All the proposed modifications can be adopted easily and economically, proper adaptation will certainly bring down the fatigue level and make driving a pleaser task.

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References

1. "8.2% GDP Growth rate—Indian Railways in India's GDP", RailNews. Available from http://www.railnews.in/8-2-gdp-growth-role-of-indian-railways-in-indias-gdp-carbon-footprint/ September 2018
2. "Statistical Summary—Indian Railways". Available from http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/IRSP_2016-17/Annual_Report_Accounts_Eng/Statistical_Summary.pdf February 2018

3. R. Ranjan, T. Prasad, Work-Life of Indian Railway's Drivers (Loco-Pilots). IOSR J. Bus. Manag. **19**(8), 93–101 (2014)
4. C.D. Katsis, N.E. Ntouvas, C.G. Bafas, D.I. Fotiadis, Assessment of Muscle Fatigue During Driving Using Surface EMG (2015). Available at https://www.researchgate.net/publication/267939549_Assessment_of_Muscle_Fatigue_During_Driving_Using_Surface_EMG Dated 27.08.2019
5. M. Ahmadi, S. Etemadinezhad, J. Yazdani, L. Akbarzadeh, R. Kaveh, Comparing the results of three ergonomic assessment tools. Ergon. Int. J. **2**(4), 1–8 (2018)
6. C. Wibisono, V. Triyanti, Work risk assessment towards wood furniture production activities using manual task risk assessment method and rodgers muscle fatigue analysis method. *Proceeding of 9th International Seminar on Industrial Engineering and Management* 1–8 (2016)
7. Herindra Adhi Nusantara and Guntarti Tatik Mulyati Suharno, Development of working facility to improve work posture at packaging section in organic vegetable industry, in *The 3rd International Conference on Agro-Industry 2016 "Competitive & Sustainable Agro-Industry: Value Creation in Agribusiness"*, KnE Life Sciences, pages 65–81 (2017)
8. K.A. Damayanti, C. Tesavrita, Fatigue measurement of elderly workers in small and medium enterprises. *Review of Integrative Business and Economics Research*, Vol. 7. Supplementary Issue **2**, 144–151 (2018)
9. Rodgers, S. H., (2006). Available from http://personal.health.usf.edu/tbernard/HollowHills/Rodgers_MFA_M20.pdf December 2006
10. S.H. Rodgers, A functional job evaluation technique, in Ergonomics, in J.S. Moore, A. Garg, *Occupational Medicine: State of the Art Reviews.* 7(4), pp. 679–711 (1992)
11. H. Suzanne, Rodgers, job evaluation in worker fitness determination. Occupat. Med.: State Art Rev. **3**(2), 219–239 (1988)
12. N. Stanton, A. Hedge, K. Brookhuis, E. Salas, muscle fatigue assessment: functional job analysis technique. Handbook Human Fact. Ergon. Methods **12**(01–12), 10 (2005)
13. "Electric Locomotive Classes—AC". Available from https://www.irfca.org/faq/faq-loco2e.html#loco 2010
14. http://www.irfca.org/faq/faq-loco2e.html#wag-7 dated 27.08.2019
15. David Ferguson, D., "Therbligs: The Keys to Simplifying Work". Available from http://gilbrethnetwork.tripod.com/therbligs.html dated 19.11.2015.
16. F. Gilbreth, L. Gilbreth, "The Gilbreth Network", *Management and Administration*, 1st on August, 1924 pp. 151–154; and 2nd on September, 1924 pp 295–297 (1924), as in [15].
17. M.R. Spiegel, L.J. Stephens, *Theory and Problems of Statistics* (Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004)
18. H.L. Chang, L.S. Ju, Effect of consecutive driving on accident risk: a comparison between passenger and freight train driving. Accid. Anal. Prev. **40**, 1844–1849 (2008)
19. G. Kecklund , T. Akerstedt , M. Ingre, M. Soderstrom, Train drivers' working conditions and their impact on safety, stress and sleepiness: a literature review, analyses of accidents and schedule. *Stress Research Report no 288.* National Institute for Psychosocial factors and Health (1999), as in [18]

Chapter 15
Causes, Symptoms and Effect of Physical Risk Factors for the Development of Work-Related Musculoskeletal Disorders (WRMSD) Among Manual Construction Workers and Labourers in India and Intervention Through Ergonomics—A Case Study of Individual House Construction

Manoj T. Gajbhiye, Debamalya Banerjee, and Saurav Nandi

1 Introduction

In India, most of the construction work is being carried out manually and there is a chance of fatal and non-fatal accident to which nobody cares. Nevertheless safety is the primary need of human being. Construction work is hard-working, irksome and hazardous work. Nowadays, lots of new technologies have been developed still construction works are always carried out manually. When we talk about construction industry, it is the biggest money transaction business. As per census 2011, 53,45,5595 people were employed in 2012 in the construction sector all over India with growth rate of 1.77% per year [4].

Every year nearly 48,000 workers die due to work-related accidents. Out of these 48,000, construction alone contributes 11,616 (24.2%) workers' accidents. This is a huge fatality number. This data is of the year 2017 [2] and within these years these numbers should have increased. The same has been mentioned by Patel et al. [4]. Patel et al. [4], also added that in India, safety in construction industry is very poor

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as compared with other countries. However there is an existing rule and regulation. The author also pointed out that Indian government and non-government agencies do not maintain the fatality data of construction industry and also they do not have any standard system. This is all about the organized labourers in construction industries which are registered with the National Institute of Health and Safety, but in India lots of construction works are carried out by unorganized labourers. According to the Times of India report [2] in India, only 20% of total workforce populations (i.e. 465 million) is registered with the National Institute of Health and Safety.

In India, most of the houses are constructed individually and people love to live in their single house (especially after purchasing land & constructing on it). For construction of house people take service of contractor or construct house with their own by hiring daily working construction workers *(Mistry)* and labourers *(Coolie)* specialized in construction work as people cannot afford to pay more labour cost. Especially in rural areas, the houses are constructed with no due importance given to its aesthetic look or facilities but with only shelter to conceal themselves. Most of the house construction work in rural areas is carried out manually from the beginning of excavation of soil for foundation to finish of the work.

These manual construction workers may be suffering from work-related musculoskeletal disorders due to physical risk factors of different work carried out in construction site. This occurs due to prolonged use of awkward postures, overexertion, work repetition, heavy lifting and lowering, heavy force/efforts, and manual material handling on construction site. The other factor which adds to this is working in diverse environmental condition and negligence. Though the construction workers are doing the same job have different physical risk level due to change of duration and work task [3].

In India, as mentioned above, construction work is carried out manually using manual labourers (male and female) which is a tedious job eventually. As per the International Ergonomics Association (IEA), physical risk factors include "working postures, materials handling, repetitive movements, work-related musculoskeletal disorders, workplace layout, safety and health" [1]. In the past decades different methods have been developed for assessment and measurement of risks factors which are responsible for WRMSD which are OWAS [5], NMQ [6], FSS [7], LMM [8], NIOSH [9], RULA [10], JSI [11], PLIBEL [12], REBA [13], PATH [14], OCRA [15], QEC [16], LUBA [17] and many more.

The workers either do not know or ignore small signs in the body like pain, tingling, shooting or radiating pain, numbness, burning, discomfort, swelling, redness, etc. and pay attention when it gets worse. The problem in India is nobody cares for these types of symptoms and they eventually cause the unidentified WRMSD when it reaches to incurable or fatal condition. The aim of this study is to find the number of manual construction workers and labourers complaint about pain or discomfort in different body parts related to WRMSD and diseases, causes and symptoms of WRMSD due to physical risk factors. The other aim is to find the most probable parts of the body having pain or discomfort, which needs further investigation.

Table 1 6- Point general questionnaire

Name		Age
Working experience		Height
Description of work		Weight
Q.N	questions	Responses
1	Do you have any pain in your body in any time since you are working?	Yes / No
2	Where do you have pain?	
3	Do you visit to doctor when pain?	Yes / No
4	Do you take medicine on your own?	Yes / No
5	Do you exercise daily?	Yes / No
6	Do you know work-related musculoskeletal disorder?	Yes / No

Symptoms, cause and diseases of WRMSD in construction work

The work-related musculoskeletal disorder arises gradually but it shows some symptoms. The only single factor is not responsible for development of WRMSD but has several ones. When the physical risk factor (Awkward Posture, Load/Force, Static exertion, Repetitive exertion, Forceful exertion, Frequency of movement, Duration, Recovery, Vibration, Mechanical Compression, Environmental Conditions, Team Work, Visual Demands, Psychosocial factor, Individual factors, Load Coupling, Workplace) and influencing factor (Intensity, Duration, and frequency) comes together repeatedly, ignored and carried for long periods of time, arise WRMSD. Table 2 shows 18 types of diseases with description, causes, body parts affected, symptoms and relevance to construction work followed by figure on different parts of body for providing at a glance symptoms to workers, labourers and readers to correlate the symptoms (Table 1).

2 Methodology

(1) **Participants**: The study has been conducted by visiting and observing construction sites, interviewing the construction workers/labourers in person, interviewing physicians/orthopedics/physiologists and other related searches. Nearly 308 male workers and labourers and 41 female labourers carrying out different construction work have been interviewed with simple questionnaire (Table 1) for primary opinion about the pain or discomfort to body. The workers included are Labourers (Excavation), Labour (construction), Worker (Shuttering/Centring), Workers (Rebar), Workers (Mason), Workers (Electrician), Workers (Plumber), Workers (Flooring/Tiles), Workers (Carpenter), Workers (Putty and Paint), workers (Granite/Marble), Workers (Mixture Operator), Workers (POP false ceiling), Workers (Gattu). These workers, called as

'*Mistry'*, are experts in their work whereas labourers can be able to carry out any kind of work to help workers *(Mistry).* They are called as '*Coolie'* except labourers (excavation). The excavation work is carried out by particular labourers.

(2) **Data collection**: When survey was being carried out, initially it was found that workers are not interested to respond scientific questionnaire formats like NMQ and others. The worker/labourers were not ready to provide their personal details like name, age, weight, any medical condition, etc. at the beginning, but after convincing them, they responded. A simple 6-Point General questionnaire (half page format in English and Hindi) have been developed (Table 1) in which question no. 1, 3, 4, 5, 6, are objective question with 'Yes' or 'No' options and question no. 2 is personal response by the workers and labourers about the part of body pain or any other one which is done deliberately to know the exact problem where the workers and labourers are facing rather than providing inputs.

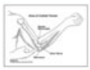
3 Results

The response to the 6-point general questionnaire has been evaluated for question number 1 and question number 2. From the study, it is revealed that out of 306 male workers and labourers, 97.08% workers and labourers have reported complaints about pain or discomfort in the different body parts and only 2.92% have said there is no pain at all and all 41 female labourers have reported complaint about the pain or discomfort.

The responses of pain given by workers and labourers are shown in Table 3. From Table 3, it is found that male workers and labourers have complaint about more pain or discomfort in lower back (69.48%), Arms (54.87%), Shoulder (46.43%), Wrist (39.94%), Legs (28.25%), Neck (24.03%). The female labourers also have complaint about more pain or discomfort in lower back (90.24%), Shoulder (70.73%), aAms (41.46%), Legs (51.22%). It is also found that 4.55% male workers and labourers and 17.07% female labourers have complaint about tingling in arms and legs at night. This tingling is experienced by labourers (construction), workers (shuttering/centring) and workers (Mason). It is also found that the labourers (male and female) who carry out excavation work have complaint about breathing problem in dip pit (7.47% male and 9.76%.

female). The details of complaint in response to question number 1 and 2 by different workers and labourers are shown in Tables 4 and 5. The response to the 6-point general questionnaire for question number 3 to 6 has been evaluated and obtained result reveals that only 9% of male workers and labourers visit to doctor when in pain and 57% of male workers and labourers take medicine on their own (Table 6). No female labourers visit to doctor for pain and 24% of female labourers take medicine on their own (Table 7). Only 1 male labourers is aware of WRMSD and no male workers and labourers and no female labourers do daily work out. The

Table 2 Types of WRMSD Diseases and relevance construction (a) Labourers (excavation of soil), (b) Labourers (construction work) (c) Centring workers (d) steel bar tying/Rebar workers (e) Masons (Brick layer/plaster) (f) Concrete Finishers (g) Electricians (h) Plumbers (i) Flooring/Tiles Installers (j) Carpenters (k) Painters (l) Marble workers (m) Welders

S. N.	Disease Name	Description	Causes	Affected body parts	Symptoms	Figure	Relevance to construction work
1	Carpal Tunnel Syndrome	Narrowed tunnel surrounding the flexor tendons swell, putting pressure on the median nerve	Heredity/repetitive hand use/hand and wrist position/pregnancy	Hand and Arms	Pain/numbness/tingling/burning/shock sensation in thumb and index, middle and ring fingers. Pain or tingling fells in forearm. weakness in hand		e, k
2	Tendonities	An inflammation of a tendon.	Repetitive work, serious injury due to accidents and sports.	Base of thumb/ elbow/ shoulder/ knee	Pain in affected areas /loss of motion and frozen in the affected area.		a, b, c, d
3	Muscle/Tendon Strain	It is a twist, pull and /or tear of a muscle and / or tendon.	Overuse and overstretching of muscles and tendons, strain, excessive muscle contraction.	Any part of the body	Pain/muscle spasm/muscle weakness/swelling/ inflammation/cramping		All
4	Ligament Spain	It is stretch or tear in a ligament.	Falls, twists or hit in a way that forces the body out of its normal position.	Ankle/foot/ knee/wrist/ thumb	Pain/muscle spasm/muscle weakness/ inflammation/ cramping		All
5	Tension neck syndrome	Neck muscle injured and irritated from overuse and postural problems	Repetitive motion/poor posture/ use of computer and phone/teeth grinding/exercise and sports/poor sleep position/ heavy lifting/ stress/trauma/ tension	Neck	Muscle tightness/ muscle spasms/ muscle stiffness/difficulty turning head in certain directions/pain that worsens in certain positions,		a, b, e
6	Thoracic outlet compression	Group of disorders that occurs when blood vessels or nerves in the space between collarbone and first rib are compressed.	Poor posture/trauma/ repetitive activity /pressure on joints/work in pregnancy.	Shoulders/ neck/ fingers	Pain/ache/swell in neck/shoulder/hand/arm. Cold fingers. Hands or arms with fatigue. Numbness or tingling in your fingers/ weakness in gripping.		a, b, e, k
7	Rotator cuff tendonitis	Affects the tendons and muscles that help move shoulder joint.	Lifting by arm over the head/ static shoulder/ sleeping on shoulder every night/swimming/ pitching	Shoulder	Pain/swelling/stiffness in front of the shoulder and side of arm. Pain in arm triggered when raise or lower. Mobility and strength loss in the affected arm.		a, b, e
8	Tennis elbow (Epicondylitis)	An inflammation or overuse of the tendons that join the forearm muscles on outside of the elbow.	Overuse, repetitive, weight lifting, age and vigorous use of the forearm muscle.	Elbow	Pain or burning on the outer part of elbow. Weak grip strength.		h, j, k
9	Cubital / Radial tunnel syndrome	Intermittent compression on radial nerve from radial head to the inferior border of supinator muscle without weakness in obvious extensor.	Repeatedly lean on elbow / bend elbow for sustained periods.	Elbow	Pain and numbness in the elbow. Pain in forearm. Tingling in the ring and little fingers. Weak ring finger, pinching ability and hand grip.		a, b, e
10	Digital Neuritis	Entrapment of a plantar inter-digital nerve as it passes under the transverse metatarsal ligament.	Neuritis can be caused by injury, infection or autoimmune disease.	Hands or foot	Numbness, prickling or tingling feet or hands and spread upward into legs and arms. Sharp jabbing, throbbing, freezing or burning pain, extreme sensitive to touch.		a, b, e, f, k
11	Trigger finger/ Thumb	Painful condition causes fingers or thumb to catch or lock when bend. Affect any finger or more.	Repeated movement or forceful use of finger or thumb.	Fingers and thumb	A painful clicking or snapping on bend or straighten finger. stiffness in finger especially in the morning.		a, b, c, d, e, f, g, h
12	DeQuervain's Syndrome	Painful swelling on tendons in wrist and lower thumb. Cause pain when rub.	Repetitive motion of hands.	Wrist and lower thumb	Pain along the back of thumb. swelling and pain at the base of thumb/wrist and affect grasping		a, b, c, d, e, f, g, h
13	Mechanical back syndrome	Pain trigged by the action of the spine. Include ligaments, tendons muscles, inter vertebral discs.	Back or neck sprain and strain. Disc Herniation, VCF, LSS, Spinal osteoarthritis (spondylosis), spondylolisthesis.	Spinal Cord	Localized back pain without any radiation, tenderness or spasm in the back, severe back stiffness, sudden onset back pain.		All
14	Degenerative Disc Disease	Spinal disk show sign of wear and tear, not work properly.	Dry out and cracks in the spinal cord.	Spinal cord	Sharp or constant pain in upper and lower back/neck /hip/thighs. Transitory and severe pain for few days to months. Worsen when sit/ bend /lift/twist and better when move or change positions.		All

(continued)

Table 2 (continued)

15	Ruptured/ Herniated/slip disk	Rubbery cushions (Disk) between the individual bones (Vertebrae) that stack up to make spine. Occurs when jelly pushes out through a tear in the tougher exterior.	A gradual wear and tear. Less flexible and more prone to tearing or rupturing with even a minor strain or twist.	Spinal cord	Arms or legs Tingling/pain/ numbness/weakness.		All
16	Raynaud's syndrome	Spasm of arteries cause incident of reduced blood flow. Fingers/toes affected.	Inflamed blood vessels in the hands and feet.	Hands and feet	Colour of fingers or toes or skin changes response to cold or stress. Numb, prickly feeling or stinging pain. Stress relief when warn or heat treated.		All
17	Myfascial pain in the neck and upper back	A chronic pain disorder occurs when pressure on sensitive points in muscles causes pain in the muscles and sometimes in seemingly unrelated part of body	Injuries or overuse of muscles.	Muscles, tendon, nerves	Deep, aching pain in a muscle. a tender knot in a muscle. Difficulty in sleeping due to pain.		All
18	Shoulder bursitis	Inflammation of a bursa.	A bursa become inflamed due to injury, infection or underlying rheumatic condition	Shoulder	Localized pain or swelling tenderness and pain with motion of the tissue in the affected area.		a, b, c, e, j, k, m

workers noted that they do not have pain during working and are comfortable when working in dynamic conditions like regular standing and sitting, moving, relaxing, etc.

4 Discussion

From the study, it is revealed that maximum workers and labourers are having work-related body discomfort problem but whenever asked they replied they are habitual to it. On the contrary, they replied that "if we stay home for three to four days we have ache or pain in our body". The simple question responses show that the construction workers are at high risk of WRMSD due to overexertion of physical work. The study reveals that construction workers and labourers (male and female):

1. Work in hazardous conditions as construction sites are temporary site and time-bound due to which workers and labourers are working under stressful and tedious condition.
2. Suffering from physical risk factors like Awkward Posture, Load/Force, Static exertion, Repetitive exertion, Forceful exertion, Frequency of movement, Duration, Recovery, Vibration, Environmental Conditions, Psychosocial factor, Individual factors, Load Coupling, Workplace, etc.
3. The workers and labourers are working for 8–12 h a day, not aware of their vulnerability and maximum complaints are about lower back, arms, shoulder, wrist, neck and legs. The standing position is more comfortable than sitting stated by workers.
4. Unaware of WRMSD, lack of daily work out and not using personal protective equipments.

Table 3 Response of male workers and labourers and female labourers to question 1 and 2

	Head	Neck	Shoulder	chest	Elbows	Arms	Hands	Wrists	Fingers	Thumbs	Eyes	Upper Back	Lower Back	Thighs/ Hip	Legs	knees	Ankle, feet, toe	TING	BREAT	SWELL	BLOAT	No Pain
Male N = 308	5	74	143	36	27	169	12	123	72	0	43	2	214	4	87	38	8	14	23	3	2	9
%	1.62	24.03	46.43	11.69	8.77	54.87	3.90	39.94	23.38	0	13.96	0.65	69.48	1.30	28.25	12.34	2.60	4.55	7.47	0.97	0.65	2.92
Female N = 41	8	22	29	3	0	17	0	0	0	0	0	0	37	0	21	0	0	7	4	0	4	0
%	19.51	53.66	70.73	7.32	0	41.46	0	0	0	0	0	0	90.24	0	51.22	0	0	17.07	9.76	0	9.76	0

Table 4 Response of male workers (*Mistry*) and Labourers (*Coolie*) to question 1 and 2. L 1—Labourers (Excavation), L 2—Labourers (construction), W 1—Workers (Shuttering/Centring), W 2—Workers (Rebar), W 3—Workers (Mason), W 3*-Masons (Ceiling) —same worker of W 3 only mentioned for ceiling risk, W 4—Workers (Electrician), W 5—Workers (Plumber), W 6—Workers (Flooring/Tiles), W 7—Workers (Carpenter), W 8—Workers (Putty and Paint), W 9—Workers (Granite/Marble), W 10—Workers (Mixture Operator), W 11—Workers (POP false ceiling), W 12—Workers (Gattu), Worker: The man who is expert in particular work, labour: The man or woman who assist the worker, TING: Tingling in hands and /or legs (at Night), BREATH: Problem in breathing in dip pit, SWELL:Swelling on veins, BLOAT: Bloat in palm (BLOAT)

			Pain or Discomfort in																	Other discomforts				No pain
S.N.	Worker (Mistry)/ Labourers	Number of persons interviewed	Head	Neck	Shoulder	chest	Elbows	Arms	Hands	Wrists	Fingers	Thumbs	Eyes	Upper Back	Lower Back	Thighs/Hip	Legs	knees	Ankle, feet and toes	TING	BREAT	SWELL	BLOAT	
1	L 1	**31**		3	29	9		30							31		11				15	3		
2	L 2	**41**	1	7	13	14		21		4					33		7	3		2				5
3	W 1	**48**		24	30			27		12					39		27			4				1
4	W 2	**34**				11	13	21	11	17	16		16		30		18	21						3
5	W 3	**42**	4	6	22	2	14	4		20				2	28	4	10		2	8				
	W 3*			16	16					8			8											
6	W 4	**12**		12	12					12	12		12											
7	W 5	**14**			2			12		14	8		7		12		10							
8	W 6	**14**													14			14						
9	W 7	**18**						18							18									
10	W 8	**40**		4	16			36		36	36													
11	W 9	**9**													6		4		6		8			
12	W 10	**1**			1				1						1									
13	W 11	**2**		2	2																			
14	W 12	**2**													2								2	
	Total	**308**	5	74	143	36	27	168	12	123	72	0	43	2	214	4	87	38	8	14	23	3	2	9

Table 5 Response of female labourers to question number 1 and 2

			Pain or Discomfort area																	Other discomforts				No pain
S.N.		Number of women interviewed	Head	Neck	Shoulder	chest	Elbows	Arms	Hands	Wrists	Fingers	Thumbs	Eyes	Upper back	Lower Back	Thighs/Hip	Legs	knees	Ankle, feet and toes	TING	BREAT	SWELL	BLOAT	
1	L 1	**7**	2	4	6	3		6							6		6				4			0
2	L 2	**34**	6	18	23			11							31		15			7			4	0
	Total	**41**	8	22	29	3	0	17	0	0	0	0	0	0	37	0	21	0	0	7	4	0	4	0

5. Do not consult doctors unless caught by flu and fever.
6. The financial conditions are very poor which force them to work beyond their physical limits and addicted to alcohol, smoking and tobacco in the early age. (Use local alcohol as a pain reliever and chew tobacco the whole day while working.)

Ergonomics intervention to minimize WRMSD of construction work: Ergonomics is defined as a tool which is meant to reduce work-related injuries, hazards and design tools, equipments and workplaces according to human concern. Hence in the construction work also it can play a vital role by paying attention to how work affects the workers and labourers. From the preliminary results, it appears that the manual construction workers are suffering from the physical risk factors. If discussed about the ergonomics intervention in construction, the workers and labourers need to be educated by providing health and safety training at ground level. Improvement is to be executed by ergonomically designed tools and equipment as well as providing safety protective equipments.

Table 6 Response of male workers (*Mistry*) and Labourers (*Coolie*) to question 4,5,6 and 7

S.N	Worker (Mistry)/labourers	Persons interviewed	Do you visit to doctor when pain?				Do you take medicine on your own?				Do you exercise daily?				Do you know work-related musculoskeletal disorder?			
			YES	%	NO	%	YES	%	NO	%	YES	%	NO	%	YES	%	NO	%
1	L 1	31	7	23	24	77	19	61	12	39	0	0	31	100	1	4	30	97
2	L 2	41	3	7	38	93	17	41	24	59	0	0	41	100	0	0	41	100
3	W 1	48	4	8	44	92	27	56	21	44	0	0	48	100	0	0	48	100
4	W 2	34	3	9	31	91	19	56	15	44	0	0	34	100	0	0	34	100
5	W 3	42	7	17	35	83	21	50	21	50	0	0	42	100	0	0	42	100
6	W 4	12	1	8	11	92	11	92	1	8	0	0	12	100	0	0	12	100
7	W 5	14	0	0	14	100	8	57	6	43	0	0	14	100	0	0	14	100
8	W 6	14	1	7	13	93	5	36	9	64	0	0	14	100	0	0	14	100
9	W 7	18	0	0	18	100	13	72	5	28	0	0	18	100	0	0	18	100
10	W 8	40	0	0	40	100	27	68	13	33	0	0	40	100	0	0	40	100
11	W 9	9	0	0	9	100	3	33	6	67	0	0	9	100	0	0	9	100
12	W 10	1	0	0	1	100	1	100	0	0	0	0	1	100	0	0	1	100
13	W 11	2	0	0	2	100	2	100	0	0	0	0	2	100	0	0	2	100
14	W 12	2	1	50	1	50	2	100	0	0	0	0	2	100	0	0	2	100
	Total	308	27	9	281	91	175	57	133	43	0	0	308	100	1	0.3	307	99.7

Table 7 Response of Female labourers to question 4,5,6 and 7

S.N	Workers (Mistry)/ Labourers	Number of women interviewed	Do you visit to doctor when pain?				Do you take medicine on your own?				Do you exercise daily?				Do you know work-related musculoskeletal disorder?			
			YES	%	NO	%	YES	%	NO	%	YES	%	NO	%	YES	%	NO	%
1	L 1	7	0	0	7	100	3	43	4	57	0	0	7	100	0	0	7	100
2	L 2	34	0	0	34	100	7	21	27	79	0	0	34	100	0	0	34	100
	Total	41	0	0	41	100	10	24	31	76	0	0	41	100	0	0	41	100

5 Conclusion

Based on the interview it could be stated that construction workers work under non-acceptable circumstances and suffer from WRMSD. As per complaints stated and results obtained it is needed to investigate for its validation and explore the exact cause of WRMSD on construction work and solve the problem by proper training and guidelines, changing poor bad habits, properly designed ergonomic tools, equipments, workplaces.

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References

1. E.R. Vieira , S. Kumar, Working postures: a literature review. J. Occupat. Rehab. **14**(2), 143–159 (2004). https://link.springer.com/content/pdf/10.1023%2FB %3 AJOOR.000001833 0.46029.05.pdf
2. https://timesofindia.indiatimes.com/business/india-business/48000-die-due-to-occupational-accidents-yearly-study/articleshow/61725 283.cms
3. V.L. Paquet, L. Punnett, B. Buchholz, Validity of fixed-interval observations for postural assessment in construction work. Appl. Ergon. **32**(3), 215–224 (2001). https://doi.org/10.1016/s0003-6870(01)00002-3
4. D.A. Patel , K.N. Jha, An estimate of fatal accidents in indian construction, in P. W. Chan, C. J. Neilson (Eds.) *Proceedings of the 32ndAnnual ARCOM Conference, 5–7 September 2016, Manchester, UK, Association of Researchers in Construction Management* (1), 577–586 (2016). https://www.researchgate.net/publication/308155592AN_ESTIMATE_OF_FATAL_ACCIDENTS_IN_INDIAN_CONSTRUCTION
5. O. Karhu, P. Kansi, I. Kuorinka, Correcting working postures in industry: a practical method for analysis. Appl. Ergon. **8**(4), 199–201 (1977). https://doi.org/10.1016/0003-6870(77)90164-8
6. I. Kuorinka, B. Jonsson, A. Kilbom, H. Vinterberg, F. Biering, G. Andersson, K. Jorgensen, Standardized Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergon. **18**(3), 233–237 (1987). https://doi.org/10.1016/0003-6870(87)90010-X
7. L.B. Krupp, N.G. LaRocca, J. Muir-Nash, A.D. Steinberg, The fatigue severity scale. Arch. Neurol. **46**(10), 1121–1123 (1989). https://doi.org/10.1001/archneur.1989.00520460115022
8. W.S. Marras, F.A. Fathallah, R.J. Miller, S.W. Davis, G.A. Mirka, Accuracy of a three-dimensional lumbar motion monitor for recording dynamic trunk motion characteristics. Int. J. Industr. Ergon. **9**(1), 75–87 (1992). https://doi.org/10.1016/0169-8141(92)90078-E
9. T.R. Waters, V. Putz-anderson, A. Garg, L.J. Fine, Revised NIOSH equation for the design and evaluation of manual lifting tasks. Ergonomics **36**(7), 749–776 (1993). https://doi.org/10.1080/00140139308967940
10. L. McAtamney, E.N. Corlett, RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993). DOI:https://doi.org/10.1016/0003-6870(93)90080-s
11. M.J. Steven , A. Garg, The strain index: a proposed method to analyze jobs for rist of distal upper exremity disorders. Amer. Industr. Hygiene Assoc. J. **56**(5), 443–458 (1995). https://doi.org/10.1080/15428119591016863

12. K. Kemmlert, A method assigned for the identification of ergonomic hazards—PLIBEL. Appl. Ergon. **26**(3), 199–211 (1995). https://doi.org/10.1016/0003-6870(95)00022-5
13. S. Hignett, L. McAtamney, REBA-a rapid entire body assessment method for investigating work related musculoskeletal disorders. Appl. Ergon. **31**(2), 201–205 (2000). DOI:https://doi.org/10.1016/s0003-6870(99)00039-3
14. B. Buchholz, V. Paquet, L. Punnett, D. Lee, S. Moir, PATH: a work sampling-based approach to ergonomic job analysis for construction and other non-repetitive work. Appl. Ergon. **27**(3), 177–187 (1996). https://doi.org/10.1016/0003-6870(95) 00078-x
15. E. Occhipinti, OCRA: a concise index for the assessment of exposure to repetitive movements of the upper limbs. Ergonomics **41**(9), 1290–1311 (1998). DOI:https://doi.org/10.1080/001401398186315
16. G. Li, P. Buckle, Current techniques for assessing physical exposure to work-related musculoskeletal risks, with emphasis on posture-based methods. Ergonomics **42**(5), 674–695 (1999). https://doi.org/10.1080/001401399185388
17. D. Kee, W. Karwowski. LUBA: an assessment technique for postural loading on the upper body based on joint motion discomfort and maximum holding time. Appl. Ergon. **32**(4), 357–366 (2001). https://doi.org/10.1016/S0003-6870(01)00006-0

Chapter 16
Assessment of Driving Seat of WAG_7 Locomotives of Indian Railways Using Howerth and Cornell Ergonomic Seating Evaluation Method

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1 Introduction

INDIAN Railways is the fourth-largest rail network in the world and a great national asset working underingle control, i.e. under Ministry of Railways. It connects far corners of the country, thus becoming the lifeline for Indian citizens and Indian economy. This government owned and operated rail network also adds score to the GDP by transporting coal, fertilizer, iron ore, cement and lots of other essential commodities [1]. It only is possible due to the efforts of 1.31 million workers working round the clock [2]. On which, the loco pilots (locomotive drivers) are playing a vital role by transporting about 26 millions of passengers and 2.8 million tonnes of freight daily [3, 4].

The duty of railway loco pilots is considered extremely stressful, leading to strain and fatigue, which further increases the probability of accident [3]. The electric loco pilot's working condition and working environment, which includes ambiance of driving cab (driver's cabin), exposure to noise–vibration–magnetic radiation, varying climatic conditions, driving posture, irregular and against the nature job conditions, considered as a stress factor, which obviously affects adversely and also on their health status.

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As there is no fixed schedule for goods train operation [4], thus for loco pilots, the prolonged duty hours are a common phenomenon. It is normally 10 h, but quite often goes beyond 14 h. Hours of Employment Regulation (HOER) indicates that the loco pilots fall under ‘Continuous’ employee category and rule suggests that they have to work for 10 h at a stretch [5].

If any goods train is allowed to run continuously without any intermediate stoppage, then it takes hardly 3 to 4 h to reach the desired destination. Means remaining time they have to spend in driver’s cabin idly at any halting station. As the loco pilots are not allowed to leave the locomotive during their duty, obviously they have to spend these idle times mostly in the sitting posture in the driving seat. So, these idle hours indicate the importance of driving seat.

It is also been observed that few loco pilots also preferred to drive the loco in sitting posture, hence prolong sitting on driver seat on daily basis is quite common.

The seating system of a railway vehicle is a key occupant protection device in the event of a collision. The improvement in this regard may reduce the probability of injury (Wei et al. 2017) [6]. An improperly designed driving seat is quite uncomfortable, imposes lot of stress upon different body segments of the driver, and may lead to injury. Thus the driving seats need to be designed ergonomically as per contours of human body (Jhinkwan et al. 2014) [7]. Most of the drivers of ICS Pendolino Series 310 train feel driver’s seat comfort and adjustability should be improved. The situation is worse due to absence of armrest, lack of adjustable lumbar support, small driver seat with few adjustment possibilities, etc. (Žnidarič et al. 2011) [8].

As industry standard truck seat yield poor body posture, so an ergonomically redesigned new truck seat was proposed, which obviously improves the sitting posture as well as reduces perceived discomfort, hopefully reducing the high rates of injury and absenteeism (Cardoso et al. 2017) [9]. A comparative study on industry standard seat and ergonomically innovated seat for truck drivers revealed that in the prototype, the participants sat with more lumbar lordosis, assumed extended thoracic posture, gluteal backrest panel and adjustable seat pan combination reduces sitting pressure in seat pan and backrest. This new innovative seat may be suitable for prolonged driving (Cardoso et al. 2018) [10].

The most sensitive body part such as lumbar and neck region feel discomfort during prolonged driving and the relationship between discomfort and physiological parameters can be used to find out which automotive seat is more comfortable (Li et al. 2014) [11]. Adjustability of lumbar supports beyond 2 cm reduces lumbar flexion, and is thus considered as an important feature for betterment of end-user performance during prolonged driving (Diana et al. 2015) [12]. Seat design should provide support when people sit with the minimum amount of lumbar spine flexion and feel comfortable, even though the posture may involve small degree of lordosis (Matthew et al. 1996) [13].

Perception of comfort for individual with driver’s car seat depends on anthropometric data (Mohamad et al. 2010) [14]. As per seat characteristics, comfortable position was obtained by correcting the sitting posture, which was qualitatively evaluated by sensor (Yamazaki et al. 1992) [15].

Majority of vehicle seat studies concentrated on vibration, pressure and ergonomics only, but as the fatigue is also having some adverse effects on driving, hence need to be considered during design of vehicle seat. The effects of thermal and humidity comfort also need to be considered in future seat research (Fai et al. 2007) [16].

The objective of the study is to identify the comfort level of driving seat by using standard assessment tools. In the present study, two sets of chair evaluation tools were used, namely (i) Howerth ergonomic seating guide and (ii) Cornell ergonomic seating evaluation method. For the present study, a sample of 26 electric goods locomotives were considered.

2 Methodology

WAG7 old variant is an indigenous design conventional type electric locomotive. It is the most successful variant of goods locomotive, manufactured either in CLW or in BHEL [17]. The driving seats of such locomotives were considered for the present study.

About 26 numbers of driving seat were assessed and for that same numbers of locomotives were considered in the present study. For data collection, a digital compact camera was used. The sitting experience on driving seat was also been collected from the opinion of the end user. To gather more accurate experience, the first author also sat for prolonged time in the driving seat (Figs. 1, 2 and 3).

The ergonomic seating guide was proposed by Howerth [18] and Cornell seating evaluation method was proposed by Alen Hedge [8]. Both the tools use few questionnaires, on the basis of those answer, the driving seats were evaluated [18, 19].

Studies suggest that work-related injuries can be reduced and productivity can be increased by using a right ergonomic chair and providing proper ergonomic training. But the challenge of designing for the human body is quite difficult due to variation in their shape and size. Henceforth, a suitable design for one may not be appropriate for others. Proper matching is much more important for a product when a person physically interacts with it for prolonged periods, an office chair. It is therefore the standards for chair are made by compiling the opinion of experts from various

Fig. 1 CLW make WAG7 old variant electric locomotive

Fig. 2 BHEL make WAG7 old variant electric locomotive

Fig. 3 Commonly used driving seat

discipline to improve the accommodation of people, and thus to reduce the risks of injury in the office environment.

The standards propose dimensional specifications based on body dimensions of 95% of the population and are intended to meet the minimum requirements of users. Haworth's ergonomic seating products are based on state-of-the-art research and are designed to exceed standards, meeting the needs of a broad range of users.

Haworth Ergonomic Seating Evaluation form is used to compare design of chairs according to its features, comfort, ease of use, body support, and identify the most ideal one. Here the scores are either yes/no or vary from 1 to 5. The score 1 means—No, 2–Yes but Poor, 3–Yes but Moderate, 4–Yes and Good & 5 is Yes and Quite Good. During scoring, the evaluator should not give five if it is not too good [18].

Cornell ergonomic seating evaluation form is designed as a practical guide to help practitioners make comparative design decisions about different ergonomic chairs. The content of the evaluation form is only addressed to the features of greatest ergonomic importance. For comparing the chairs, the evaluator preferably needs to sit on each type of chair for at least 90 min, and after this test period, rates their experiences of sitting.

An eleven points scoring system gives a true mid-value of 5, which represents a rating of average experience for the chair. The extremes end of the scale represents unacceptable experience minimum of 0 value and maximum of 10 as exceptionally good experience.

These rating responses are subjective but focus on factors such as the usability and comfort of the chair. The form is organized into 5 Separate sections, e.g. chair adjustments, seat comfort, ease of use, body support, and overall comfort. The final score evaluates the ergonomic design of each chair [19].

Due to presence of few hypothetical questionnaires, the result may vary from evaluator to evaluator, but more or less the results yield a closer outcome.

To carry out appropriate statistics on the collected data and analyse the results unbiased, excel software was used. Also the assistance of standard textbook was taken for basic formulations [20].

3 Results

About 26 WAG7 old variant electric goods locomotives were selected for present study and these are selected randomly.

The total Howerth ergonomic seating score for the above said driving seats is depicted in Table 1.

The graphical representation of the same is represented below (Fig. 4).

Result indicates that about 80% driving seats have Howerth score of 25–40 out of total possible score of 135. The Mode value for the same is at 29 and Mean 32.85

Table 1 Howerth ergonomic seating scores

Total Howerth score	Frequency
21–25	2
26–30	11
31–35	5
36–40	5
41–45	2
46–50	1
Mean	32.85
Median	30.50
Mode	29.00
SD	± 5.95

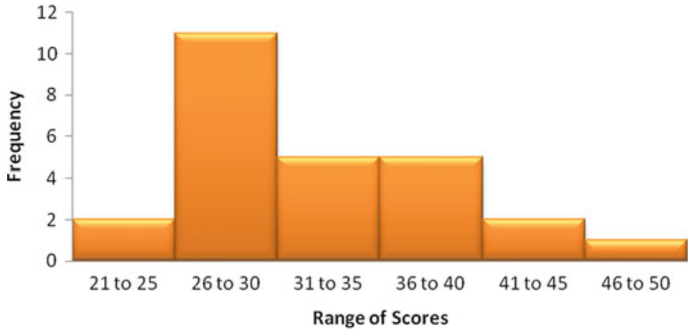

Fig. 4 Graphical representation of total Howerth scores

Table 2 Elaboration of chair features scores

Total chair features score	Frequency
0	18
1	6
2	1
3	1

with a Standard Deviation of $\pm$ 5.95. None of the results crosses the 50% value. The reason for same may be revealed by elaboration of the Howerth Seat Evaluation scoring system.

As it contains five sub-section, hence one by one elaboration is made as under.

(i) Total Chair Features Score (Table 2).
Out of 16 possible scores, about 70% driving seats are allotted no mark. The highest mark obtained is also quite poor, i.e. only 3, which means below 20% of possible scores.

(ii) Total Aesthetics Score (Table 3).
Out of maximum 03 possible scores, above 92% of driving seat's aesthetics scores are unable to reach beyond zero.

(iii) Total Chair Comfort Score (Table 4).
Here the situation is somewhat better. Out of 55 maximum and 11 minimum possible scores, above 73% of population of driving seats score lies between 16 and 25, i.e. approximately between 30 and 45% of possible scores.

Table 3 Elaboration of aesthetics scores

Total aesthetics score	Frequency
0	24
1	1
2	1

Table 4 Elaboration of chair comfort scores

Total chair comfort score	Frequency
11–15	4
16–20	10
21–25	9
26–30	3

Table 5 Elaboration of ease of use scores

Total ease of use score	Frequency
7	24
11	2

(iv) Total Ease of Use Score (Table 5).
Out of 35 maximum and 7 minimum possible scores, above 92% of driving seats score is the minimum. Only in two occasions, the score goes beyond minimum.

(v) Total Body Support (Table 6).
Out of 25 maximum and 5 minimum possible scores, above 96% of driving seats were unable to cross the minimum scoreline.
During evaluation of the same driving seats by Cornell ergonomic seating evaluation method, the following results were obtained (Table 7).
The graphical representation of the same is represented below (Fig. 5).

Table 6 Elaboration of body support scores

Total body support score	Frequency
5	25
6	1

Table 7 Cornell ergonomic seating scores

Total % of Cornell ergonomic design score	Frequency
1–5	6
6–10	8
11–15	6
16–20	5
21–25	0
26–30	1
Mean	10.95
Median	9.76
Mode	9.05
SD	+ 6.06

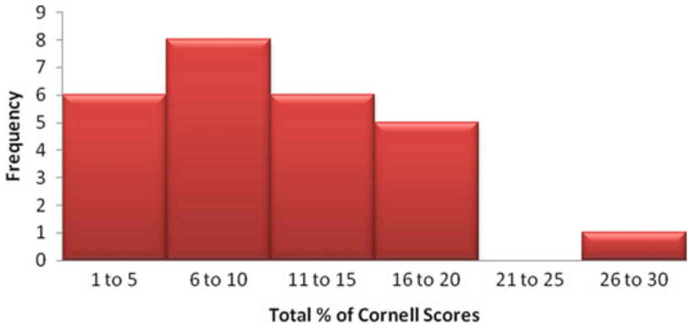

Fig. 5 Graphical representation of total percentage of Cornell ergonomic design scores

From the table and graphical representation, it is clear that 96% population of driving seats are belonging to total % of Cornell ergonomic design scores between 1 and 20. The mode is at 9.05%, Mean 10.95% and the Standard Deviation of $\pm$ 6.06%.

Here also, the further elaboration of Cornell scoring method executed to reveal and understand the real situation. It also contains five sub-sections. One by one elaboration of the same is as under:

(i) Total Chair Adjustment Score (Table 8).
Out of maximum 50 possible scores, from the table, it is clear that only in one case the chair adjustment scores reach to any mark, which is also only 20% of possible scores. Otherwise, the remaining results are zero.

(ii) Total Seat Comfort Score (Table 9).
Out of maximum 40 possible scores, the seat comfort scores above 50% of possible scores only reached in two cases out of 26.

(iii) Total Ease to Use Score (Table 10).
Out of maximum 50 possible scores, 96% of driving seats lay between 1 and 10, i.e. up to 20% of maximum possible scores.

(iv) Total Body Support Score (Table 11).
Out of maximum 40 possible scores, 92% of driving seats are unable to reach in a single score. Only one got to score one and another two, i.e. 5% of maximum possible score.

(v) Total Overall Chair Experience Score (Table 12).
Out of 30 maximum possible scores, the overall chair experience reaches above 50% marks only in a single case.

Table 8 Elaboration of chair adjustment scores

Chair adjustment score	Frequency
0	25
10	1

Table 9 Elaboration of seat comfort scores

Seat comfort score	Frequency
0–5	9
6–10	6
11–15	6
16–20	3
21–25	2

Table 10 Elaboration of ease of use scores

Ease to use score	Frequency
1–5	12
6–10	13
11–15	0
16–20	1

Table 11 Elaboration of body support scores

Body support score	Frequency
0	24
1	1
2	1

Table 12 Elaboration of overall chair experience scores

Overall chair experience score	Frequency
0–5	9
6–10	11
11–15	5
16–20	1

4 Discussion

Result indicates that only three driving seats have crossed the total Howerth score of 40, which indicates the driving seat for WAG7 locomotive is not at all comfortable. Even none of the scores reached beyond 50, means the situation is quite worse.

If focus is made on Howerth scoring system, it has been noticed that the chair features are not up to the mark due to absence of lumber support, armrest, and various seat adjustments. The aesthetic appearance of present driving seats is also not impressive at all. Chair comfort in very few cases is somewhat better considering the prolonged duty hours. But further improvement can easily be made possible. Elaborated result of total ease of use score and total body support score indicates a horrible outcome. It is due to absence of all the minimum chair features in the

Fig. 6 Pictorial presentation of exceptional driving seat

above-said driving seat. Hence, design modification is very much essential as per this study.

The table and graphical representation indicates that about 96% of driving seats have Cornell scores up to 20, which also confirms the previous finding, i.e. the driving seat for WAG7 locomotive is not at all comfortable.

Further elaboration of Cornell scoring system demonstrates that due to absence of various seat adjustments, the chair adjustment scores are zero in each case, except one. Seat comfort scores indicate absence of armrest, proper backrest and spongy cushion. Ease of use scores again specifies the deficiency of various seat adjustments and body support scores specifies the lack of lumber support, armrest and chair reclining facility. The appearance and overall comfort level is also not up to the mark, as suggested in the overall chair experience scores. It therefore strongly supports the previous outcome of design modification on essential mode.

However, both the Howerth and Cornell scoring system significantly specify that the comfort level of a single driving seat is exceptional and somewhat better than others.

Further investigation revealed that it is a commonly used driving seat as depicted in Fig. 3, but a driving chair with somewhat better features as shown in Fig. 6.

5 Conclusion

Howerth ergonomic seating guide and Cornell seating evaluation method are two popular and reliable tools used for ergonomic assessment of chair. In Indian Railways, prolong sitting during goods train driving is quite obvious. Ergonomic assessment does not indicate that WAG7 locomotive's driving seat is a comfortable one. Improper designed driving seat may impose stress on human body, which may lead to injury, thus ergonomic design modification is necessary [7]. The present study also supports the opinion of drivers regarding the improvement of driving seat comfort and adjustability [8]. An ergonomically re-designed seat improves the sitting posture as well as reduces perceived discomfort, hopefully reducing the high rates of injury

[9]. The sensitive body segments feel discomfort during prolonged driving [11]. Ergonomically innovated seat may find solution to it [10]. In this present study, only driving seats are evaluated, during that vibration due to loco running, fatigue due to prolong driving, thermal effect and comfort level due to humidity [16] were not considered.

In this scenario, the following modifications are suggested

(i) Perception of comfort of driving seat for individual depends on anthropometric data [14]. So small driving seat needs to be prohibited [8], and the driving seat needs to be designed ergonomically as per contours of human body [7].
(ii) In driving seat, soft, foldable and adjustable armrests need to be provided [8].
(iii) In driving seat, adjustable lumbar support is also very essential [8], and this lumber support must be projected beyond 2 cm for betterment of end-user during prolong driving [12].
(iv) The seat pan and backrest should be soft padded, and need to provide with adjustable features [18, 19].
(v) Instead of Rexene, cloth cover is preferable, which may reduce the probability of pressure point [18, 19].
(vi) Relocation of master controller box with suitable arrangement is essential to provide more legroom.

The above said ergonomic design modifications are economic and can be adopted easily. Proper adaptation will certainly bring down the stress level and make driving as a pleaser task.

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References

1. 8.2% GDP Growth rate—Indian Railways in India's GDP. RailNews. Available from http://www.railnews.in/8-2-gdp-growth-role-of-indian-railways-in-indias-gdp-carbon-footprint/ September 2018
2. Statistical Summary—Indian Railways. Available from http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/IRSP_2016-17/Annual_Report_Accounts_Eng/Statistical_Summary.pdf February 2018
3. R. Ranjan, T. Prasad, Working-conditions, stress and their outcomes: a review study among loco-pilots (railway drivers) in India. IOSR J. Hum. Soc. Sci. **9**(2), 39–48 (2013)
4. R. Ranjan, T. Prasad, Work-life of Indian railway's drivers (loco-pilots). IOSR J. Bus. Manag. **19**(8), 93–101 (2014)
5. HOER Rules (Hours of Employment and Period of Rest rules 2005). Indian Railway Employee. Available from https://indianrailwayemployee.com/content/hoer-rules-hours-employment-and-period-rest-rules-2005.

6. L. Wei, L. Zhang, Evaluation and improvement of crashworthiness for high-speed train seats. Int. J. Crashworthiness, 1–8 (2017)
7. A. Jhinkwan, J. Singh, Design specifications and ergonomic evaluation of car seat (A Review). Int. J. Eng. Res. Technol. (IJERT) **3**(5) (2014)
8. M. Žnidarič, P. Jenček, J. Kolenc, Ergonomic analysis of train driver workplace at train ICS pendolino series 310. In *Proceedings the 14th international conference on transport science*. Potoroz, Slovenia
9. M. Cardoso, C. McKinnon, D. Viggiani, M. J. Johnson, J. P. Callaghan, W. J. Albert, Biomechanical investigation of prolonged driving in an ergonomically designed truck seat prototype. Ergonomics **61**(3), 367–380 (2017)
10. M. Cardoso, F. Fulton, C. McKinnon, J. P. Callaghan, M. J. Johnson, W. J. Albert, Ergonomic evaluation of a new truck seat design: a field study. Int. J. Occup. Safe. Ergon 1–13 (2018)
11. X. Li, L. Ding, Q. Zhou, H. Hu, C. Zhao, Study on the evaluation of automotive seat comfort during prolonged simulated driving. Digital human modeling. Appl. Health Safe. Ergon. Risk Manage. 101–111 (2014)
12. D. E. De Carvalho, J. P. Callaghan, Spine posture and discomfort during prolonged simulated driving with self-selected Lumbar. Support Promin. Hum. Fact. Ergon. Soc. **XX**(X), 1–12 (2015)
13. M. P. Reed, L. W. Schneider, Lumbar Support in auto seats: conclusions from a study of preferred driving posture. SAE international by Imperial College London (2018)
14. D. Mohamad, B. Md. Deros, D. A. Wahab, D. D. I. Daruis, A. R. Ismail, Integration of comfort into a driver's car seat design using image analysis. Am. J. Appl. Sci. **7**(7), 937–942 (2010)
15. N. Yamazaki, Analysis of sitting comfortability of driver's seat by contact shape. Ergonomics **35**(5–6), 677–692 (1992)
16. T.C Fai1, F. Delbressine, M. Rauterberg. Vehicle seat design: state of the art and recent development. In: *Proceedings World Engineering Congress 2007* (pp. 51–61), Penang Malaysia
17. Electric Locomotive Classes – AC. Available from https://www.irfca.org/faq/faq-loco2e.html#loco (2010)
18. Howerth, *The Ergonomic Seating Guide* (Handbook, 2008)
19. A. Hedge, Cornell ergonomic seating evaluation V21 administration instructions. Available from http://ergo.human.cornell.edu/Pub/AHquest/seatingevalv21.pdf (2007)
20. M.R. Spiegel, L.J. Stephens, *Theory and Problems of Statistics* (Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004)

Chapter 17
A Comparative Review of Available Systems for e-health Monitoring

Harminder Kaur and Sharavan Kumar Pahuja

1 Introduction

In the whole world, aging makes challenges in the medical field. According to World Health organisation, between the year 2015–2050, the number of aged, i.e., aged 60 or above will increase by 11 to 22% of the entire world population [1]. In France, this population took more than 100 years to double (from 7 to 14%) from the total population, and on the other hand, countries like China, Brazil, and India, etc., will take only 25 years for the same growth [2]. With aging, the person loses his/her ability to be independent due to many enduring diseases like heart diseases, psychological and physical disabilities, and other health diseases, i.e., communicable and non-communicable diseases. In India, both infectious and non-communicable health diseases are common in remote areas. But most deaths are caused due to non-communicable diseases, which are predicted to increase in the year 2020 [3]. Due to any of these diseases, the patient's life can be in danger, and it is difficult for the family members to provide help to the older people by staying 24 h at the home which creates problems for the patient. Because of this, health care monitoring applications are designed which enhance 24 hours home care for the aged and disabled people. . These systems are designed to make the family member or the doctor to aware of the health status of the patient by continuously monitoring the physiological condition. The healthcare applications are based on wireless technologies, which collect the patient's data by using different sensors and routes that collect data from the authorized person or doctor wirelessly. The wireless transmission of data deals with the various requirements which perform a significant role in efficient communication.

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These requirements are related to the routing of the data, reliability of the system, mobility of nodes, and security of data [4, 5, and 6]. The healthcare applications are designed on the bases of these requirements for the efficient working of the system. This paper focuses on the review of the different applications and existing systems designed for the home care applications, their use in the smart home, and challenges for designing the home care systems.

2 Literature Review

The purpose of this paper is to study the different designed health care applications to detect the activities of older people. Based on this, we have divided our discussion into two parts: (1) System based on Wireless Sensor Network Technology and (2) System based on Internet of Things.

A. *System Based on Wireless Sensor Network*

A wireless sensor network is a collection of the sensor nodes, which collects the data and forward this collected data to the base station for external world communication [7]. The basic principle of a WSN is to perform networked sensing using a vast number of comparatively unsophisticated sensors instead of the probable approach of developing a few expensive and sophisticated sensing modules and the advantage of networked recognizing over the conservative approach, can be concise as more excellent coverage, precision, and dependability at a possibly lower cost [8]. In the medical field, sensors are used for medical healthcare applications called Wireless Medical Sensor Network [9]. The medical sensors are placed on the human body for acquiring physiological data like blood pressure, temperature, SpO_2, etc. Wireless Medical Sensor networks support high mobility for high data rates with reliable communication.

The different healthcare systems are designed by using wireless technologies to fulfill the needed requirements. WiSPH is a system proposed by [10] to observe the real situation of the patient inside home. The system is based on the wireless technology called IEEE 802.15.4 Zigg-Bee, which is used with a 128-bit AES encryption security algorithm [11] for the protection of the data from external attacks. The system acquires the heart rate and rate of motion of the patient within the home. The wireless infrastructure nodes control the Received Signal Strength Indication (RSSI) to create the network proactively and the mobile nodes send the data when the event occurs, i.e., fluctuations in heart rate or a fall.

An essential requirement for designing healthcare applications is cost, reliability, and power consumption. The system should be at a low cost, with reliable communication and less power consumption. The author in [12] proposed a system based on these requirements which detect the fall and movement of the patient for indoor environments. ZUPS (Zigbee and Ultrasound Positioning System) is a system based proposed by [13] for the location detection of the patient inside home. The system uses Zigbee and ultrasound to fulfill the application requirements differing from all other existing methods. Based on the location service, authors in [14] proposed a position algorithm to provide the efficient monitoring of the position and location of the patient.

Another system based on the wireless sensor network is Giraff Plus proposed by the authors in [15]. The system is based on the wireless infrastructure network, which collects the human physiological parameters and environmental parameters by indicating the alarm if a sudden change occurs. Another reason of designing the healthcare applications is to know about the drug intaker that is whether the patient has taken the medicine or not. The solution is provided by [16], i.e., iCabiNET that services a smart medicine manager to alert a person through a message and alarm to take the medicine. Another application for medicine intake is the iPackage, which consists of medication wrappers with RFID tags. The RFID sensor detects these at the moment of ingestion and allows the person to monitor whether the patient is following the instructions or not [17].

Another health monitoring application is the AlarmNet, which is designed to monitor the abnormalities and physical variables of the patient by alarming the authorized person if any defect occurs [18]. To monitor the early-stage disease of neonates the different health parameters are needed to consider like body temperature, pulse rate etc. Authors in [19] proposed an application for the neonates; the baby's romper collects data and transmits that data wirelessly to the continuous measurement of the variables.

Medical Ad Hoc Sensor Networks (MASN) is a system based on Adhoc networking which collects the ECG data of the patient through the wireless medium [20]. Rafiq et al. [21], which uses the 3-electrode, and the system is combined with Wi-Fi Lan or Bluetooth for transmission of the attained data and to intersect with the doctor for immediate guidance. SMART (Scalable Medical Alert and Response Technology) is a wireless sensor-based system for monitoring the oxygen level in the blood (SpO2), ECG (electrical motion of the heart), and situation of the patient [22]. The data is sent wirelessly to the central computer, which assembles the data and analyzes that collected data. If any abnormality occurs in the patient's situation, it will alert the doctor or any authorized person.

B. *System Based on IoT*

IoT (Internet of Things) word refers to the internet, i.e., used to connect the devices to a network or sensors for exchanging data [23]. The word things in IoT refers to devices like medical devices, sensors, transponders, etc. [24]. In the passing years, IoT plays an essential role in designing healthcare applications. Like, if the collected data of patients have to be sent to the doctor sitting away from the patient, the devices have to be connected to the internet. IoT provides this linearity to the network to send the data to the cloud. Based on this, authors in [25] discussed the different healthcare technologies based on IoT, and to discuss these technologies data is collected from various databases like IEEE Explore, Science Direct, and Web of Sciences.

Telemedicine provides quality healthcare in the rural areas where medical help is not available by using the various wireless technologies with IoT. A security system had been provided by the authors in [26], which is based on the IoT Health Prescription Assistant (HPA), which helps the patient to follow up the doctor's instructions. Health problems are increasing day by day due to the lack of a medical facility. Due to the availability of the health care systems, the issues in the health can be looked after if the doctor is sitting far away. In [27], the authors proposed a system based on wireless technology to observe the patient's situation during traveling—the IoT sensors placed on the human body and link with the smartphone. The network's working is based on the five IoT layers which collect the data, analyze the data, store the data, and transfer the data, respectively. According to the World Health Organization, the unexpected falls are the second foremost reason for health injury in aged and disabled people. So, there is a need for analyzing the fall detection systems. Based on this, the author in [28] proposed a portable fall detection system based on the smartphone technology which is placed in the pocket and the self-organizing maps distinguishes between typical fall and dangerous fall of the patient.

IoT uses various smart technologies for diagnoses the disease and development of the health care monitoring systems during traveling and inside home, etc. An intelligent shoe is one of the smart technologies with the IoT, which could define the aspects in life, i.e., related to heart diseases and worse condition of the patient [29]. Smart shoes have the ability of sustenance anticipation, systematic work-up, and disease monitoring with constant gait and mobility. Smart shoes can be planned to help as ubiquitous wearable computing schemes that permit advanced resolutions and services for the up-gradation of well-living and the revolution of health care. Another technology is the machine to machine technology, which is related to data communication and is used with the IoT in various fields. A system is proposed by [30] based on machine to machine technology along with the use of wireless sensor network and IoT, which provides security to the home. The system consists of two networks, i.e., External Network and Home Network. The home network connects the home appliances and external network based on the TD-CDMA technique, which is responsible for external world communication. These two networks are related to the home gateway.

Wireless Sensor Network includes the wireless technologies which are used to connect the appliances like medical sensors to the internet so that the collected physiological data can be interpreted. These technologies are Bluetooth, Zigbee, etc. By using these technologies, [31] presents a system that is divided into two scenarios, i.e., remote access and internet access. The primitive part of the network collects the physiological data from the sensors and collected data from the user sent to the server. Internet access is implemented to the smart home to provide internet access to the remote part of the network. Another technique for collecting the physiological parameters of the patient is SMMC [32], i.e., Sensors, Microcontroller, Machine to Machine Protocols, and Cloud, which measures the weight of the patient. The data collected by the patient was sent to the ThingsSpeak website, which stores and analyzes data.

3 Challenges for Designing Healthcare Applications

Wireless sensor networks and IoT are extensively used in designing healthcare applications, logistics, and transportation, environmental monitoring, etc. Wireless sensor networks are used in healthcare applications for monitoring the physiological and non-physiological parameters of human. The medical application of the wireless sensor network can be divided into two types, i.e., wearable devices and implanted devices. In a wearable wireless sensor network, the sensor devices are placed on the human body surface, and just at nearby immediacy of the user such as for measurement of temperature, heart rate, blood pressure, SpO2, etc., this is called a non-invasive method of analysis of physiological parameters. On the other side, in the implanted wireless sensor network, the sensor devices are placed inside the human body, which is an invasive method of measuring the physiological parameters. Security break in healthcare applications of sensor networks is primary anxiety [33]. Because in a wireless sensor network and IoT the data which is collected from sensors is transmitted wirelessly; therefore, security issues have occurred. The security threats and attacks in wireless sensor network attacks can be divided into two types, i.e., active attacks and passive attacks [34]. The passive attacks are related to the data routing, which expresses the path to the packet from source to destination. The attacker can change the destination address of the routing packets and can make routing unreliable. Active threats can be more destructive than passive threats. The hackers or unauthorized person can locate the position of the user by snooping and may harm. The different routing attacks in WSN include the black hole attack and sinkhole attack, which can damage the useful information collected from the sensors. Authors in [35] define the security and designing issues for developing universal e-health monitoring applications. Universal e-health monitoring systems have the capability of measuring the temperature, oxygen saturation, ECG, etc. of the patient continuously. So, these devices should be small enough to be carried out, which leads to being a significant challenge to design the e-health applications. The wireless sensor network is a wireless network in which different sensors are distributed to monitor the physical and environmental parameters. So, the main challenge for designing healthcare applications based on wireless sensor networks is the selection of the appropriate sensors. In the medical field, the physical parameters are measured using different medical sensors like temperature sensor, heart rate sensor, breath sensor, etc. Figure 1 demonstrates the various challenges for wireless sensor-based applications designing.

Smart health applications based on the IoT give a numeral of benefits, but these technologies are not the exact solution for communication networking. There are several challenges described by the different authors for designing these applications based on IoT. IoT-based applications depend on the communication between the two or more nodes. So, this can create a problem of flow of data between the heterogeneous nodes owed to the attacks or hackers, and there can be a risk of electrical hardware failure which can lead to an extensive amount of data loss [36].

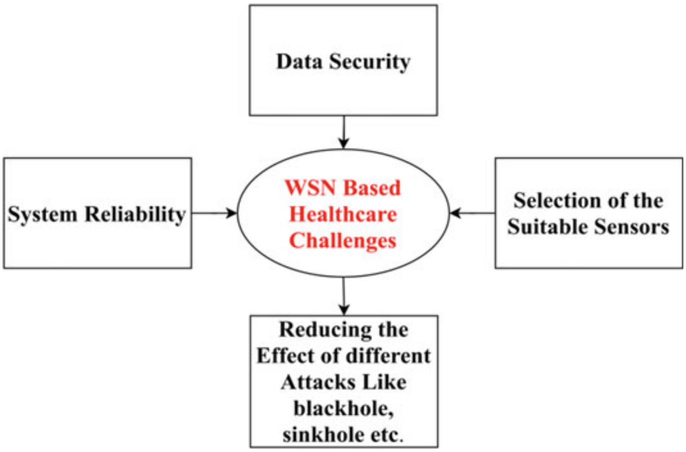

Fig. 1 Challenges for designing the E-health application based on WSN

Communication problems can arise in the communication devices from the manufacturer, which implements the different standards for designing these devices [37], and these problems can occur in smart homes by use of the various sensors. The distinct design challenges for healthcare are given in Fig. 2.

Information security and privacy give the challenging task for designing healthcare applications. So, the statistics collected from the sensors should be highly secured during transmission from one place to another. The security of home is dependent on the security mechanism; if the security mechanism fails, it can cause a house to break down [38]. For designing the smart home IoT-based applications, the scenario

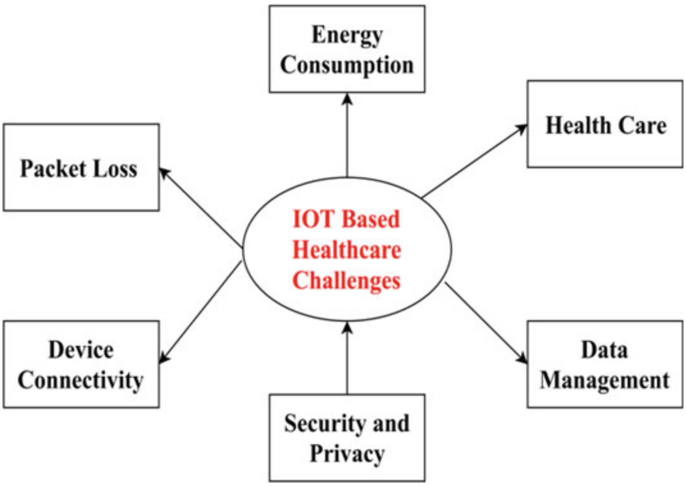

Fig. 2 Challenges for designing the E-health application based on IoT

is a buildup of different heterogeneous devices which can be sometimes accessed by unauthorized person or malicious nodes. Therefore, physical injury or change of the precise functionalities of these devices should be forbidden [39]. The wireless network-based smart home systems are created on the connectionless routing for the packet or data transmission. Due to the collision, wrong channels, unsecured wireless communication, and lack of a security system: This can lead to packet loss during the transmission [40].

4 Comparison of Existing Healthcare Systems

E-health applications include the monitoring of the medical and non-medical constraints of the human by using wireless sensor networks and IoT-based technologies. To design these healthcare applications, the system has to justify the different requirements. These requirements include the reliability of the system, efficient routing technique, less energy consumption, affordable cost, and the foremost requirement is the security of the data. Based on these requirements, different authors have proposed the different e-health platforms which have the capability of measuring the various physiological and non-physiological parameters non-invasively. Some of the platforms are based on the real-time monitoring of patient data.

Based on these requirements, Table 1 presents the comparison of the available e-health platforms.

5 Conclusion

Healthcare monitoring is essential for the aged and disabled people because due to the increase in age, they lose their abilities and suffer from many chronic diseases like heart disease, high blood pressure, etc., which can be hazardous to their lives. Healthcare applications provide the best solution for the medical field to give medical help to the aged and disabled people within the range. These applications are designed using a wireless body sensor network and the Internet of things. In this paper, we have presented the review of the available healthcare systems which are based on the wireless sensor networks and the Internet of Things. These systems collect the physiological and non-physiological parameters of the patient non-invasively through the biosensors. And this data is further analyzed and processed by using different wireless techniques and algorithms. Wireless networking includes many challenges for designing like system reliability, routing, security, and privacy, etc., which can create difficulties to design these applications.

Table 1 Comparison of Existing System

Requirements	Open-wise [41]	Giraaf plus [15]	MASN [20]	WiSPH [10]	ZUPS [13]
Technology used	Solar power model based on Wireless Sensor Networks (Standard used 802.15.4/802.11n)	Based on wireless Sensor Network contains the software and hardware platforms and used middleware infrastructure	Wireless Adhoc Networks and Data Mining Based on Wavelet Theories	IEEE 802.15.4 Zigbee	Zigbee and Ultrasound Indoor Positioning
Parameters measured	humidity, temperature, and light of a soccer field	Physiological parameters like weight, BP, Oxygen saturation, and Environmental Parameters like motion, electrical usage, etc	ECG (Cardiac Patient Monitoring)	Heart Rate, Rate of Motion	Location of the Patient
Routing technique used	Routing Algorithm (Network Layer and Application Layer)	Proactive routing	Intra-Cluster and Inter-Cluster Routing	Multihop Broadcasting (one to many)	Zigbee Mesh Network
Security algorithm	None	Giraff Plus LTS Web Service used for secure communication in Giraff Plus System	Only the source and destination can decrypt the data with crypto-keys	AES 128-bit Encryption Mechanism	AES 128-bit Encryption Mechanism

(continued)

Table 1 (continued)

Requirements	Open-wise [41]	Giraaf plus [15]	MASN [20]	WiSPH [10]	ZUPS [13]
System reliability	Energy consumed by WSN modules in wake-up and sleep states I_{awake}/I_{sleep} 68.5 mA/6.28 mA	RSSI, system reliability tested in six real homes	Dynamic Reliability Adaption Scheme	Received Signal Strength Indication (RSSI), a packet loss rate of 1.83%	Maximum synchronization error with 95% probability in a four-level network and distance estimation near about 0.33 mm/ms
Software used	PaRTiKle Operating System	Not Provided	TinyOS Platform and Support Vector Machine Algorithm	MATLAB	Not Provided, Least-Median-of-Squares (LMedS) location algorithm used for detecting the location
Supported application	The system provides hardware solar-powered WSN platform and adds the new user libraries to The POSIX Real-Time Kernel for WSN applications	Real-time monitoring of the physiological and environmental parameters based on the daily activities of the patient	Provides the Real-time collection of ECG data by using Wavelet theories	Provides a system based on WSN technology to measure heart rate and rate of motion of the senior citizen within the home	Detection of the location of the disabled patient and provides medical care to the same

References

1. WHO Website, 10 Facts on Ageing and the Life Course. http://www.who.int/features/factfiles/ageing/es/index.html
2. WHO Website, Interesting Facts about Ageing. http://www.who.int/ageing/about/facts/en/index.html
3. S.G. Kumar, G. Roy, S.S. Kar, Disability and rehabilitation services in India: issues and challenges. J. Family Med. Primary Care **1**(1), 69 (2012)
4. M. Alaa, A.A. Zaidan, B.B. Zaidan, M. Talal, M.L.M. Kiah, A review of smart home applications based on internet of things. J. Netw. Comput. Appl. **97**, 48–65 (2017)
5. V.P.G. Jiménez, A.G. Armada, Field measurements and guidelines for the application of wireless sensor networks to the environment and security. Sensors **9**(12), 10309–10325 (2009)
6. E.E. Egbogah, A.O. Fapojuwo, A survey of system architecture requirements for healthcare-based wireless sensor networks. Sensors **11**(5), 4875–4898 (2011)
7. E. Stroulia, D. Chodos, N. M. Boers, J. Huang, P. Gburzynski, I. Nikolaidis, Software engineering for health education and care delivery systems: The Smart Condo project. In *2009 ICSE Workshop on Software Engineering in Health Care*, pp 20–28 IEEE
8. Y. Li, M. T. Thai (Eds.), *Wireless Sensor Networks and Applications* (Springer Science & Business Media, 2008)
9. A. Minaie, Application of wireless sensor networks in health care system application of wireless sensor networks in health care system. In *Proceedings of the 120th ASEE Conference & Exposition* June 23–26 (2013)
10. P. Magaña-Espinoza, R. Aquino-Santos, N. Cárdenas-Benítez, J. Aguilar-Velasco, C. Buenrostro-Segura, A. Edwards-Block, A. Medina-Cass, WiSPH: a wireless sensor network-based home care monitoring system. Sensors **14**(4), 7096–7119 (2014)
11. P. Kumar, H.J. Lee, Security issues in healthcare applications using wireless medical sensor networks: a survey. Sensors **12**(1), 55–91 (2012)
12. A.M. Tabar, A. Keshavarz, H. Aghajan, Smart home care network using sensor fusion and distributed vision-based reasoning. In *Proceedings of the 4th ACM International Workshop on Video Surveillance and Sensor Networks*, pp. 145–154. ACM
13. A. Marco, R. Casas, J. Falco, H. Gracia, J.I. Artigas, A. Roy, Location-based services for elderly and disabled people. Comput. Commun. **31**(6), 1055–1066 (2008)
14. H. Yan, Y. Xu, M. Gidlund, R. Nohr, An experimental study on home-wireless passive positioning. In: *2008 Second International Conference on Sensor Technologies and Applications (SENSORCOMM 2008)*, pp. 223–228, IEEE (2008)
15. F. Palumbo, J. Ullberg, A. Štimec, F. Furfari, L. Karlsson, S. Coradeschi, Sensor network infrastructure for a home care monitoring system. Sensors **14**(3), 3833–3860 (2014)
16. M. López-Nores, J.J. Pazos-Arias, J. García-Duque, Y. Blanco-Fernández, Monitoring medicine intake in the networked home: the iCabiNET solution. In: *2008 Second International Conference on Pervasive Computing Technologies for Healthcare*, pp. 116–117. IEEE (2008)
17. Z. Pang, Q. Chen, L. Zheng, A pervasive and preventive healthcare solution for medication noncompliance and daily monitoring. In: 2009 2nd *International Symposium on Applied Sciences in Biomedical and Communication Technologies*, pp. 1–6. IEEE (2009)
18. A.D. Wood, J.A. Stankovic, G.V.L. Selavo, Z. He, Q. Cao, T. Doan, Y.W.L. Fang, R. Stoleru, Context-aware wireless sensor networks for assisted living and residential monitoring. IEEE Network **22**(4), 26–33 (2008)
19. C.R. Baker, K. Armijo, S. Belka, M. Benhabib, V. Bhargava, N. Burkhart, A.D. Minassians, G. Dervisoglu, L. Gutnik, M.B. Haick, Wireless sensor networks for home health care. In: Proceedings of the 21st *International Conference on Advanced Information Networking and Applications Workshops (AINAW'07),* Ontario, ON, Canada, 21–23 May 2007, pp. 832–837
20. F. Hu, M. Jiang, L. Celentano, Y. Xiao, Robust medical ad hoc sensor networks (MASN) with wavelet-based ECG data mining. Ad Hoc Networks, Vo. **6**(7), 986–1012 (2008)

21. S. Rafiq, A.Z. Alam, M.R. Islam, Development of ECG home monitoring system. In: *2017 IEEE Regional Symposium on Micro and Nanoelectronics (RSM)*, pp. 80–83, IEEE (2017)
22. C. Dorothy, E. Shih, J. Waterman, J. Guttag, J. Bailey, T. Stair, R. A. Greenes, L. Ohno-Machado, Physiological signal monitoring in the waiting areas of an emergency room. In *Proceedings of the ICST 3rd international conference on Body area networks (p. 5). ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering)* , (2008)
23. https://www.eduonix.com/blog/internet-of-things/introduction-internet-things-iot/
24. https://www.slideshare.net/Blackvard/introduction-to-internet-of-things-iot
25. M. Alaa, A.A. Zaidan, B.B. Zaidan, M. Talal, M.L.M Kiah, A review of smart home applications based on Internet of things. J. Netw. Comput. Appl. **97**, 48–65 (2017)
26. M. Hossain, S.R. Islam, F. Ali, K.S. Kwak, R. Hasan, An Internet of Things-based health prescription assistant and its security system design. Future Gener. Comput. Syst. **82**, 422–439 (2018)
27. Z.U. Abideen, M.A. Shah, An IoT based robust healthcare model for continuous health monitoring. In: *2017 23rd International Conference on Automation and Computing (ICAC)*, pp. 1–6. IEEE (2017)
28. V. Carletti, A. Greco, A. Saggese, M. Vento, A smartphone-based system for detecting falls using anomaly detection. In: *International Conference on Image Analysis and Processing*, pp. 490–499, Springer, Cham (2017)
29. B. Eskofier, S. Lee, S., M. Baron, A. Simon, C. Martindale, H. Gaßner, J. Klucken, An overview of smart shoes in the internet of health things: gait and mobility assessment in health promotion and disease monitoring. Appl. Sci. 7(10), 986 (2017)
30. T. Jiang, M. Yang, Y. Zhang, Research and implementation of M2M smart home and security system. Secur. Commun. Netw. **8**(16), 2704–2711 (2015)
31. Y. Jiang, X. Liu, S. Lian, Design and implementation of smart-home monitoring system with the Internet of Things technology. In: *Wireless Communications, Networking and Applications*, pp. 473–484, Springer, New Delhi (2016)
32. J. Ma, H. Nguyen, F. Mirza, O. Neuland, Two-way architecture between IoT sensors and cloud computing for remote health care monitoring applications. In: *Twenty-Fifth European Conference on Information Systems (ECIS)*, Guimarães, Portugal, pp. 2834–2841 (2017)
33. M. Al Ameen, J. Liu, K. Kwak, Security and privacy issues in wireless sensor networks for healthcare applications. J. Med. Syst. **36**(1), 93–101 (2012)
34. H.S. Ng, M.L. Sim, C.M. Tan, Security issues of wireless sensor networks in healthcare applications. BT Technol. J. **2**(2), 138–144 (2006)
35. F. Kargl, E. Lawrence, M. Fischer, Y.Y. Lim, Security, privacy and legal issues in pervasive e-health monitoring systems. In: *2008 7th International Conference on Mobile Business*, pp. 296–304, IEEE (2008)
36. T. Kirkham, D. Armstrong, K. Djemame, M. Jiang, Risk driven Smart Home resource management using cloud services. Fut. Gener. Comput. Syst. **38**, 13–22 (2014)
37. M. Schiefer, Smart home definition and security threats. In: *2015 ninth international conference on IT security incident management & IT forensics*, pp. 114–118, IEEE (2015)
38. B. Min, V. Varadharajan, Design and evaluation of feature distributed malware attacks against the Internet of Things (IoT). In: *2015 20th International Conference on Engineering of Complex Computer Systems (ICECCS)*, pp. 80–89, IEEE (2015)
39. R. Fisher, G. Hancke, DTLS for lightweight secure data streaming in the internet of things. In: *2014 Ninth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, pp. 585–590, IEEE (2014)
40. J. Lloret, E. Macías, A. Suárez, R. Lacuesta, Ubiquitous monitoring of electrical household appliances. Sensors **12**(11), 15159–15191 (2012)
41. A. González, R. Aquino, W. Mata, A. Ochoa, P. Saldaña, A. Edwards, Open-wise: a solar-powered wireless sensor network platform. Sensors **12**(6), 8204–8217 (2012)

Chapter 18
Prevention of Cold Injuries in Defense Personnel and Other Vulnerable-Populations: Great Potential with Many Challenges

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1 Introduction

The devastating impact of cold weather on the human body is one of the world's oldest recorded injuries which are commonly known as cold weather injuries (CWIs) [1]. CWIs are very common amongst the members of armed forces, who participate in the combat as well as military training missions in extremely cold areas. In addition to defence personnel, residents of cold regions, particularly those belonging to geriatric age group and athletes participating in cold weather sports/activities including skiing, running, sled racing and high-altitude mountaineering are at high risk of CWIs [2, 3].

Globally, approximately 140 million people live in high altitude areas (2500 m above sea level) and 40 million travel to these areas every year for occupation, sports or recreation purposes. In India, the whole Ladakh region, part of Northwest Kashmir, Northern part of Sikkim and Tenga valley of Arunachal are considered inhabited high altitude areas [4]. In US Armed forces, 478 members were diagnosed with CWI in the year 2017-2018 and the incidence was reported to be 19.6% higher as compared to previous year [5]. Exposure to cold temperatures contributes to higher risks of mortality (7.29%) than hot temperatures (0.42%). During winters, the incidence of hypothermia and frostbite in athletes is low. Frostbite and hypothermia account for only 3–5% of all injuries in mountaineers and 20% of all injuries in Nordic skiers [6]. In India, a substantially greater number of deaths i.e. 5,84,300 attributable to moderately cold temperature (13.8-30 °C) has been documented in year 2015 as compared to number of deaths (47,800) in extremely cold temperature (0.4-13.8 °C). The greater risk of moderately cold temperature is attributed partly to the higher proportion of moderately cold days than extremely cold and hot days in India [7].

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Based on etiology, the underlying reason for hypothermia may be due to: (a) increased heat loss (exposure to cold environment, iatrogenic, cold fluid infusion, toxins, dermatological) (b) decreased heat production (age related, hypoglycemia, hypopituitarism, hypothyroidism, hypoadrenalism, trauma) (c) impaired thermoregulation (Wernicke encephalopathy, stroke, spinal cord injury, Guillian-Barre syndrome, amyotrophic lateral sclerosis, multiple sclerosis, myopathy) [8–10]. CWIs are also known to present in patients suffering from certain metabolic disorders with a decreased basal metabolic rate including hypothyroidism, hypoadrenalism and hypopituitarism [11]. In addition, it may be induced by certain drugs like phenothiazines, sedative-hypnotics (like barbiturates), tricyclic anti-depressants, opioids, β-blockers, neuromuscular blocking agents and benzodiazepines [12]. Some other drugs like lithium, valproic acid and certain alpha blockers like prazosin are reported to cause hypothermia. Alcohol is also known to cause hypothermia by increasing heat loss via vasodilation, impaired shivering and other behavioral responses to cold and even lowering of thermoregulatory set points [13]. Sepsis, particularly in geriatric patients is known to present with hypothermia (approximately 9-10% incidence), and heralds a poor prognosis with approximately double the incidence of mortality as compared to patients developing fever. Though the mechanism of hypothermia in response to sepsis still remains unclear, increase in cytokine response, tumor necrosis factor-α, interleukin-6, prostacyclin and thromboxane B2 metabolites has been observed. High dose of lipopolysaccharides (LPS) have been reported to induce hypothermia while its lower doses result in pyrexia [14].

Hypothermia has profound systemic effects that include vasoconstriction, tachycardia, and increased myocardial oxygen consumption as initial sympathetic response. In mild hypothermia, patients have vigorous shivering and cold white skin. Patients with moderate hypothermia exhibit psychological symptoms such as confusion, amnesia and apathy, in addition to reduced shivering, slurred speech, hyporeflexia, and loss of fine motorskills. The symptoms of severe hypothermia include cold edematous skin, hallucinations, oliguria, dilated pupil, areflexia, bradycardia, hypotension, and pulmonary edema [8].

Hypothermia causes poor tissue oxygenation throughout the body due to peripheral vasoconstriction, decreased myocardial contractility and decreased oxygen release from hemoglobin to tissue. This, in turn, increases cellular anaerobic metabolism and results in decreased adenosine triphosphate (ATP) synthesis. Normally, during aerobic metabolism, heat is produced by the hydrolysis of ATP to adenosine diphosphate (ADP); but due to less ATP synthesis in hypothermia, the hydrolysis of ATP is diminished which consequently results in decreased heat production. Anaerobic metabolism also caused metabolic acidosis owing to higher production of lactic acid [15]. Hypothermia also depresses respiratory ventilation rate, causes an accumulation of carbon dioxide and produces respiratory acidosis. Normally, as a feedback mechanism, kidneys respond to these metabolic changes and thereby increase the bicarbonate reabsorption in respiratory acidosis or increase the excretion of hydrogen ions in metabolic acidosis. Hypothermia presumably blocks many of the enzymatic activities of the renal tubular cell, so that the regulatory effect of the kidney upon acid-base homeostasis is completely lost [16].

2 Classification of Cold Injuries

Conditions that compromise the ability of body to maintain normal temperature may lead to CWIs which can be classified into three main categories: (a) non-freezing cold injury (NFCI) such as trench or cold immersion foot (b) freezing cold injury (FCI), also known as frost nip or in late stage frostbite and (c) systematic or accidental hypothermia [17–19].

A. *Non-freezing cold injury (NFCI)*

NFCI is an umbrella term for clinical conditions such as trench foot, immersion foot, shelter limb and paddy foot and is part of spectrum of cold environmental injuries [20]. Trench foot was first described by Dr. Dominique Jean Larrey, a French surgeon, in 1812. It has been reported that approximately 75,000 British soldiers died in World War I due to trench foot [21]. The disease largely affects the toes; but in many cases, there is swelling in the legs upto the knee. In severe cases, large blisters, filled with clear "gangrene smelling" fluid, ulceration and gangrene have been seen [22–24]. Tinea infection, lymphoedema, venous hypertension, physical trauma, dietary inadequacy and fatigue may increase an individual's susceptibility to trench foot [21, 25]. Immersion foot, first described during World War II, is the pseudonym for trench foot seen in sailors following prolonged exposure to cold water, with a similar pathogenesis and clinical course. Immersion foot injury may extend proximally and involve the knees, thighs, and buttocks, depending on the depth of immersion. The term 'immersion foot' is neither accurate nor adequate, since the syndrome may arise without immersion and may affect the hands [26]. Patients with erythromelalgia have been reported to develop immersion foot after using extreme cooling measures (such as fans, ice, and cold water) to relieve symptoms. Alcohol consumption has also resulted in immersion foot [27]. In shelter limb (dependency without cold) and paddy foot (wet but not cold), the injury appears to be very similar to NFCI [28].

NFCI is a peripheral cold injury occurring due to exposure to temperatures between 0-15°C and is distinct from frostbite as tissue freezing does not occur. NFCI classically occurs in military personnel, but may also occur in mountaineers and homeless [29, 30]. There are four clinical phases that characterize the course of NFCI (Table 1). During cold exposure, acute neurological symptoms such as numbness, paresthesia, pain, as well as vasomotor disturbance (pallor) occur that may be followed by swelling, erythema and exacerbation of pain on rewarming of the affected limbs. In chronic NFCI, people develop persistent sensory symptoms such as chronic pain and cold hypersensitivity of hands and feet. In mild cases, persistent symptoms are trivial and short-lived and usually recover within few days; while in severe cases, sensory neuropathy persists that is usually accompanied by neuropathic pain [31, 32]. NFCI of peripheral nerve damages the blood-nerve barrier and vascular endothelial cell layer, resulting in endoneurial edema, increased blood vessel permeability and local hydrostatic pressure, which may lead to cellular hypoxia [33].

Table 1 Clinical phases of non-freezing cold injury [34, 35]

Phase	Clinical symptoms
Prehyperemic phase	Extremities may initially be bright red color, but later almost change to a pale color, even completely blanched white, loss of a sensory modality, most typically complete local anesthesia, occasionally blisters
Cynotic phase	Increase in peripheral blood flow, change of extremities color from white to mottled pale blue, initial edema or swelling
Hyperemic phase	Extremities become hot and flushed, intense pain including hyperalgesia to the slightest touch, blisters formation, loss of neuromuscular function and general muscle weakness
Posthyperemic phase	Reduced inflammation, fall in limb temperature, increased sensitivity to cold stimuli, hyperhidrosis

B. *Freezing cold injury (FCI)*

Frostbite is the most serious peripheral tissue injury, typically of the digits, and sometimes of the face, that results from exposure to extremely low temperatures (below 0°C) for prolonged period of time [36]. Contact frostbite can also occur when skin is exposed to a substance with a temperature below skin-freezing temperature such as metal, gasoline, stove fuel, ice packs or alcohol. Gasoline and other petroleum products are particularly risky due to their extremely low freezing point (−50 °C) [2].

Frostbite is associated with tissue necrosis either due to direct cellular damage or indirect damage secondary to vasospasm and arterial thrombosis, also referred to as progressive dermal ischemia [37–39]. Direct cellular damage like ice crystals formation may lead to a variety of affects like cell dehydration and shrinkage, electrolyte imbalance, denaturation of lipid-protein complexes and thermal shock. Indirect cellular damage is more severe as compared to direct cellular effect, and a number of factors such as endothelial damage, intravascular sludging, increased levels of inflammatory mediators and free radicals, reperfusion injury and thrombosis play a role in contributing to progressive dermal ischemia and reinforce each other [38, 40, 41].

Frostbite injuries can be classified into four stages based on clinical findings (Table 2). First- and second degree frostbite injuries represent superficial injuries in which there is no or minimal anticipated tissue loss; while third- and fourth degree frostbite injuries comprise deep frostbite injuries with significant tissue loss [42].

C. *Systematic or accidental hypothermia*

Accidental hypothermia is defined as an unintentional fall in core temperature to less than 35°C, without the presence of a primary defect in the patient's thermoregulatory mechanism. It can be subdivided into mild (32–35 °C), moderate (28–32 °C), and severe (<28 °C) [45–47]. It is a leading cause of death in children in developed countries with a wide mortality rate ranging from 20 to 80% [48]. It is also a common condition in young children in both low and middle income countries. Infants are more vulnerable to hypothermia due to their limited thermoregulatory response [49].

Table 2 Classification and clinical symptoms of frostbite injuries [42–44]

Stages	Clinical findings
First degree frostbite	Numbness, erythema, plaque and mild edema
Second degree frostbite	Erythema, edema, bullae containing clear or milky fluid and tissue destruction confined to dermal layer
Third degree frostbite	Tissue destruction extending to subcutaneous levels, deep hemorrhagic blisters, skin necrosis, and a blue-gray discoloration of skin
Fourth degree frostbite	Tissue necrosis upto deeper layer of skin including muscle, bone and tendons; deep red or cyanotic skin, which later becomes dry, black, and mummified

Accidental hypothermia can be caused by environmental exposure and by diseases or conditions that decrease thermoregulatory responses [50, 51]. Three types of accidental hypothermia have been recognized:

(a) Acute hypothermia/Immersion hypothermia: It is caused by sudden exposure to cold such as immersion in cold water or for a person caught in snow avalanche.
(b) Exhaustion hypothermia: It is caused by exposure to cold in association with lack of food and exhaustion such that heat can no longer be generated.
(c) Chronic hypothermia: It comes on over days or weeks and mainly affects the elderly [52]. It is also very well known to occur due to hypothalamic dysfunction as well as spinal cord lesions and is reported as a complication of multiple sclerosis [53].

The cardiovascular response to hypothermia begins with tachycardia, followed by progressive bradycardia at approximately 34 °C, which further results in 50% decrease in heart rate and concomitant fall in blood pressure at 28 °C [54, 55]. Patients with severe hypothermia have significant risk of arrhythmia and cardiac arrest [56].

The characteristics features of non-freezing cold injury, freezing injury and accidental hypothermia have been summarized in Table 3.

3 Body Response to Cold

The initial physiological response of the body to cold exposure is in the form of peripheral skin vasoconstriction and a reduction in skin blood flow, which reduces convective heat transfer between the body's core and shell (skin, subcutaneous fat and skeletal muscle). This, in turn, results in decreased heat loss to the environment [57, 58]. Peripheral vasoconstriction occurs when the mean skin temperature drops below 34–35 °C and is very effective for short durations as the body acts as insulator for the inner core. In an attempt to protect peripheral tissues, intermittent cold-induced

Table 3 Features of various cold-weather injuries [34, 55]

Feature	Non-freezing cold injury	Freezing cold injury	Accidental hypothermia
Cause	Caused by exposure to temperatures between 0–15 °C	Due to exposure to extremely low temperatures (<0 °C) for prolonged period of time	Due to unintentional fall in core temperature to <35 °C
Alteration in physiology	Alternating phases of vasoconstriction and vasodilation in protracted hypothermia	Tissue necrosis due to direct cellular damage or indirect progressive dermal ischemia	Peripheral vasoconstriction due to reflex mechanism
Type of damage	Incomplete damage of tissue, nerve fibers react at early stage	Direct damage of entire tissue by formation of ice crystals	Ischemia induced tissue infarcts
Clinical phases	Four clinical phases Prehyperemic phase, cyanotic phase, hyperemic phase and posthyperemic phase	Four clinical phases: First degree-, second degree-, third degree-, fourth degree frostbite	Classified as mild (32 to 35 °C), moderate (28–32 °C), and severe (<28 °C)
Occurrence of blister	Blister formation rare	Blister formation in second and third degree stages	Blister formation in severe cases
	Slow rewarming	Rewarming in warm water (37–39 °C) for 15–60 min	Rewarming alone generally leads to full recovery
Treatment recommendation	Slight loading of the affected area possible, no bandaging necessary	Sterile and protective bandages, topical antiseptics as required, splinting of affected extremities	No bandaging necessary

vasodilation results in temporary increases in blood flow and skin temperature. As core temperature drops further, the vasodilation response decreases and frostbite risk increases [2].

Cold exposure also elicits increased metabolic heat production which helps to maintain core body temperatures through involuntary shivering and by voluntarily modifying behavior i.e. increasing physical activity (e.g. exercise, increased fidgeting) [59]. Exposure to cold activates the sympathetic nervous system, which immediately releases heat by increasing the metabolism in all the cells of the body. The direct stimulation of β-adrenergic receptors by the sympathetic nervous system also activates brown adipose tissue, a specialized metabolic tissue that converts energy into heat [60–62]. When the metabolic heat production (non-shivering thermogenesis) together with the cutaneous vasoconstriction is not sufficient to maintain the optimal balance, shivering begins.

Shivering is an involuntary response to cold temperatures that involves rhythmic repeated skeletal muscle contractions starting at the core and spreading to the extremities [63]. When the skin senses cold via the transient receptor potential cation channel subfamily M member 8 (TRPM8) on the sensory nerves, it signals to the temperature center in the posterior hypothalamus, which transmits signals to the skeletal muscles to initiate shivering throughout the body. Shivering may start immediately or after several minutes of cold exposure, and is initiated by decrease in skin temperature (17–20 °C) and core body temperature (32–35 °C). If the core body temperature drops further, the shivering response declines and core body temperature drops further. Shivering increases basal metabolic rate 5-6 times, hence sufficient energy stores are required to maintain this response [2, 64].

4 Risk factors

Extreme cold weather does not cause any harm if skin, fingers, toes, ears, and nose are well protected or are exposed only briefly. In fact, the body temperature varies at different parts of the body such as 37 °C sublingually, 32 °C at the skin, 38°C in the rectum, 36.5 °C tympanic, and 38.5 °C deep within the liver [17, 65]. The processes that increase local heat loss or decrease heat production play a crucial role in the development of cold injury [66]. Body heat is lost through radiation (55-60% heat loss), respiration (20–30%), evaporation (20–30%), convection (12%) and conduction (3%) [67].

Environmental factors like duration of exposure, exposure to water, temperature and wind velocity play a crucial role in CWIs [68]. Along with these factors, physical inactivity or immobility, poor quality of protective clothing, fear and anxiety, local skin injury, consumption of alcohol, excessive smoking, touching of metal objects with bare hands, wet garments, and lack of personal hygiene are the other important factors responsible for the cause of cold injuries [1]. Wind and moisture accelerate the onset of frostbite. There is increased risk of cold injuries in case of impeded blood flow, inadequate food intake, or lack of oxygen at high altitudes [44]. Exhaustive exercise also alters the thermoregulatory response, predisposing the individual to hypothermia. Malnutrition and dehydration also limit heat production thus making the exposed individual prone to develop injuries [66, 69]. Certain medical conditions like hypothyroidism, multiple sclerosis, strokes, Parkinson's disease, pancreatitis and sepsis affects the thermoregulation process and make the individual vulnerable to damage by the cold conditions. Drugs belonging to the category of sedatives, tranquilizers, antidepressants, antipsychotics and beta blockers can also alter the body's thermoregulation. Vasoconstrictors like caffeine, nicotine or other drugs reduce blood flow to the extremities and are important risk factors for generation of frostbite and chilblain. All the risk factors associated with CWI have been summarized in Table 4.

Table 4 Risk factors of cold weather injuries [70–72]

Environmental	Individual	Behavioural	Physiological
Temperature	Physical characteristics	Alcohol and other drug abuse	Peripheral vascular disease
Wind	Age	Smoking	Neuropathy
Rain	Genetic susceptibility	Inadequate clothing and shelter	Endocrine conditions (Hypopituitarism, hypoandrenalism, hypothyroidism, hypoglycaemia)
Duration of cold exposure	Low body fat	Prolonged stationary exposure	Hyperhidrosis
Physical contact with cold objects or liquids		Situational misjudgement	Infections (Sepsis)
High altitude		Lack of hygiene	Medications (Phenothiazines, barbiturates, benzodiazepines, narcotics, tricyclic anti-depressants, β-blockers, anaesthetics, neuromuscular blockers)
Latitude of residence			

5 Prevention of Cold Wind Injuries

The strategies for the prevention of CWIs in dependent on the underlying pathophysiology and risk factors associated with these injuries. The susceptibility to cold related injuries increases when tissue heat loss is more than the ability of local tissue perfusion to prevent freezing of soft tissues. Preventive measures to ensure local tissue perfusion include:

- Maintenance of adequate core temperature and body hydration
- Minimization of the effects of known diseases, medications, and substances (including awareness and symptoms of alcohol and drug use) that might decrease perfusion
- Covering all skin and the scalp to insulate from the cold, moisture and wind
- Minimization of blood flow restriction, such as occurs with constrictive clothing, footwear, or immobility
- Adequate nutrition
- Supplementation of oxygen at extreme altitudes (over 7500) [43, 66].

Table 5 Clothing layers and their features [75]

Layer of clothing	Features
Inner layer	• Light or midweight short or long underwear that absorbs sweat from skin during aerobic activities • Provides extra insulation • Preferred material is polypropylene, polyester, silk or other synthetic fabrics; cotton should be avoided as it takes more time to dry when becomes wet
Middle layer	• Includes long pants, long-sleeved shirts, shorts, and T-shirts • Should be lightweight and comfortable
Insulation layer	• Include vests, jackets, pullovers, and sweaters • Wool, pile, and fleece are common insulation layers that retain some insulation capabilities even when wet • Should be warm, lightweight, not too bulky, and breathable
Outer layer	• Protects from wind, rain, and snow • Clothing made up of polyvinylchloride is preferred

Appropriate preparation for environmental exposure is the most important parameter to avoid hypothermia and frostbite. Three major causes of frostbite among mountaineers are inappropriate clothing, lack or incorrect use of equipments and lack of knowledge [73]. Proper clothing and prompt response to weather conditions help to maintain core body temperature and decreases the incidence of CWIs. In order to prevent and treat hypothermia, modalities may range from simple, non-invasive, passive external warming techniques (such as, removal of cold, wet clothing; movement to a warm environment) to active external rewarming (e.g. insulation with warm blankets) to active core rewarming (e.g. warmed intravenous fluid fusions, heated humidified oxygen, body cavity lavage, and extracorporeal blood warming) [74].

Appropriate clothing plays a critical role in prevention of CWIs. The multiple layers of clothing provide better temperature control as the air entrapped between the layers provides sufficient insulation. There are four clothing layers to consider and their characteristics are summarized in Table 5.

Exercise is a specific method to maintain peripheral perfusion by increasing both the level and frequency of peripheral vasodilation. It has been reported that cold-induced peripheral vasodilation has been observed in 58% of exercising persons as compared to non-exercising persons (28%) [76]. Although exercise is a preventive strategy in dry conditions when there is no wind, but in wet and/or windy conditions, the increased metabolic heat production from exercise is not sufficient to increase the temperature of exposed digits.

The use of skin-protecting emollients increases the risk of frostbite and should not be used. The incidence of facial frostbite is double in subjects who use emollient due to false sense of protection and negligence of other protective measures [2, 66].

6 Management of Cold Weather Injuries

The primary step in the management of any CWIs is to evacuate the patient from cold environment so that further damage can be avoided as far as possible. The next step in treatment strategy is to identify whether a patient is suffering from NFCI or FCI. If there is no evidence of tissue necrosis, patient should be regarded as suffering from NFCI and treatment started accordingly. In order to identify whether the patient has frostnip or frostbite, field rewarming can be attempted using auxiliary warmth. The complete resolution of symptoms after half an hour of field rewarming with no skin changes or paraesthesia indicates that the patient is having sustained frostnip and requires no further treatment other than continual prudence to ensure no further injuries. However, if the same digit of the patient has another episode of frostnip, the patient should be regarded as having sustained frostbite and treated accordingly. However, if the patient is suffering from both FCI and NFCI, the initial focus should be on FCI followed by treatment of NFCI subsequently [1].

A. *Treatment of FCI*

The strategy for the treatment of frostbite includes three different phases: pre-thaw field care phase, immediate hospital care phase, and post-thaw phase [77].

In field care phase, one should move out of the cold wind and seek suitable shelter. The consumption of warm liquid drinks, replacement of wet clothes, shoes, gloves with dry ones, warming the cold extremities by placing in companion's armpit or groin for 10 minutes, insulation layers, vapor barrier and medicines likes aspirin (75 mg, for anti-platelet effect) and ibuprofen (800 mg, for anti-prostaglandin effect) to get relief from pain and to improve circulation are the various first aid measures in FCI [78, 79]. The rubbing of affected part should be avoided as it may cause tissue damage [80, 81]. Field rewarming should only be attempted when there is no further risk of refreezing as subsequent refreezing increases the level of prostaglandin and thromboxane significantly which may result in morbidity [82, 83].

In mild hypothermia, a thick insulation layer (e.g. wool blankets) may be sufficient as the patients may warm themselves through the heat produced by shivering. Although active rewarming may not be required, but it provides advantages of decreasing the energy requirements and cardiac work of shivering. In moderate to severe hypothermia, active rewarming by chemical heat packs is necessary to rewarm the patient. Other effective active rewarming methods include a charcoal-burning heat pack, hot water bags, forced-air heating packs and chemical/electrical heating blankets. External heat should be applied on the axilla, chest and/or back (if possible), as these are the locations that provide the most efficient heat transfer [15, 84].

Treatment of frostbite has remained relatively unchanged for many years and is largely reflective of strategy developed by McCauley et al in 1983 [85]. The immediate care involves rapid rewarming of affected body parts in a whirlpool (recirculating water) maintained at 40-42 °C until rewarming is complete (core body temperature 34 °C) [39, 86]. Mild antibacterial agents such as povidone-iodine or chlorhexidine can be added in circulating water to combat infection [87]. Rewarming should continue until a red/purple colour appears and the extremity becomes pliable. The rewarming phase can take 15 min to 1 hour depending upon the severity of frostbite. Due to painful thawing procedure, an appropriate analgesic is usually prescribed along with tetanus prophylaxis. Active motion is encouraged during rewarming phase but care must be taken to prevent the extremities from touching the sides of the whirlpool. At high altitudes, patients may suffer from cold diuresis due to suppression of antidiuretic hormone which is a response for severe dehydration. Resuscitation of intravenous fluid volume is required in these cases [88, 89].

Post-rewarming strategies involve prevention of further tissue damage and reperfusion injury, along with infection prevention and appropriate wound care [40]. White blisters containing clear or milky fluid are debrided to discharge the excess of prostaglandin $F_{2\alpha}$ and thromboxane present in blister fluid. Haemorrhagic blisters should be left intact to prevent desiccation of the underlying tissue. Topical application of *Aloe vera*, a thromboxane inhibitor, in both the cases is usually recommended after every 6 h in order to inhibit local release of inflammatory mediators as well as to inhibit tissue necrosis [90]. Medications such as tetanus toxoid, opioid analgesics and non-steroidal anti-inflammatory agents are recommended in cold injuries. Aspirin and ibuprofen are reported to decrease the production of inflammatory mediators by inhibition of cyclooxygenase, thus limit the cascade of inflammatory damage. Ibuprofen is preferred over aspirin due to inhibitory effect of aspirin on prostacyclin synthesis which are helpful in wound healing. Patients at the risk of partial or complete amputation of extremities are candidates for thrombolytic treatment with tissue plasminogen activator (tPA) and heparin provided treatment has been started within 24 h of thawing [66, 91, 92]. tPA is a naturally occurring substance that converts plasminogen to plasmin which, in turn, lyses fibrin in the blood clots and restore the blood flow in damaged tissue [39]. To counteract infection, the use of antibiotic (penicillin) is recommended in tissue necrosis. Extremities are treated with clean, dry dressings and twice daily whirlpool baths with added chlorhexidine. Injured extremities should be elevated above heart level to avoid edema. Botulinum toxin type A (BTX-A) injections have been used to improve pain control, decrease numbness and increase blood perfusion in affected parts. BTX-A blocks the release of acetylcholine at motor end plate terminals, thus inhibiting smooth muscle vasoconstriction. It also blocks the transmission of adrenaline and prevents sympathetic vasoconstriction of vascular smooth muscles [93].

Compartment syndrome sometimes, develops due to cold injuries, resulting in built up of excessive pressure inside an enclosed muscle space at the site of injury. The high pressure in compartment syndrome impedes the flow of blood to and from the affected tissues. In such cases, fasciotomy should be performed. Generally amputation is delayed upto 3 months except in case of development of moist gangrene or sepsis. With the advent of Technetium^{99} scintigraphy and MRI scanning, more accurate prediction of tissue necrosis and bone viability is possible, hence plastic/reconstructive surgery can be planned accordingly [94, 95].

Adjunctive therapies

In many recent studies, role of adjunct therapies in the treatment of frostbite has been assessed. These include hyperbaric oxygen, surgical lumbar sympathectomy, vasodilators and thrombolytic agents.

Treatment of cold injury with hyperbaric oxygen (HBO) was first reported by Ledingham in 1963 [96]. HBO increases the local tissue oxygen tension which improves and maintains the viability of adjacent tissue. HBO therapy decreases ischemia-reperfusion injury and accelerates demarcation between viable and nonviable tissue [97]. HBO increases the deformability of erythrocytes, diminishes edema formation in burned and post-ischaemic tissues by causing vasoconstriction without the occurrence of hypoxia. HBO increases leukocyte bactericidal activity, resistance to infection, the growth of new capillaries, collagen synthesis and storage, and oxygen-sensitive fibroplast replication in wound healing [98]. HBO therapy also prevents the late changes in the growing bones [99].

Lumbar epidural sympathectomy has proved to be a therapeutic option for the treatment of pain, paresthesia, numbness, and hyperesthesia associated with frostbite injury [100, 101]. Surgical lumbar sympathectomy is only considered in patients with severe or intractable pain where the initial pain management with warming, best rest and non-steroidal anti-inflammatory drugs is not possible. Early sympathectomy performed within 24 h of injury has deleterious effects, as it increases edema formation and further tissue damage. However, if performed within 48 h of thawing, it has been reported to resolve the edema and decrease tissue destruction. Lumbar epidural sympathectomy has been proved to be a safe, quick, and effective means of resolving the symptoms of frostbite injury with quick recovery. Although it does not offer protection against future injury, the effects of lumbar sympathetic blockade are lasting in the majority of patients. This procedure is readily available worldwide and has applicability in both military operations and civilian practice [37, 102].

To counteract the vasospasm associated with freezing cold injury, a number of vasodilators (iloprost, pentoxifyllin, buflomedil, alprostadil) are prescribed along with other therapeutic agents [103, 104]. Iloprost, a stable metabolite of prostacyclin I_2, inhibits platelet aggregation, down regulates lymphocyte adhesion to endothelial cells and has cytoprotective and profibrolytic activity. The improved blood supply to collateral vessels by vasodilator activity is the possible reason for its beneficial effects in frostbite [105]. Epoprostenol is a reasonable alternative to intravenous iloprost as it is not available in certain countries such as United States [106]. Pentoxifylline, a methylxanthine derived phosphodiesterase inhibitor, has hematologic and an immunomodulating properties which lead to vasodilatation, improves erythrocyte flexibility, enhances blood flow, inhibits platelet aggregation, reduction in blood viscosity and inhibits tumor necrosis factor-α; all these pharmacological actions prevent the further tissue necrosis [107, 108]. Intravenous administration of buflomedil, α-blocker, during rewarming phase increases the peripheral blood flow and prevents the anticipated amputation of frozen limbs [109]. *Aloe vera* is used to prevent progressive dermal ischemia due to frostbite [110]. In 1990 Heggers et al have reported that topical application of *Aloe vera* reduces the chances of tissue loss and amputation in frostbite patients [111, 112]. The strategy for the management of FCI has been summarized in Fig. 1.

B. *Treatment of NFCI*

Similar to FCI, the first step in management strategy is to remove the patient from cold environment. The options for the treatment of NFCI are limited, hence the focus should be on prevention of non-freezing injuries [113]. Slow rewarming at 37-39°C is recommended as rapid rewarming can exacerbate the injury. Rewarming of cooled

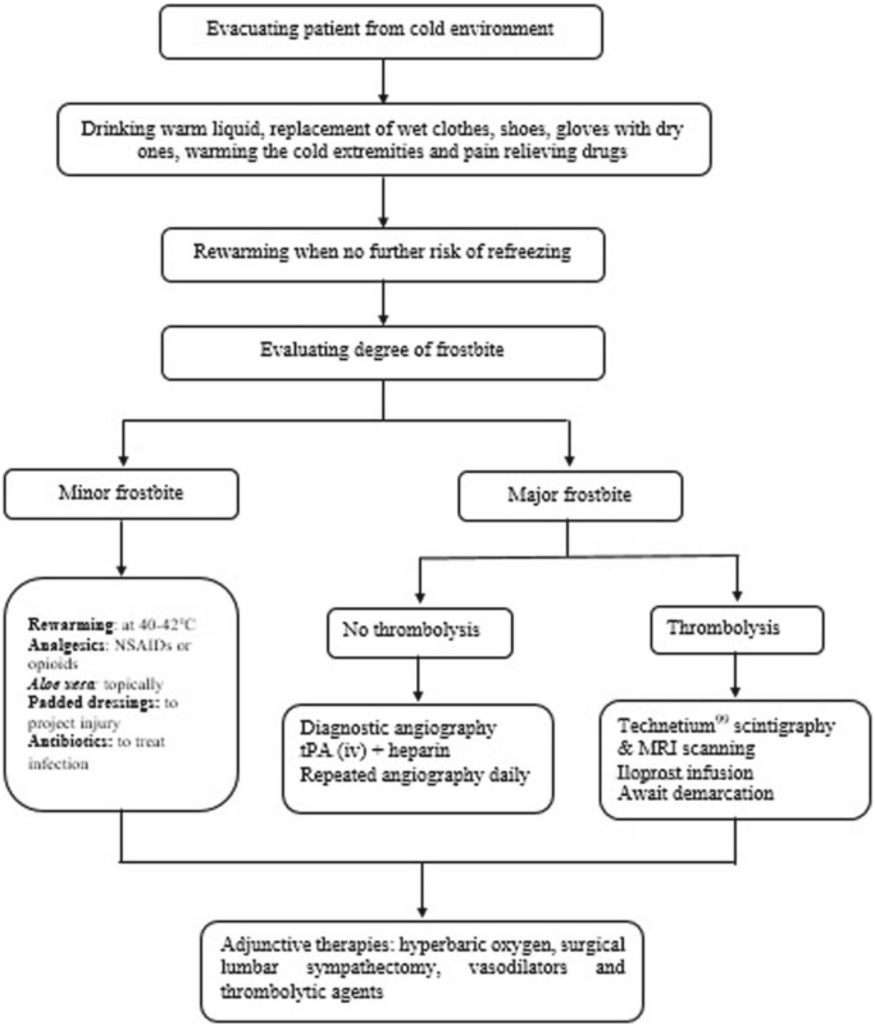

Fig. 1 Management of freezing cold injury

tissue is accompanied by additional tissue injury, as evidenced by the increased release of lactic acid dehydrogenase and creatine kinase, as well as enhanced lipid peroxidation, as evidenced by increased malonaldehyde formation. Quinacrine, a phospholipase inhibitor, has been reported to reduce the release of these intracellular enzymes and decrease lipid peroxidation, and thus is considered to be an effective therapeutic agent in hypothermic injury [114]. Although iloprost has shown promising effects in treatment of freezing cold injuries, a very few studies reported the use of this drug in NFCI. In 2017, Lonescu et al reported the symptomatic beneficial effects of iloporst in non-freezing injuries [115]. Iloprost reduces pain and increases mobility initially, but symptoms get worse after second infusion [21]. In early studies, quinine sulfate was reported to be superior to other analgesics but it is no longer recommended now. Tricyclic anti-depressant, amitriptyline 50-100 mg, is commonly recommended in neuropathic pain [116]. Sympathectomy by medical or surgical means should be avoided as it has been demonstrated to cause medium- to long-term deterioration in patient symptoms (Fig. 2).

C. *Treatment of Accidental hypothermia*

The management of accidental hypothermia consists of careful monitoring of vital organs, rewarming, vigorous supportive care, and treatment of underlying disorder. The first and most urgent treatment from the beginning is cardiac pulmonary resuscitation [117]. The core body temperature is maintained by rewarming process either by immersion of trunk in a hot bath maintained at 40-42°C or application of hyperthermic blankets. Vigorous supportive care has to be employed during rewarming process and

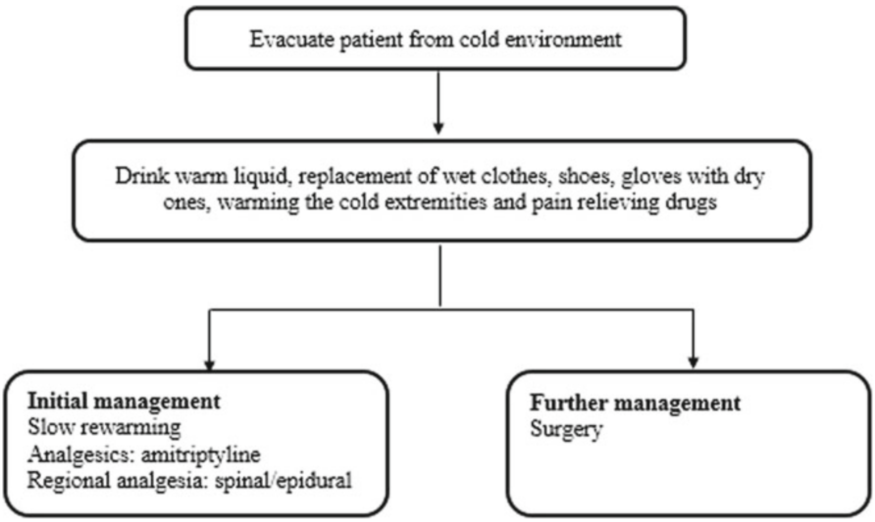

Fig. 2 Management of non-freezing cold injury

is important to improve the survival rate from accidental hypothermia. Supportive care includes external cardiac massage, hyperbaric oxygen and heated intravenous fluids. Thrombolytic agents, analgesics, and antibiotics are also prescribed by the physicians depending upon the condition of the patients [51, 118, 119].

7 Conclusion

A number of options are available for the treatment of cold injuries based on their type, degree and time elapsed since incidence. A constant progress in this direction has led to an evolution of the treatments leading to higher recovery and rehabilitation.

In contrast to the burn injuries, exposure to extreme cold is generally pre-decided. The reliance on preventive measures, therefore, should me more as compared to that on the curative measures. However, except for topical application of *Aloe vera* gel, no pharmacological measures are available for prevention of cold injuries. Despite the fact that the incidence of cold injuries is much less than that of burns [34], development of some preventive pharmacological interventions needs immediate attention of the scientific community. The thermogenic substances, currently being used for treatment of obesity can be explored in this direction.

References

1. K. Heil, R. Thomas, G. Robertson, A. Porter, R. Milner, A. Wood, Freezing and non-freezing cold weather injuries: a systematic review (in eng). British Med. Bull. **117**(1), 79–93 (2016). https://doi.org/10.1093/bmb/ldw001
2. J. Fudge, Preventing and managing hypothermia and frostbite injury (in eng). Sports Health **8**(2), 133–9 (2016). https://doi.org/10.1177/1941738116630542
3. D.S. Shenaq, L.J. Gottlieb, Cold Injuries (in eng). Hand Clinics **33**(2), 257–267 (2017). https://doi.org/10.1016/j.hcl.2016.12.003
4. L. C. G. K. Singh, High altitude dermatology (in eng). Ind. J. Dermatol. **62**(1), 59–65 (2017). https://doi.org/10.4103/0019-5154.198050
5. Update: Cold weather injuries, active and reserve components, U.S. Armed Forces, July 2013–June 2018 (in eng). Msmr **25**(11), 10–17 (2018)
6. J.R. Fudge, B.L. Bennett, J.P. Simanis, W.O. Roberts, Medical evaluation for exposure extremes: cold (in eng). Clinic J. Sport Med. Official J. Canad. Acad. Sport Med. **25**(5), 432–6 (2015). https://doi.org/10.1097/jsm.0000000000000224
7. S.H. Fu, A. Gasparrini, P.S. Rodriguez, P. Jha, Mortality attributable to hot and cold ambient temperatures in India: a nationally representative case-crossover study (in eng). PLoS Med. **15**(7), e1002619. https://doi.org/10.1371/journal.pmed.1002619
8. P. Petrone, J. A. Asensio, C. P. Marini, In brief. Curr Prob. Sur. **51**(10), 414–415 (2014). https://doi.org/10.1067/j.cpsurg.2014.07.005
9. F. Lapostolle et al., Risk factors for onset of hypothermia in trauma victims: the HypoTraum study. Critic. Care **16**(4), R142 (2012). https://doi.org/10.1186/cc11449
10. W. P. Cheshire, Thermoregulatory disorders and illness related to heat and cold stress. Auto. Neurosci. **196**, 91–104 (2016). https://doi.org/10.1016/j.autneu.2016.01.001

11. F.J. Curley, R.S. Irwin, Disorders of temperature control: hypothermia, Part III. J. Intens. Care Med. **1**(5), 270–288 (1986). https://doi.org/10.1177/088506668600100507
12. L. McCullough, S. Arora, Diagnosis and treatment of hypothermia (in eng). Amer. Fam. Phys. **70**(12), 2325–32 (2004)
13. R. Raheja, V.K. Puri, R.C. Schaeffer Jr., Shock due to profound hypothermia and alcohol ingestion: report of two cases (in eng). Critic. Care Med. **9**(9), 644–6 (Sep 1981). https://doi.org/10.1097/00003246-198109000-00006
14. E. Blair, G. Henning, R. Hornick, R. A. Cowley, Hypothermia in Bacteremic shock (in eng). Arch. Surgery **89**, 619–29. https://doi.org/10.1001/archsurg.1964.01320040035006
15. F. J. C. Haverkamp, G. G. Giesbrecht, E. C. T. H. Tan, The prehospital management of hypothermia—An up-to-date overview. Injury **49**(2), 149–164 (2018). https://doi.org/10.1016/j.injury.2017.11.001
16. J. B. Rosenfeld, Acid-base and electrolyte disturbances in hypothermia. Amer. J. Cardiol. **12**(5), 678–682 (1963). https://doi.org/10.1016/0002-9149(63)90259-5
17. P. Petrone, J.A. Asensio, C.P. Marini, Management of accidental hypothermia and cold injury (in eng). Curr. Prob. Surg. **51**(10), 417–31 (2014). https://doi.org/10.1067/j.cpsurg.2014.07.004
18. B. D. Grooms, D. Straley, Exposure injury: examining heat- and cold-related illnesses and injuries. Osteopath Fam. Phys. **5**(5), 200–207 (2013). https://doi.org/10.1016/j.osfp.2013.04.002
19. A. Golant, R.M. Nord, N. Paksima, M.A. Posner, Cold exposure injuries to the extremities (in eng). J. Amer. Acad. Orthopaed. Surg. **16**(12), 704–15 (2008)
20. T.A. Vale et al., Chronic non-freezing cold injury results in neuropathic pain due to a sensory neuropathy (in eng). Brain J. Neurol. **140**(10), 2557–2569 (2017). https://doi.org/10.1093/brain/awx215
21. K. Mistry, C. Ondhia, N. J. Levell, A review of trench foot: a disease of the past in the present (in eng). Clinic. Exper. Dermatol. (2019). https://doi.org/10.1111/ced.14031
22. R. L. Atenstaedt, Trench foot: the medical response in the first World War 1914–18 (in eng). Wilderness Environ. Med. **17**(4), 282–9 (2006)
23. K.S. Kant, A. Agarwal, T. Suri, N. Gupta, I. Verma, A. Shaharyar, Trench foot: a relatively rare condition in tropical countries—a case report (in eng). Tropic. Doctor **44**(2), 119–21 (2014). https://doi.org/10.1177/0049475514521803
24. A. Hall et al., Frostbite and immersion foot care (in eng). Military Med. **183**(suppl_2), 168–171. https://doi.org/10.1093/milmed/usy085
25. P. Anand, R. Privitera, Y. Yiangou, P. Donatien, R. Birch, P. Misra, Trench foot or non-freezing cold injury as a painful vaso-neuropathy: clinical and skin biopsy assessments (in eng). Front. Neurol. **8**, 514 (2017). https://doi.org/10.3389/fneur.2017.00514
26. C.H. Imray, Non-freezing cold injury (in eng). J. R. Army Med. Corps (2019). https://doi.org/10.1136/jramc-2018-001145
27. M.D. Davis, Immersion foot associated with the overuse of ice, cold water, and fans: a distinctive clinical presentation complicating the syndrome of erythromelalgia (in eng). J. Amer. Acad. Dermatol. **69**(1), 169–71 (Jul 2013). https://doi.org/10.1016/j.jaad.2013.02.021
28. C.H. Imray, P. Richards, J. Greeves, J.W. Castellani, Nonfreezing cold-induced injuries (in eng). J. R. Army Med. Corps **157**(1), 79–84 (Mar 2011)
29. E. Jorum, P.K. Opstad, A 4-year follow-up of non-freezing cold injury with cold allodynia and neuropathy in 26 naval soldiers (in eng). Scand. J. Pain **19**(3), 441–451 (2019). https://doi.org/10.1515/sjpain-2019-0035
30. M.S. Irwin, R. Sanders, C.J. Green, G. Terenghi, Neuropathy in non-freezing cold injury (trench foot) (in eng). J. R. Soc. Med. **90**(8), 433–8 (1997). https://doi.org/10.1177/014107689709000805
31. J. A. Kuht, D. Woods, S. Hollis, Case series of non-freezing cold injury: epidemiology and risk factors (in eng). J. R. Army Med. Corps (2018). https://doi.org/10.1136/jramc-2018-000992
32. J. A. Kuht, D. Woods, S. Hollis, Case series of non-freezing cold injury: the modern clinical syndrome (in eng). J. R. Army Med. Corps (2019). https://doi.org/10.1136/jramc-2018-001099

33. H. Li, L. Zhang, M. Xu, Dexamethasone prevents vascular damage in early-stage non-freezing cold injury of the sciatic nerve (in eng). Neur. Regener. Res. **11**(1), 163–7 (Jan 2016). https://doi.org/10.4103/1673-5374.175064
34. C. Sachs, M. Lehnhardt, A. Daigeler, O. Goertz, The Triaging and Treatment of Cold-Induced Injuries (in eng). Dtsch Arztebl Int **112**(44), 741–747 (2015). https://doi.org/10.3238/arztebl.2015.0741
35. C.M. Eglin, F.S. Golden, M.J. Tipton, Cold sensitivity test for individuals with non-freezing cold injury: the effect of prior exercise (in eng). Extrem Phys. Med. **2**(1), 16. https://doi.org/10.1186/2046-7648-2-16
36. S.L. Khan, R. Parikh, T. Mooncai, S. Sandhu, R. Jawa, H.W. Farber, Barriers to frostbite treatment at an academic medical center. Amer. J. Emer. Med. **37**(8), 1601.e3–1601.e5 (2019). https://doi.org/10.1016/j.ajem.2019.05.012
37. A. Cochran, S. E. Morris, 39—Cold-induced injury: frostbite. Total Burn Care (Fifth Ed.), D. N. Herndon Ed.: Elsevier, 2018, pp. 403-407.e2
38. C. Handford, O. Thomas, C. H. E. Imray, Frostbite. Emer. Med. Clinics North Amer. **35**(2), 281–299 (2017). https://doi.org/10.1016/j.emc.2016.12.006
39. L.M. Jones, R.A. Coffey, M.P. Natwa, J.K. Bailey, The use of intravenous tPA for the treatment of severe frostbite (in eng). Burns **43**(5), 1088–1096 (Aug 2017). https://doi.org/10.1016/j.burns.2017.01.013
40. A. Ghumman, C. Malic, A novel application for Aquacel Ag in paediatric frostbite. Burns Open **3**(1), 36–38 (2019)
41. R.L. Hutchison, Frostbite of the hand (in eng). J. Hand Surg. **39**(9), 1863–8 (2014). https://doi.org/10.1016/j.jhsa.2014.01.035
42. A. K. Lorentzen, L. Penninga, Frostbite—a case series from Arctic Greenland. Wildern. Environ. Med. **29**(3), 392–400 (2018). https://doi.org/10.1016/j.wem.2018.03.001
43. S.E. McIntosh et al., Wilderness medical society practice guidelines for the prevention and treatment of frostbite: 2019 update (in eng). Wildern. Environ Med. (2019). https://doi.org/10.1016/j.wem.2019.05.002
44. L. Laskowski-Jones, L.J. Jones, Frostbite: don't be left out in the cold (in eng). Nursing **48**(2), 26–33 (Feb 2018). https://doi.org/10.1097/01.NURSE.0000529802.75665.d7
45. L. Gordon, P. Paal, Managing accidental hypothermia: progress but still some way to go (in eng). Emer. Med. J. EMJ **35**(11), 657–658 (Nov 2018). https://doi.org/10.1136/emermed-2018-207898
46. P. Paal et al., Accidental hypothermia-an update: the content of this review is endorsed by the international commission for mountain emergency medicine (ICAR MEDCOM) (in eng). Scand. J. Trauma Resuscit. Emerg. Med. **24**(1), 111 (2016). https://doi.org/10.1186/s13049-016-0303-7
47. L.R. Klein et al., Endovascular rewarming in the emergency department for moderate to severe accidental hypothermia (in eng). Am. J. Emerg. Med. **35**(11), 1624–1629 (Nov 2017). https://doi.org/10.1016/j.ajem.2017.05.001
48. S. Mehrotra, A. Misir, Special traumatized populations: accidental hypothermia in children (in eng). Curr. Pediatric Rev. **14**(1), 28–33 (2018). https://doi.org/10.2174/1573396314666180412090930
49. A. Totapally, M. Leoncio, F. Beltramo, K. Meyer, A. Raszynski, B.R. Totapally, Epidemiology and outcomes of children with accidental hypothermia: a propensity-matched study (in eng). J. Trauma Acute Care Surg. **82**(2), 362–367 (2017). https://doi.org/10.1097/ta.0000000000001280
50. K. Zafren, Out-of-hospital evaluation and treatment of accidental hypothermia (in eng). Emerg Med Clin North Am **35**(2), 261–279 (2017). https://doi.org/10.1016/j.emc.2017.01.003
51. E. L. Lloyd, Accidental hypothermia. Resuscitation **32**(2), 111–124 (1996). https://doi.org/10.1016/0300-9572(96)00983-5
52. H. Guly, History of accidental hypothermia (in eng). Resuscitation **82**(1), 122–125 (2011). https://doi.org/10.1016/j.resuscitation.2010.09.465

53. F. Berti, Z. Arif, C. Constantinescu, B. Gran, Hypothermia in multiple sclerosis: beyond the hypothalamus? A case report and review of the literature (in eng). Case Report. Neurol. Med. **2018**, 2768493 (2018). https://doi.org/10.1155/2018/2768493
54. G.J. Jurkovich, Environmental cold-induced injury. Surg. Clinics North Am. **87**(1), 247–267 (2007). https://doi.org/10.1016/j.suc.2006.10.003
55. M.L. Mallet, Pathophysiology of accidental hypothermia. QJM Int. J. Med. **95**(12), 775–785 (2002). https://doi.org/10.1093/qjmed/95.12.775
56. J.L. Tan, M. Saks, J.M. DelCollo, M. Paryavi, S. Visvanathan, C. Geller, Accidental hypothermia cardiac arrest treated successfully with invasive body cavity lavage (in eng). QJM Month. J. Assoc. Phys. (2018). https://doi.org/10.1093/qjmed/hcy075
57. C.J. Madden, S.F. Morrison, Central nervous system circuits that control body temperature (in eng). Neurosci. Lett. **696**, 225–232 (2019). https://doi.org/10.1016/j.neulet.2018.11.027
58. J. W. Castellani, A. J. Young, Human physiological responses to cold exposure: acute responses and acclimatization to prolonged exposure. Auto. Neurosci. **196**, 63–74 (2016). https://doi.org/10.1016/j.autneu.2016.02.009
59. G. Sanchez-Delgado et al., Estimation of non-shivering thermogenesis and cold-induced nutrient oxidation rates: impact of method for data selection and analysis (in eng). Clinical Nutrit. (Edinburgh, Scotland) (2018). https://doi.org/10.1016/j.clnu.2018.09.009
60. Y. Hiroshima, T. Yamamoto, M. Watanabe, Y. Baba, Y. Shinohara, Effects of cold exposure on metabolites in brown adipose tissue of rats. Molecul. Genetics Metabol. Rep. **15**, 36–42 (2018). https://doi.org/10.1016/j.ymgmr.2018.01.005
61. K.L. Marlatt, E. Ravussin, Brown adipose tissue: an update on recent findings (in eng). Curr. Obesity Rep. **6**(4), 389–396 (2017). https://doi.org/10.1007/s13679-017-0283-6
62. X. Lu et al., The early metabolomic response of adipose tissue during acute cold exposure in mice. Sci. Rep. **7**(1), 3455 (2017). https://doi.org/10.1038/s41598-017-03108-x
63. K. Kaikaew, J.C. van den Beukel, S. Neggers, A.P.N. Themmen, J.A. Visser, A. Grefhorst, Sex difference in cold perception and shivering onset upon gradual cold exposure (in eng). J. Therm. Biol. **77**, 137–144 (2018). https://doi.org/10.1016/j.jtherbio.2018.08.016
64. F.M. Acosta et al., Physiological responses to acute cold exposure in young lean men (in eng). PloS One **13**(5), e0196543 (2018). https://doi.org/10.1371/journal.pone.0196543
65. M. Sund-Levander, C. Forsberg, L.K. Wahren, Normal oral, rectal, tympanic and axillary body temperature in adult men and women: a systematic literature review (in eng). Scand. J. Caring Sci. **16**(2), 122–8 (Jun 2002)
66. K. Zafren, Frostbite: prevention and initial management (in eng). High Altitude Med. Biol. **14**(1), 9–12 (Mar 2013). https://doi.org/10.1089/ham.2012.1114
67. T. L. Kanzenbach, W. W. Dexter, Cold injuries. Postgraduate Med. **105**(1), 72–78 (1999). https://doi.org/10.3810/pgm.1999.01.490
68. B.M. Nagpal, R. Sharma, Cold injuries: the chill within (in eng). Med. J. Armed Forces India **60**(2), 165–171 (2004). https://doi.org/10.1016/S0377-1237(04)80111-4
69. H.M. Corneli, Accidental hypothermia (in eng). Pediat. Emer. Care **28**(5), 475–80, quiz 481–2 (2012). https://doi.org/10.1097/PEC.0b013e3182539098
70. T.L. Kiss, Critical care for frostbite (in eng). Critic. Care Nurs Clinics North Am. **24**(4), 581–91 (Dec 2012). https://doi.org/10.1016/j.ccell.2012.07.001
71. A. Stjernbrandt, D. Carlsson, H. Pettersson, I. Liljelind, T. Nilsson, J. Wahlström, Cold sensitivity and associated factors: a nested case–control study performed in Northern Sweden. Int. Arch. Occup. Environ. Health **91**(7), 785–797 (2018)
72. J.R. Fudge, B.L. Bennett, J.P. Simanis, W.O. Roberts, Medical evaluation for exposure extremes: cold (in eng). Wildern. Environ. Med. **26**(4 Suppl), S63-8 (2015). https://doi.org/10.1016/j.wem.2015.09.006
73. I. Harirchi, A. Arvin, J.H. Vash, V. Zafarmand, Frostbite: incidence and predisposing factors in mountaineers (in eng). Br. J. Sports Med. **39**(12), 898–901 (2005). https://doi.org/10.1136/bjsm.2004.016097
74. K. Soreide, Clinical and translational aspects of hypothermia in major trauma patients: from pathophysiology to prevention, prognosis and potential preservation (in eng). Injury **45**(4), 647–54 (2014). https://doi.org/10.1016/j.injury.2012.12.027

75. D. Angert, E.A. Schaff, Preventing injuries and illnesses in the wilderness (in eng). Pedia. Clinics North Am. **57**(3), 683–95 (2010). https://doi.org/10.1016/j.pcl.2010.02.001
76. S.S. Cheung, Responses of the hands and feet to cold exposure (in eng). Temperature (Austin) **2**(1), 105–120 (2015). https://doi.org/10.1080/23328940.2015.1008890
77. C. Imray, A. Grieve, S. Dhillon, Cold damage to the extremities: frostbite and non-freezing cold injuries (in eng). Postgraduate Med. J. **85**(1007), 481–8 (2009). https://doi.org/10.1136/pgmj.2008.068635
78. B.J. Ingram, T.J. Raymond, Recognition and treatment of freezing and nonfreezing cold injuries (in eng). Curr. Sports Med. Rep. **12**(2), 125–30 (2013). https://doi.org/10.1249/JSR.0b013e3182877454
79. A.J. Norheim, T. Alræk, Acupuncture for frostbite sequel—a case report. Eur. J. Integr. Med. **17**, 102–106 (2018). https://doi.org/10.1016/j.eujim.2017.12.003
80. C. Handford et al., Frostbite: a practical approach to hospital management (in eng). Extrem. Physiol. Med. **3**, 7–7 (2014). https://doi.org/10.1186/2046-7648-3-7
81. D. Syme, Position paper: on-site treatment of frostbite for mountaineers (in eng). High Altitude Med. Biol. **3**(3), 297–8 (2002). https://doi.org/10.1089/152702902320604296
82. S.E. McIntosh et al., Wilderness Medical Society practice guidelines for the prevention and treatment of frostbite (in eng). Wilderness Environ. Med. **22**(2), 156–66 (2011). https://doi.org/10.1016/j.wem.2011.03.003
83. E. Cauchy, C.B. Davis, M. Pasquier, E.F. Meyer, P.H. Hackett, A new proposal for management of severe frostbite in the austere environment (in eng). Wilderness Environ. Med. **27**(1), 92–9 (Mar 2016). https://doi.org/10.1016/j.wem.2015.11.014
84. D.J. Brown, H. Brugger, J. Boyd, P. Paal, Accidental hypothermia (in eng). New Eng. J. Med. **367**(20), 1930–8 (2012). https://doi.org/10.1056/NEJMra1114208
85. R.L. McCauley, D.N. Hing, M.C. Robson, J.P. Heggers, Frostbite injuries: a rational approach based on the pathophysiology (in eng). J. Trauma **23**(2), 143–7 (1983)
86. A.N. Fiutko, C.O. Foreman, M. Mycyk, J. Weber, A novel approach to rapid rewarming of a frostbitten extremity: the sous vide method. Am. J. Emerg. Med. (2019)
87. A. Lindford et al., The evolution of the Helsinki frostbite management protocol. Burns **43**(7), 1455–1463 (2017). https://doi.org/10.1016/j.burns.2017.04.016
88. A.S. Goldfarb-Rumyantzev, S.L. Alper, Short-term responses of the kidney to high altitude in mountain climbers (in eng). Nephrol Dialysis Transpl. Official Public. Eur. Dialysis Transpl. Assoc. Eur. Renal Assoc. **29**(3), 497–506 (2014). https://doi.org/10.1093/ndt/gft051
89. B. Haditsch, A. Roessler, P. Krisper, H. Frisch, H.G. Hinghofer-Szalkay, N. Goswami, Volume regulation and renal function at high altitude across gender (in eng). PloS one **10**(3), e0118730 (2015). https://doi.org/10.1371/journal.pone.0118730
90. P. Petrone, E.J. Kuncir, J.A. Asensio, Surgical management and strategies in the treatment of hypothermia and cold injury (in eng). Emerg. Med. Clin. North Am. **21**(4), 1165–78 (2003)
91. P. Tilney, M. Choate, P. Perrault, A 63-year-old man with frostbite (in eng). Air Med. J. **38**(4), 248-250 (2019). https://doi.org/10.1016/j.amj.2019.03.017
92. M.N. Al Yafi, M.A. Danino, A. Izadpanah, E. Coeugniet, Using intra-arterial tPA for severe frostbite cases. An observational comparative retrospective study (in eng). J. Burn Care Res. Off. Public. Am. Burn Assoc. (2019). https://doi.org/10.1093/jbcr/irz118
93. A.J. Norheim, J. Mercer, F. Musial, L. de Weerd, A new treatment for frostbite sequelae; Botulinum toxin (in eng). Int. J. Circumpol Health **76**(1), 1273677 (2017). https://doi.org/10.1080/22423982.2016.1273677
94. A.W. Grieve, P. Davis, S. Dhillon, P. Richards, D. Hillebrandt, C.H. Imray, A clinical review of the management of frostbite (in eng). J. R. Army Med. Corps **157**(1), 73–8 (2011)
95. E. Cauchy, B. Marsigny, G. Allamel, R. Verhellen, E. Chetaille, The value of technetium 99 scintigraphy in the prognosis of amputation in severe frostbite injuries of the extremities: a retrospective study of 92 severe frostbite injuries (in eng). J. Hand Surg. **25**(5), 969–78 (2000)
96. I.M. Ledingham, Some clinical and experimental applications of high pressure oxygen (in eng). Proc. R. Soc. Med. **56**, 999–1002 (1963)

97. O.L. Fisher, R.A. Benson, M.R. Venus, C.H.E. Imray, Pedicled abdominal flaps for enhanced digital salvage after severe frostbite injury (in eng). Wilderness Environ. Med. **30**(1), 59–62 (2019). https://doi.org/10.1016/j.wem.2018.09.003
98. H. Ay, S. Yildiz, G. Uzun, E. Solmazgul, K. Dundar, I. Yildirim, The treatment of deep frostbite with hyperbaric oxygen. Injury Extra **36**(11), 499–502 (2005)
99. D. von Heimburg, E.M. Noah, U.P. Sieckmann, N. Pallua, Hyperbaric oxygen treatment in deep frostbite of both hands in a boy (in eng). Burns **27**(4), 404–8 (2001)
100. N. Beglaibter, Y. Berlatzky, O. Zamir, R.M. Spira, H.R. Freund, Retroperitoneoscopic lumbar sympathectomy. J. Vascul. Surg. **35**(4), 815-817 (2002). https://doi.org/10.1067/mva.2002.121130
101. N. Patel et al., Intra-arterial thrombolysis for extremity frostbite decreases digital amputation rates and hospital length of stay (in eng). Cardiovascul. Intervent. Radiol. **40**(12), 1824–1831 (2017). https://doi.org/10.1007/s00270-017-1729-7
102. M.S. Taylor, Lumbar epidural sympathectomy for frostbite injuries of the feet (in eng). Military Med. **164**(8), 566–7 (1999)
103. E.-K. Woo et al., Proposed treatment protocol for frostbite: a retrospective analysis of 17 cases based on a 3-year single-institution experience (in eng). Arch. Plast. Surg. **40**(5), 510–516 (2013). https://doi.org/10.5999/aps.2013.40.5.510
104. P. Pandey, R. Vadlamudi, R. Pradhan, K.R. Pandey, A. Kumar, P. Hackett, Case report: severe frostbite in extreme altitude climbers-the kathmandu iloprost experience (in eng). Wilderness Environ. Med. **29**(3), 366–374 (2018). https://doi.org/10.1016/j.wem.2018.03.003
105. E. Groechenig, Treatment of frostbite with iloprost (in eng). Lancet (London, England) **344**(8930), 1152–3 (1994). https://doi.org/10.1016/s0140-6736(94)90657-2
106. S. Khan, T. Mooncai, S. Sandhu, R. Jawa, R.A.J. Parikh, H. Farber, "Thawing the system: frostbite treated with epoprostenol. Chest **154**(4)(Supplement), 826A-827A (2018). https://doi.org/10.1016/j.chest.2018.08.748
107. A.A. Abdin, M.A.A. El-Hamid, S.H.A. El-Seoud, M.F.H. Balaha, Effect of pentoxifylline and/or alpha lipoic acid on experimentally induced acute pancreatitis. Eur. J. Pharmacol. **643**(2), 289-296 (2010). https://doi.org/10.1016/j.ejphar.2010.06.020
108. A. Scagnelli, Pentoxifylline. J. Exotic Pet Med. **26**(3) (2017)
109. P.S. Daum, W.D. Bowers Jr., J. Tejada, D. Morehouse, M.P. Hamlet, An evaluation of the ability of the peripheral vasodilator buflomedil to improve vascular patency after acute frostbite (in eng). Cryobiology **26**(1), 85–92 (Feb 1989)
110. R. Kumar, A. K. Singh, A. Gupta, A. Bishayee, A. K. Pandey, Therapeutic potential of aloe vera—a miracle gift of nature. Phytomedicine, 152996 (2019). https://doi.org/10.1016/j.phymed.2019.152996
111. J.P. Heggers, L.G. Phillips, R.L. McCauley, M.C. Robson, Frostbite: experimental and clinical evaluations of treatment. J. Wilderness Med. **1**(1), 27-32 (1990). https://doi.org/10.1580/0953-9859-1.1.27
112. R. L. McCauley, Frostbite. Postgraduate Med. **88**(8), 196-197 (1990). https://doi.org/10.1080/00325481.1990.11704782
113. J. Whitaker, Non-freezing cold injury, lessons from history for future prevention. Trauma **18**(3), 178–185 (2016)
114. D.K. Das, J. Iyengar, R.M. Jones, D. Lu, S. Maity, Protection from nonfreezing cold injury by quinacrine, a phospholipase inhibitor (in eng). Cryobiology **28**(2), 177–84 (Apr 1991)
115. A.M. Ionescu, S. Hutchinson, M. Ahmad, C. Imray, Potential new treatment for non-freezing cold injury: is Iloprost the way forward? (in eng). J. R. Army Med. Corps **163**(5), 361–363 (2017). https://doi.org/10.1136/jramc-2016-000672
116. Z. Olson, N. Kman, Immersion foot: a case report (in eng). J. Emerg. Med. **49**(2), e45-8 (2015). https://doi.org/10.1016/j.jemermed.2015.02.040

117. G. Schrijver, J. van der Maten, Severe accidental hypothermia: pathophysiology and therapeutic options for hospitals without cardiopulmonary bypass equipment. The Netherlands J. Med. **49**(4), 167-176 (1996). https://doi.org/10.1016/0300-2977(96)00027-7
118. R.J. Stine, Accidental hypothermia. J. Am. Coll. Emerg. Phys. **6**(9), 413-416 (1977). https://doi.org/10.1016/S0361-1124(77)80007-5
119. M.G. Hector, Treatment of accidental hypothermia (in eng). Am. Fam. Phys. **45**(2), 785–92 (1992)

Chapter 19
Development of a Methodology for Investigating Thermal Comfort and Quality of Air Inside Indian Railway Pantry Car

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1 Introduction

Indian Railway, operated by the Ministry of Railways manages the 4th largest railway network in the world by size, functions as a vertically integrated organization providing passenger and freight services with a route length of 67,368 km and total track length of 121,407 km as of March 2017. It carries approximately 23 million passengers per day, on both long-distance and suburban routes, from 7,349 stations across India. These trains' running time can reach up to 3.5 days (Longest running train by time & distance the Vivek express covers 4286 km with 80 h 15 min scheduled running time). There are 347 trains of Indian Railway runs with pantry car services as on 31.03.2016. Which include 22 pairs of Rajdhanis, 24 pairs of Shatabdis, 18 pairs of Duranto trains and 283 pairs of mail/express trains [1]. The pantry cars are mainly of two types.

Rajdhani type Pantry cars:

They are attached to a complete vestibule type trains. The pantry car is completely air-conditioned equipped with induction cooking ware.

Conventional type Pantry cars:

These pantry cars have no air conditioning system and are purely designed with ventilating system standalone with LPG as cooking fuel.

Most of the trains having pantry service run by the conventional type pantry as it is more economic than air-conditioned with induction cookware. Cooking inside the less efficient and less effectively ventilated pantry coach a huge amount of heat

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produced and there prevails a high humidity level. Cooking byproducts like particulate matter, organic volatile compounds also change the quality of air inside the pantry, which can cause health problems to the workers and their work performance is also reduced.

But, there are not that much research works or methodology development is done to have an account for the thermal environment and air quality inside the Indian Railway Pantry. The works which are done are like—Evaluation of the overall thermal comfort inside a vehicle [2], Energy conversion for thermal comfort and air quality within car cabin [Daniel Kristanto et al.], Occupational Hazards among Cooks in Commercial Kitchens [3].

2 Aim and Objectives

The aim is to introduce a comprehensive methodology to investigate the thermal environment and indoor air quality inside the pantry in Indian Railway context. This project mainly deals with the impact of these two factors upon the pantry chefs only.

This methodology will help to develop an holistic idea about workplace conditions, occupational health hazards and performance level of the chefs of Indian Railway Pantry.

Results taken from this methodology will help to develop a new design for the pantry car which will be beneficial for the improvement of the thermal environment and the air quality inside pantry and improvement of pantry food supply and workers' health condition as a whole.

3 Methodology and Result

(A) *Methodology for Measurement of Thermal Comfort*

Thermal comfort can be stated as the condition of mind that describes the human satisfactory perception about the thermal environment. It refers to a number of conditions in which the majority of people feel comfortable and their body maintains normal physiological homeostasis.

Three different parameters can be used to have an idea about the thermal comfort of the pantry [4], viz-

1. Heat stress inside the pantry car
2. Performance of the chefs
3. Health condition of the chefs.

1. *Measurement of Thermal Comfort by Heat Stress*

Heat stress is a condition that occurs when the workers have to work in a hot environment or in a area exposed to a temperature zone. Measuring parameters for the heat stress are [5] :

i. Air temperature
ii. Humidity
iii. Radiant temperature
iv. Air velocity
v. Workload
vi. Clothing of the chefs.

- Air temperature

Air temperature is described as the temperature of the air that surrounds a worker. K-type thermocouple can be used to measure the pantry air temperature. As they can deal with extreme temperatures like 454F to 2,300F (–270 to 1260 C) and have the benefits like high accuracy, fast measurement response times, interchangeable probes suitable for every application, dual sensor models to allow comparative readings the K-type thermocouple can be used in the pantry car air temperature measurement.

Measuring the real feel of the air temperature can also be done from the following questionnaire (Table 1).

- Humidity

During cooking heated water evaporates into the air and creates humidity inside the pantry. High humid environment contains a lot of water vapors and this reduces the ability of sweat evaporation which is the main means by which the workers loose heat.

Humidity can be measured by using hygrometer. Besides that the following questionnaire can also help to measure humidity inside pantry (Table 2).

- Radiant Temperature (RT)

It is the average temperature of the objects and surfaces of the pantry car which radiates heat to the workers and absorbs radiant heat from the workers' body.

Table 1 Questionnaire for air temperature assessment

Subjective description of air temperature	Score	Tick
Cool	-1	
Natural	0	
Slightly warm	1	
Warm	2	
Hot	3	
Very hot	4	
Don't know	–	

Table 2 Questionnaire for humidity assessment

Subjective description of Humidity	Score	Tick
Slight humid air is turning into dry with drying processes or other mechanisms No humidity	−1 0	
Slight humidity	1	
Moderate humidity	3	
Air is very humid	5	
Vapor impermeable PPE is worn	6	
Don't know	–	

RT can be measured by using a globe thermometer. From the temperature recorded, along with air velocity and air temperature (to account for convective heat exchange), the mean radiant temperature can be calculated:

RT = globe temperature + 2.42 X air velocity in m/s (globe temperature – air Temperature) [6].

Here also an account for radiant temperature can be taken from the following questionnaire (Table 3).

- Air velocity

Thermal anemometers with velocity/temperature profiling can be used to measure both the temperature and velocity of the wind inside the pantry. If the passing air is cool (that can be from HVAC or air conditioning system or from any other source of fresh air ventilation) then it is beneficial for maintaining the thermal comfort equilibrium of the pantry car. But, if the air is not cooler or warmer than the pantry car environment (as from the gas burners, cooked foods or from many other sources)

Table 3 Questionnaire for radiant temperature assessment

Subjective description of radiant temperature	Score	Tick
Presence of objects colder than the surrounding air near the workers	−1	
No heat sources in the pantry environment	0	
Heat source is present but the workers are not in close proximity to it, Presence of a heat source surface which is warm to touch but there is no risk of burning	1	
Heat source near the worker	2	
Workers can not work in close proximity to the heat source for more than 10 min without wearing any protection or, heat source surface may burn the skin	4	
Workers cannot work in close proximity to the heat source for more than 5 min without wearing PPE & burning of skin occurs	5	
Workers are not permitted to work in the environment without PPE	6	
Don't know	–	

Table 4 Questionnaire for air velocity assessment

Subjective description of air velocity	Score	Tick
Cold air at a high speed	−3	
Cold air at a moderate speed	−2	
Cold air and low air speed	−1	
Still air in a neutral environment	0	
Warm air at low air speed Still air in a warm environment	2	
Still air in a hot environment Warm air at a moderate air speed	4	
Still air in a very hot environment Hot air and moderate air speed	5	
Very hot air at a high speed	6	
Don't know	–	

it can add heat stress inside the pantry car. For help, four categories of air velocities are provided:

1. Still air where there is no noticeable flow of air.
2. Low airspeed is when you can just feel air movement on exposed flesh.
3. Moderate airspeed is when you can feel air movement (e.g. a light breeze) on exposed flesh.
4. High airspeed, may be similar to the airspeed on a windy day, or at or near fans or other machines or equipment that generate air movement.

A questionnaire can be made to develop an idea of air velocity inside the pantry as the following (Table 4).

- Workload

It is obvious that humans can take more workload when the working environment is comfortable for their health. So if the pantry car is in thermal comfort zone then workload for the same work can vary. So measuring score of workload one can have an idea about the thermal comfort.

Workload can be measured by measuring the workers' BMR. As BMR is directly dependent to the work load andthermal environment [7].

By observing the chef's movements, posture, speed, effort, weight of cooking equipments they handle, parts of their bodies responsible for their movement, etc. workload can be categorized as:

Resting (When worker is resting as part of a work-rest schedule or is awaiting for instructions, etc.)
Low (Like vegetable cutting, preparing raw materials for cooking, etc.)
Moderate (Like works of helper of the main chef, cleaning the kitchen, etc.)
High (Making huge amount of food for long time.)
Very high (When the same person has to do all the above stated works.)

Table 5 Questionnaire for work load assessment

Subjective descriptions of work load	Score	Tick
Resting	−2	
Low	0	
Moderate	2	
High	4	
Very high	6	
Don't know	–	

Table 6 Questionnaire for clothing of the workers assessment

Subjective descriptions of clothing	Score	Tick
Light loose fit cotton clothes	0	
Cotton apron with a toque and gloves	1	
Double cloth coveralls, light weight vapor barrier suits	3	
Fully enclosed suit with hood and gloves	5	
Don't know	-	

The chefs can be asked to tick the category which they actually feel while working by the following (Table 5).

- Clothing of the workers

Clothing interferes with our ability to lose heat to the environment. It is important to identify whether the clothing of the workers may contribute to the risk of heat stress.

We can select the best fitted clothing type of the pantry workers from the given below chart (Table 6).

- Risk assessment chart

From the responses of the above listed questionnaire assessment of the thermal environmental condition of the pantry car can be done by the following:

- Where workers chooses the score for the parameters are in between −3 and −1 it means that there is a very little chance of heat stress i.e. the pantry environment is in thermal comfort zone.
- In case of 0, we can say that the environment is in natural condition.
- Where the score is higher than 1 the greater is the heat stress risk.
- Where the workers mark 2 or 3 it means we have to give special attention to make improvement of the thermal air condition.
- Where the worker chooses 5 or 6 it means the pantry car is in very high risky state for the chefs.

No risk Natural envio. Increasing rate of risk→ (Table 7).

Table 7 Risk assessment chart

	SCORES									
	-3	-2	-1	0	1	2	3	4	5	6
Air temperature										
Radiant heat										
Air velocity										
Humidity										
Work load										
Clothing										

2. *Measurement of Thermal Comfort by PERFORMANCE of the Chefs*

Performance of the chefs can be an important parameter for knowing if the pantry car environment is within thermal comfort zone or not. It is quite obvious that productivity will increase if the chefs works in thermal comfort zone as people who are satisfied with their work setting have been proven to be healthier and to work more effectively [6, 8].

By the following methods the productivity or better to say performance of chefs can be measured.

- Performance analysis by the Covers per Labour Hour
- Performance analysis by the Labour Hours per Cover

(i) Covers per Labour Hour

Covers per Labor Hour is calculated by dividing total covers (food served to the passengers as per their order) by total labor hours. From the result, the number of meal served by each of the chefs in their total working time will help to found a holistic idea about productivity of the chefs. **formula: total covers/total labor hours**.

(ii) Labor Hours per Cover

This is calculated by dividing labor hours by one cover. By this method, we will be able to know how much time is needed for a chef to make one cover.

formula: total labor hours/one cover.

Taking results from these two methods, a constrain like maintaining labor salary per total covers and labor salary by the total labor hours have to be kept same as before to avoid any influence to the chefs for making more covers to get higher salary against their thermal comfort limit.

The workers can also be asked how they feel to do work inside the pantry car and how is their feeling to meet up the covers as per passenger's order like the following Table 8:

From their answer it can be verified that how much the

perception about their work differs from the perception that a chef normally percepts while working inside a comfortable thermal environment.

Table 8 Questionnaire for the feeling of the pantry workers to do work inside the pantry car

Answer options	Job satisfaction	Joy with work	Motivation to work	Work load
Very positive				
Positive				
Satisfactory				
Negative				
Very negative				
Don't know				

3. *Measurement of Thermal Comfort by HEALTH CONDITION of the Chefs*

When a person works in a hot environment, the human body gets rid of excess heat to maintain a stable internal (core) temperature. It is done mainly through circulating blood to the skin and through sweating.

When the air temperature gets close to or warmer than normal body temperature, cooling of the body becomes difficult because blood circulated to the skin cannot lose its heat from the skin by radiation, conduction and convection. Sweating (evaporation) then becomes the main way for the body to cool off. But sweating is effective only if the humidity level is low enough to allow evaporation, and if the fluids and salts that are lost are adequately replaced [9].

So, inside pantry car because of heat and humidity, if the chefs cannot get rid of excess heat, it starts to be stored in the body. When this happens, the body's core temperature rises and the heart rate, blood pressure, BMR increases. As the body continues to store heat, the person begins to lose concentration and has difficulty to focusing on a task, may become irritable or sick, and often loses the desire to drink. The next stage is most often fainting and even death if the worker is not cooled down [3].

Excessive exposure to heat can cause a range of heat-related illnesses from heat rash, heat cramps to heat exhaustion, heat stroke.

Exposure to heat can also increase the risk of injuries to chefs because of **sweaty palms, dizziness, and burns from hot surfaces or steam** [10].

Here some symptoms are being provided which appears when the thermal discomfort reaches to a certain level:

- Cool, moist skin with piloerection even inside the hot environment.
- Profuse sweating, rapid pulse, Fatigue.
- Headache, Thirst, Nausea, vomiting or diarrhea.
- Light headedness, weakness, fainting or dizziness (Heat syncope).
- Low blood pressure upon standing.
- Fast heart beat or tachycardia.
- Dark-colored urine (as a sign of dehydration).
- Increased body both core and shell temperature (Hyperthermia).

These symptoms can be a sign of ***Heat Exhaustion***.

- Muscle spasms that is painful, involuntary, usually self-limited with a brief time period.
- Pain in the muscle which are exposed directly to the heat and which is being used for cooking.
- Cramps in abdomen, arms, or legs.

These symptoms can be a sign of ***Heat Cramps***.

- Appearance of Clusters of pimple-like red bumps on skin develops underneath clothing that has become soaked with sweat.
- Prickly or itchy feeling to the skin.

These symptoms can be a sign of ***Heat Rashes***.

- Swelling of feet, arm and other extremities because the veins expand to cool the body by increasing blood circulation.

These symptoms can be a sign of **Heat Edema**.

By asking the chefs if they feel any of the symptoms above an idea can be developed about their health condition. This survey can also help to build up an idea about the risk level of the thermal environment inside the pantry car [11].

(B) **Methodology for Measurement of Indoor air quality of the Pantry Car**

In the conventional type pantry car LPG is used as cooking fuel. The cook stoves using LPG releases CO, NO2, SO2 ,SPM (Suspended Particulate Matter), VOC (Volatile Organic Compounds) in the indoor environment of the pantry car. Burning of cooking oil, food stuffs and even water vapors produced by cooking gives an account to indoor air pollution in absence of proper ventilation inside the pantry.

Particulate matter (PM) is a widespread air pollutant, consisting of a mixture of solid and liquid particles suspended in the air.

PM Increases the lower respiratory symptoms like cough, phlegm, chest pain on deep inhalation, and wheezing. This may suggest the presence of asthma, an allergic reaction, or an infection in lungs, trachea or bronchi. PM can also cause chronic obstructive pulmonary disease and reduced lung function in the human [12].

VOC (Volatile Organic Compounds) can be generated as a result of cooking inside pantry car. The VOCs can cause serious health effects in both the short and long term. Short-term effects of VOC include—headache, nose throat eye inflammation, coughing, painful breathing, pneumonia, bronchitis, skin irritation, etc. Long-term VOC exposure causes adverse effect on CNS, cardiovascular disorder, respiratory disorder like asthma and cancer also, adverse impact on liver spleen blood and can also cause reproductive system problems.

So, it is important to check out the level of the PM and VOC in the pantry and detection of the kind of PM and VOC to take further action for reducing the PM and VOC level [13].

We can use **6 In 1 Air Quality Monitor With PM 2.5 & PM 10** (Aqpm 801) for detecting PM in pantry as it has specifications like: PM2.5 , PM10 detection, formaldehyde TVOC detection, can measure temp. range of -15c to 50c, humidity range of 15 to 90% HR and as it is user friendly and reasonable in price.

By checking lung and respiratory functions it can possible to check out if the workers are having any lung or respiration related problems as a result of working inside the pantry car where high level of PM or VOC causes these problems or not. This health checkups may include –

Lung function tests like **Computerized Spirometry** to know if the chefs having COPD or asthma or if they are having chances to develop this kind of illness. Spirometry measures how much air a person can breathe in and out of the lungs, as well as how easily and fast the person can blow the air out of his lungs [American Lung Association].

Peak flow meter (a portable, easy-to-use device) test to know how well the workers' lungs are able to expel air. By blowing hard through a mouthpiece on one end, the peak flow meter can measure the force of air in liters per minute. If peak flow rate is less than 75–80 percent it indicates some lung or respiratory problems which are can be for worse air quality inside pantry car [14].

The following questionnaire can also be prepared to have an account about the pantry car air quality:

- How would they rate the indoor air quality of the pantry?
  - Good - Average - Poor.
- If they feel that there is an indoor air quality problem, when they feel the problem most?
  - During cooking time - 1–2 h after cooking - More than 2 h after cooking.
- Since they have worked in the pantry, have they ever been diagnosed with?
  - Allergic Rhinitis - Emphysema - Asthma, - Laryngitis - Allergies - Bronchitis - Conjunctivitis -Other chest conditions - Sinusitis - None
- During the last year while working in pantry, if they experience any of the following?
  - Frequent cough - Nasal congestion - Wheezing (except colds) - Sinus infections - Multiple colds - Sore throat - Shortness of breath Hoarse voice - Migraines Headaches (at least 2/month) - Burning or irritated eyes - Sneezing attacks - None of the above.
- The symptoms which the chefs feel go away by which of the following?
  - 1 h after leaving the pantry - Goes away by the next morning - Goes away when they take a short time leave (2 to 5 days) - Goes away when they take a long time leave (more than 7 days) - Not goes without medicine.

From these questionnaire and the instrumental results, an idea about the air quality inside pantry car can be developed.

4 Discussion

All the above-mentioned methodologies for investigatigating thermal comfort and indoor air quality inside Indian Railway Pantry Car have to be done in different seasonal and environmental conditions as results can vary according to different seasons and weather conditions.

- The different climate for data collection for thermal comfort should include:

  i. Summertime when there is scorching heat of sun
  ii. Summertime when the sunlight is not that much scorching
  iii. Wintertime when the environment is very cold and dry
  iv. Rainy season
  v. Both Dry and Humid weather
  vi. A day with high air velocity and a day with almost no noticeable airflow.

- For each type of the climatic conditions data should be collected for different times like:

  i. In the morning before starting of any work (cooking).
  ii. When food for breakfast, lunch, evening snacks and dinner is being prepared in morning, noon, evening and night simultaneously.
  iii. Gap time between the 4-time cooking schedule when no cooking is being performed.

- The different conditions for data collection for indoor air quality should include:

  i. the morning before starting of cooking
  ii. During the time of cooking
  iii. 1–2 h after cooking.

- For both the thermal comfort and air quality investigation methodology, the data should be collected from the chefs who satisfies the following conditions like:

  i. The chef should be a healthy adult male.
  ii. Should have work experience in pantry car for at least 2 years as this time is required to adapt their body for working inside a moving kitchen.

5 Conclusion

This comprehensive methodology will help to put up a complete idea about the thermal environment and indoor air quality inside Indian Railway Pantry Car. If the data collected from the methodologies differ significantly from the normal range of thermal comfort and air quality, a new design of ventilation system for Indian Railway Pantry Car can be introduced to maintain a soothing thermal and air quality environment inside pantry which will not cause any interruption to the worker's health and their performance to give supply of covers as per passenger demand.

The better designed ventilation system with a modified kitchen hood, exhaust fan, exhaust duct, make up air system, air conditioning system (HVAC), airflow control system, thermal temperature indicator and control system can have the power to expel out the excess heat and air polluting particles from the pantry to the outside environment and to bring out fresh air from outside or from the makeup air chamber and to cool down the temperature of the air to maintain thermal comfort in the pantry.

So, the data collected from this comprehensive methodology can be the basis of introducing a ergonomically designed more efficient and more effective and economic ventilation system for Indian Railway Pantry Car to provide a comfortable workplace to the chefs to meet up the huge need of quality food supply to the rail passengers.

References

1. Standing committee on railways (2017–18) (sixteenth lok sabha). Ministry of railways (railway board) twenty first report. New railway catering policy 2017
2. C. Neacsu1, I. Tabacu, M. Ivanescu, I. Vieru, The evaluation of the overall thermal comfort inside a vehicle. In: IOP Conference Series: Materials Science and Engineering, Vol. 252, Conference 1
3. E. Shirin Hima Bindu1, M.V. Reddy, Occupational hazards among cooks in commercial kitchens **5**(6) (2016)
4. HSE [http://www.hse.gov.uk/temperature/heatstress/measuring.htm].
5. Screening for heat stress in workers and athletes by Lilly Ramphal-Naley. Proc. (Bayl Univ Med Cent) **25**(3): 224–228 (2012)
6. R.K. Macpherson, Thermal stress and thermal comfort. School of Public Health and, Tropical Medicine, University of Sydney, N.S.W, Australia
7. R. Murat Hancer, T. George, Job satisfaction of restaurant employees: an empirical investigation using the minnesota satisfaction questionnaire. J. Hospital. Tour. Res. **27**(1), 85–100 (2003)
8. A.A. Shikdarnaseem, M. Sawaqed, Worker productivity, and occupational health and safety issues in selected industries. Comput. Indus. Eng. **45**(4) (2003)
9. M. Frontczak, P. Wargocki, Literature survey on how different factors influence human comfort in indoor environments. Build. Environ. **46**, 922–937 (2011)
10. OSHA [https://www.osha.gov/SLTC/heatstress/heat_illnesses.html]
11. Heat-Related Illnesses and Heat waves | National Health Portal Of India. [Nhp.gov.in/disease/non-communicable-disease/heat-related-illnesses-and-heat-waves]
12. S. Svedahl, K. Svendsen, T. Qvenild, A.K. Sjaastad, B. Hilt, Short term exposure to cooking fumes and pulmonary function. J. Occup. Med. Toxicol. **4**(9) (2009)
13. J. Ross, A. Seaton, W. Morgan, Toxic gases and fumes. Occupational lung diseases (3rd ed., WB Saunders Company, pp. 568–596, 1995)

14. Common pollutants from household heating, cooking and lighting - WHO
15. Lung function tests and [https://www.lung.org/lung-health-and-diseases/lung-procedures-and-tests/lung-function-tests.html]

Chapter 20
Experimental Investigation for Single Cylinder Engine Fueled with Mustard Oil Biodiesel

Sarthak Baweja, Ajay Trehan, and Pramod Kumar

1 Introduction

In today's era energy demand of the world is being largely met through non-renewable sources.

Heavy reliance on these sources can trigger severe energy crises, such as rapid depletion and increasing levels of pollution.

Globally, the transport industry depends on non-renewable sources such as liquid fossil fuels such as petrol and diesel. Hence it is required to find the substitute for this problem by alternative fuels.

Biofuels promise a ray of hope as an alternative, as they have virtually no sulphur and aromatic content and therefore no SO2 and polycyclic aromatic hydrocarbon (PAH) emissions (Demirbas 2007; Trewella et al. 2015).

Biofuels are therefore carbon neutral since the amount of carbon dioxide produced by their combustion during their growth is the same as that consumed by plants (Sorate and Bhale 2014).

Taking into account the advantages of the use of biofuels and reducing reliance on fossil fuels, it has been mandatory for the US and EU to use blends of biofuels with fossil fuels (Jank et al. 2007). Asian countries such as India and China have also taken a move forward to make use of 10–15% biodiesel blending by 2020.

Since biodiesel is made from vegetable oils, the availability of vegetable oil is the leading source of biodiesel production in a specific area. The feedstock for producing biodiesel is therefore country specific, such as the use of rapeseed and sunflower oil in European countries (Labecki et al. 2012), the use of soybean and animal fats in the US (Srivastava and Prasad 2000) as a source of biodiesel. Improving biodiesel production through these traditional feedstocks is not feasible, as it can lead to a global food crisis (Patel and Shah 2015). A nation like India is also deficient in edible

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oils. There is a need, therefore to thoroughly examine all the options available. The leading non-edible sources listed in literature as an alternative fuel for diesel engines are Jatropha (Chauhan et al. 2010) and karanja (Mamualiya and Lal 2015).

Azadirachta indica or Neem (Dhar et al. 2012), yellow oleander (Adebowale et al. 2012), luffa cylindrical (Oniya and Bamgboye 2014) and Argemone Mexicana (Kumar and Sharma 2011) are the other possible unconventional non-edible sources available.

It is also mentioned that in a CI engine, various biodiesel feedstocks behave differently as they have different profiles of free fatty acids (Mustafa and Havva 2008; Rakopoulos et al. 2008).

The engine's operating conditions also have a major impact on its efficiency (Anet al. 2012; Qi et al. 2009). It was found that most of the previous studies were performed on engines at constant speed. Agarwal and Rajamanoharan (2009) conducted experiments on single cylinder constant speed CI engines and found that up to 50% (v/v) of the Karanja oil blends with diesel would substitute diesel to run the CI engine for enhanced efficiency. The increase in brake thermal efficiency of a single cylinder constant speed engine fueled with Neem oil biodiesel was also noticed by Dhar et al. (2012).

Different studies are dedicated to studying the impact of biodiesel on engine efficiency on a multi-cylinder variable speed engine.

Avinash et al. (2012) conducted a series of experiments with transesterified waste cooking oil on the multi-cylinder DI engine.

Biodiesel and its blends show improvement in engine efficiency at full load, they said.

In a multi-cylinder CRDI variable speed engine, Tesfa et al. (2013) tested waste oil, rapeseed oil and corn oil and found higher peak engine cylinder pressure running with biodiesel blends. The key explanation given for the higher in cylinder pressure is that the higher lubrication effect of biodiesel and its other related physical properties, such as viscosity, density and bulk modulus, are initiated by the advanced combustion process.

The present work uses Mustard oil as a source for biodiesel as it is considered as non-edible in many countries like the US due to high amount of erucic acid. Also for experiment purpose the above oil is chosen so as to get the proper insight of combustion and performance parameters. The detailed methodology is discussed in Sect. 2.

2 Materials and Method

Transesterification reactor of 5 L per batch was used to prepare the mustard oil methyl ester. One litre mustard oil is fed to transesterification reactor along with 260 ml methanol and 0.68 gm KOH. The mixture was stirred and heated to 60–65 °C and left for 1 h to continue the transesterification reaction. After the completion of reaction, the mixture of mustard oil methyl ester and glycerol was taken out from

Table 1 Engine specifications

Make	Kirloskar
Model	TV1
Type	Four Stroke, Water Cooled, Diesel Engine
Number of cylinder	Single cylinder
Bore and stroke	870.5 mm × 110 mm
Compression ratio	17.5:1
Cubic capacity	661 cc
Rated power	5.2 kW @ 1500 rpm
Orifice diameter	20 mm
Inlet valve opens	4.5° before TDC
Inlet valve closes	35.5° after BDC
Exhaust valve opens	35.5° before BDC
Exhaust valve closes	4.5° after TDC
Fuel injection starts	23° before TDC
Eddy current dynamometer	Model AG10, of Saj Test Plant Pvt. Ltd
Drum brake diameter	185 mm
Temperature sensor	Make Radix Type
Piezo-sensor	Range 5000 psi, Diaphragm stainless steel type & hermetic Sealed

transesterification reactor tank to a separating funnel where two layers got separated. It is kept in separating funnel for 24 h. Next day glycerol is separated and then the top layer (methyl ester) was then washed with the distilled water at 45–50 °C. To remove the moisture completely, the methyl ester was taken out in a big beaker and heated on a heater to 100 °C. It is to be noted that total biodiesel production depends on methanol used, base catalyst quantity, reaction time, reaction temperature and stirrer speed. After the preparation of biodiesel, the next task is to make blend by mixing 20% biodiesel in 80% diesel i.e. B20. Now the two samples (diesel and B20) are ready for the experiment on engine and the specifications are given in Table 1.

3 Experimental Setup

The performance and combustion characteristics of the fuel were studied in a Kirloskar single cylinder engine, coupled with an eddy current dynamometer. This is water cooled, four stroke, and single cylinder diesel engine. The eddy current dynamometer is equipped with a dynamometer controller capable of loading the engine at desired speed/load combination (Fig. 1). The detailed specifications were given in Table 1.

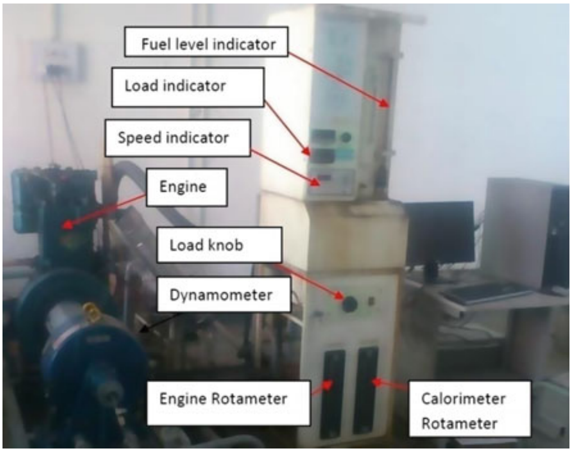

Fig. 1 Experimental test rig

4 Experimental Results

The details of various fuel properties which are tested for B20 blend and compared with diesel are mentioned in Table 2.

All the combustion parameters and performance parameters are discussed in detail with their graphs and the results are justified with diesel at different loads and constant engine speed of 1500 r.p.m.

4.1 Combustion Characteristics

4.1.1 Cylinder Pressure

Peak pressure is decided by amount of fuel taking part in the uncontrolled phase of combustion, which depends on delay period and spray envelope of the injectd fuel [3]. It is measure of the amount of fuel accumulated during the delay period that takes part in the premixed combustion phase. The higher bulk modulus and cetane number

Table 2 Fuel properties

Sr.no	Properties	Diesel	Mustard biodiesel(MB-20)
1	Density (kg/m3)	821	830.9
2	Viscosity (at 40 °C in mm^2/s)	3.66	4.10
3	Flash point(°C)	72.5	80.5
4	Cloud point (°)	−8	+ 8
5	Pour point(°)	−6	−3
6	Calorific value(MJ/kg)	45.30	43.80

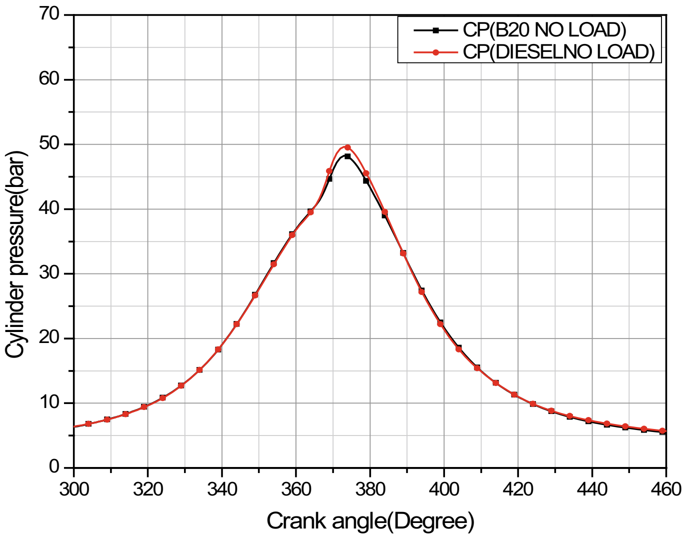

Fig. 2 Cylinder pressure versus crank angle at No load

of the biodiesel advance the position of cylinder peak pressure as compared to diesel, this shift is due to advancement of injection due to higher density and consequently earlier combustion due to shorter ignition delay period caused by higher density and bulk modulus and cetane number [3]. But at 75% load and 100% load conditions for MB20, the cylinder peak pressure was higher as compared to diesel because at high loading condition MB20 have 7% to 8.1% more oxygen content as compared to diesel [5]. The higher bulk modulus and cetane number of the biodiesel advance the position of cylinder peak pressure as compared to diesel, this shift is due to advancement of injection due to higher density and consequently earlier combustion due to shorter ignition delay period caused by higher density and bulk modulus and cetane number [6]. As load is increased, the amount of fuel injected is also increased with the result that at higher temperature in engine cylinder and because of higher fuel bound oxygen, the combustion is relatively quite better. Peak cylinder pressure is increasing with load and these phenomena is clearly visible from Figs. 2, 3, 4, 5 and 6.

4.1.2 Rate of Pressure Rise

The rate of pressure rise is first derivative of cylinder pressure and it relates to the smoothness of engine operation. The variation of rate of pressure rise with crank angle for different fuels and different loads is shown in Figs. 7, 8, 9, 10 and 11. Rate of pressure rise for biodiesel blend is less than that of diesel at lower loads but it increases with increase in load and approaches that of diesel and this is due to better combustion of biodiesel at higher load. If the rate of pressure rise is less than 8 bar/CA then it indicates normal combustion and if more than 8 bar/CA then

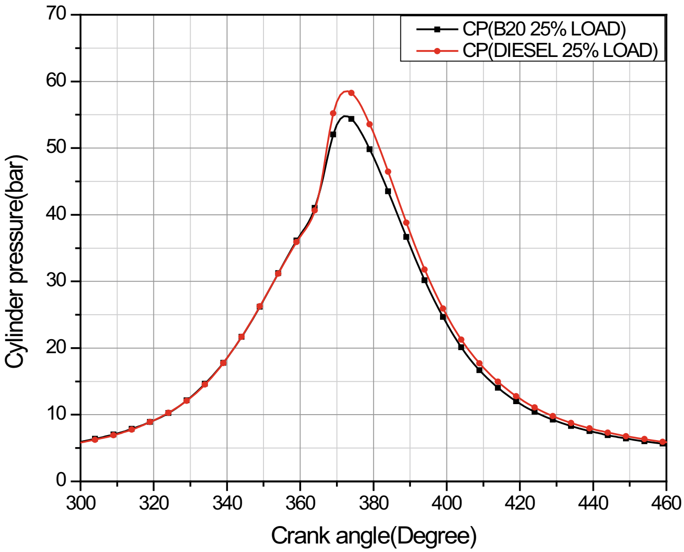

Fig. 3 Cylinder pressure versus crank angle at 25% load

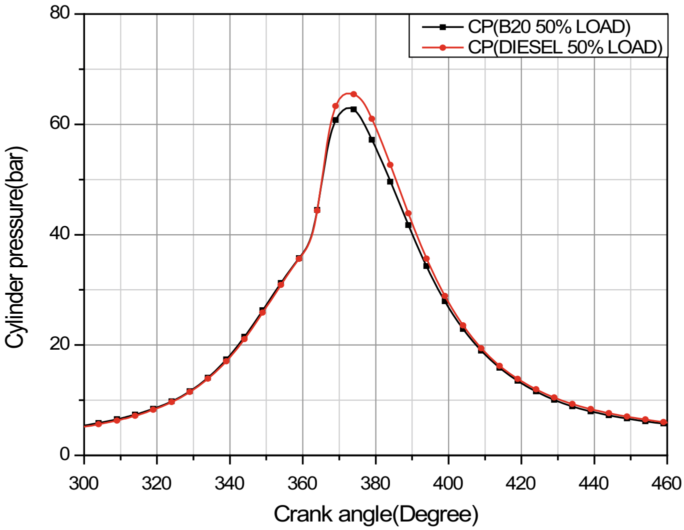

Fig. 4 Cylinder pressure versus crank angle at 50% load

it is abnormal combustion. It was found that rate of pressure rise for the biodiesel blend is less than 8 bar/crank angle [7] which means it is safe to run the engine with mustard oil biodiesel without knocking and vibration.

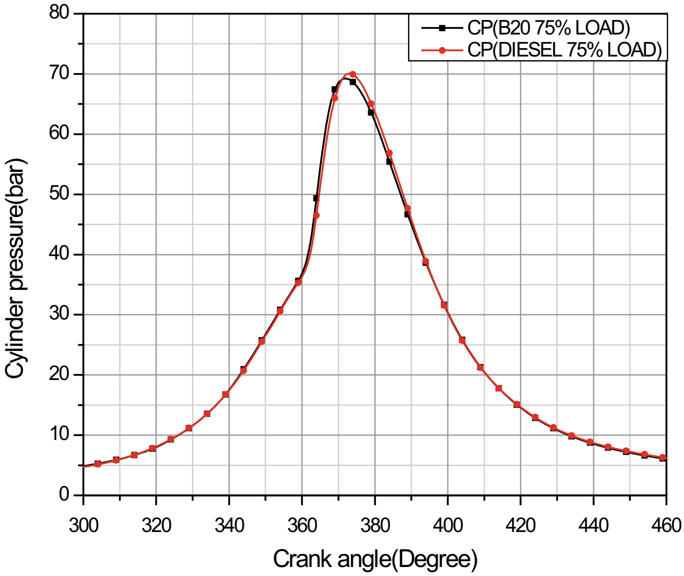

Fig. 5 Cylinder pressure versus crank angle at 75% load

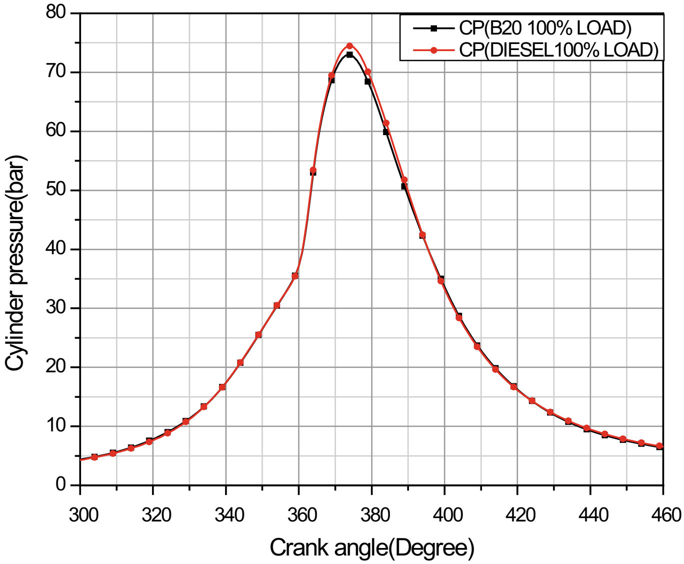

Fig. 6 Cylinder pressure versus crank angle at 100% load

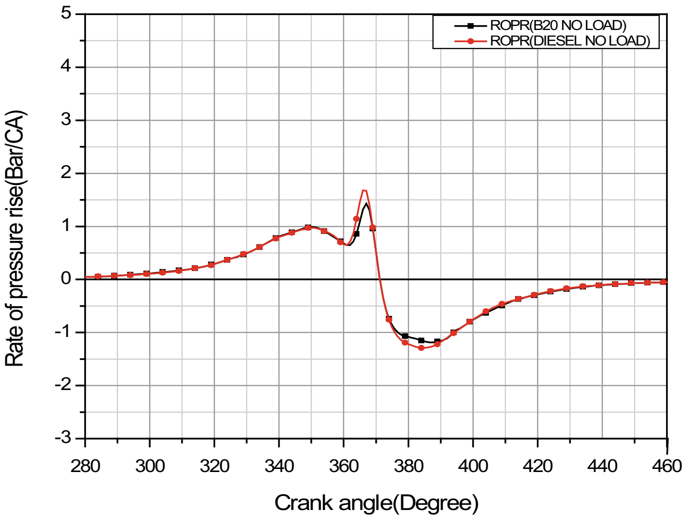

Fig. 7 Rate of pressure rise versus crank angle at No load

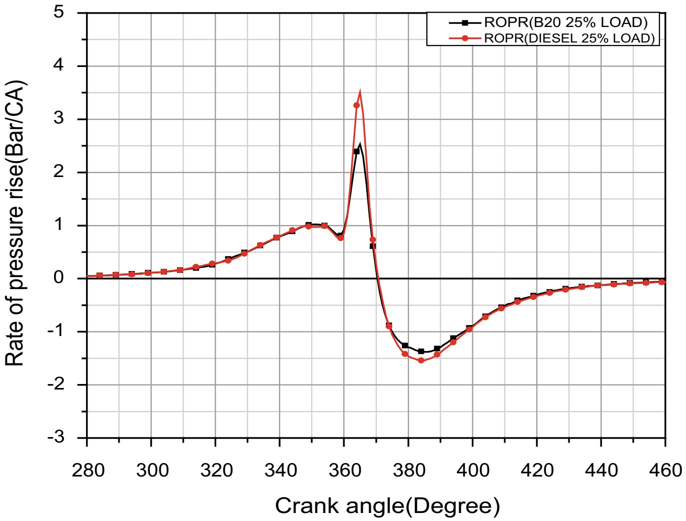

Fig. 8 Rate of pressure rise versus crank angle at 25% load

4.1.3 *Net Heat Release Rate* Versus *Crank Angle*

The variation of heat release rate with crank angle for different fuels and at different loads is shown in Figs. 12, 13, 14, 15 and 16. It was observed that at No load and 25% load condition diesel has higher heat release rate as compared to blends

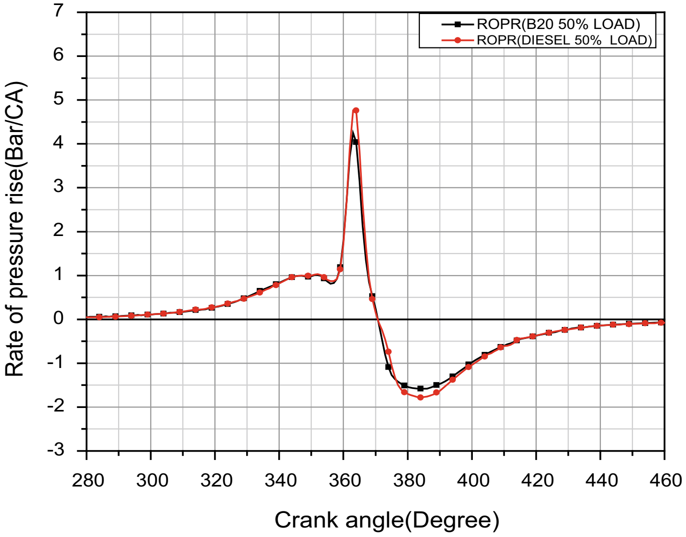

Fig. 9 Rate of pressure rise versus crank angle at 50% load

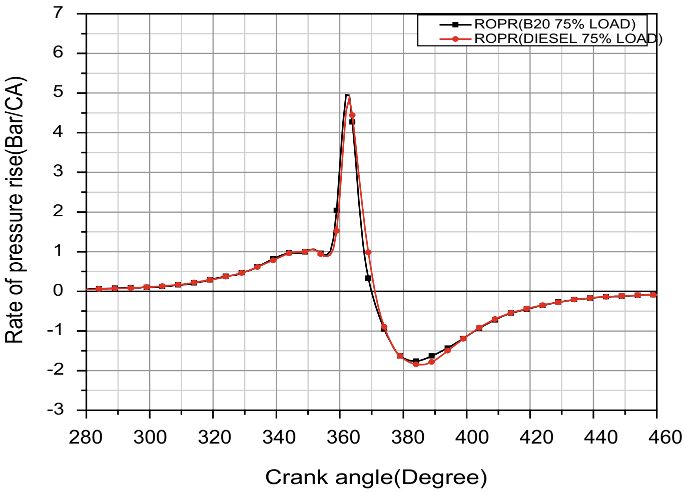

Fig. 10 Rate of pressure rise versus crank angle at 75% load

of biodiesel with diesel because diesel has more calorific value and high ignition period compared to biodiesel and its blends. As load increased heat release rate also increased. At 50%, 75% and full load condition biodiesel blends have higher heat release rate compared to diesel because at higher loading conditions, more amount of blended fuel is injected and also at higher loads, the incylinder temperature is higher due to which biodiesel burns better despite its lower calorific value to diesel. With

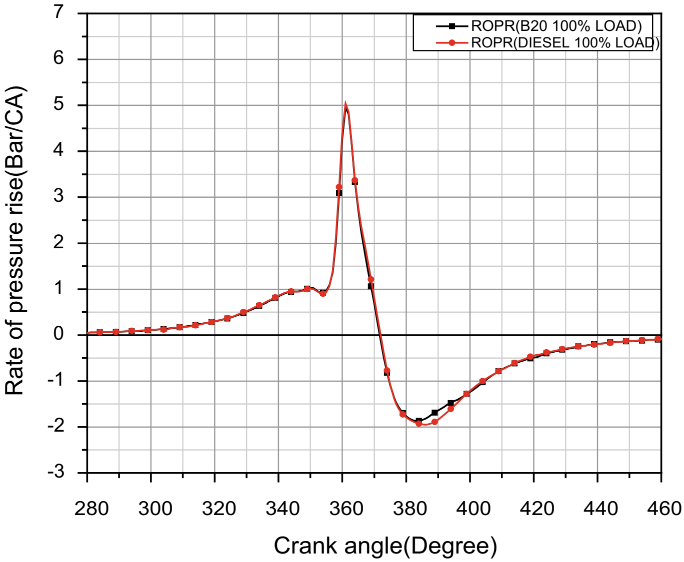

Fig. 11 Rate of pressure rise versus crank angle at 100% load

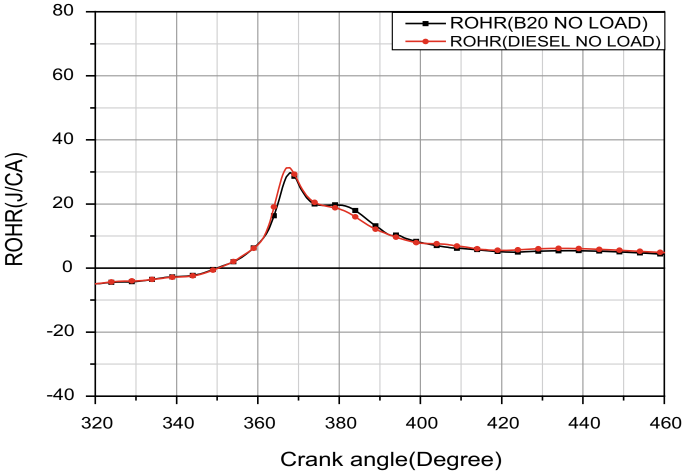

Fig. 12 Net Heat release rate versus crank angle at No load

the increase in the load, two peaks of energy release were found and second peak was of lower magnitude, which indicates that at lower load, premixed combustion phase is more dominant and while at higher loads the diffusion phase of combustion also becomes prominent.

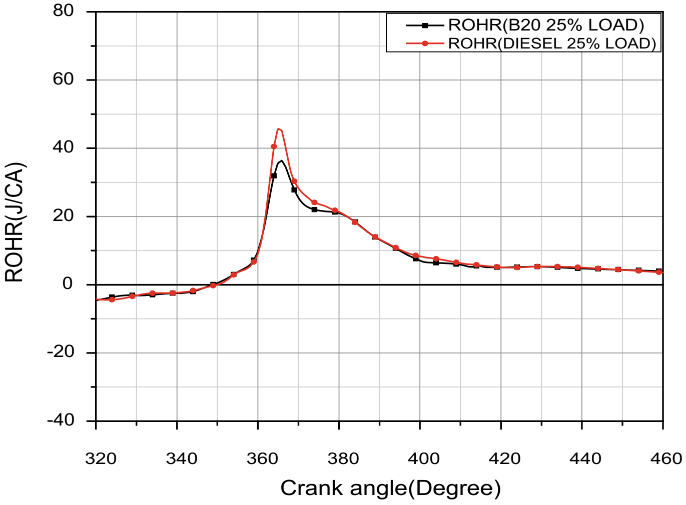

Fig. 13 Net Heat release rate versus crank angle at 25% load

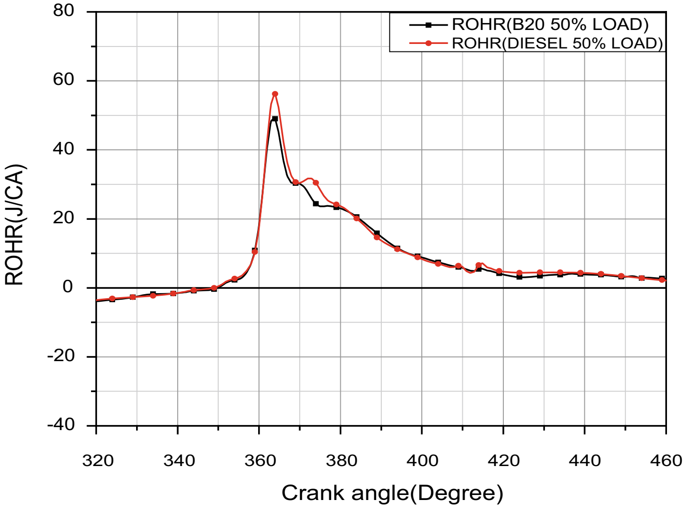

Fig. 14 Net Heat release rate versus crank angle at 50% load

4.1.4 Cumulative Heat Release Rate Versus Crank Angle

Cumulative heat release (CHR) is a result of inefficiency of conversion of thermal energy into useful work during power stroke and also indicates the tendency of delayed heat release from the fuel. In other words, CHR is the residual heat energy during combustion stroke. Therefore, higher values of CHR mean higher heat energy

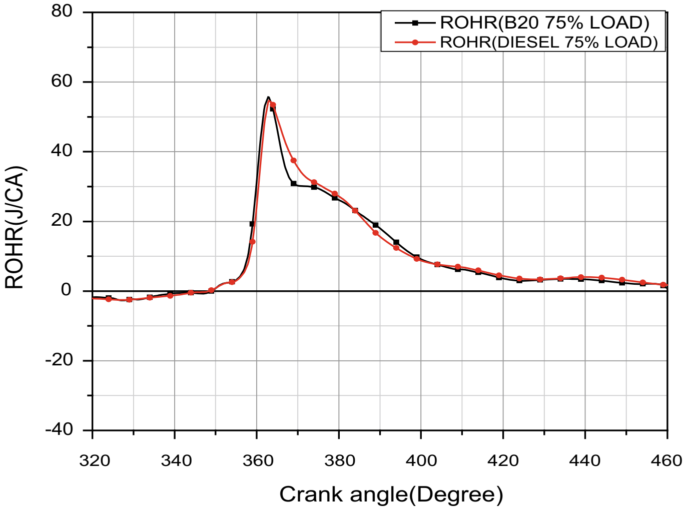

Fig. 15 Net Heat release rate versus crank angle at 75% load

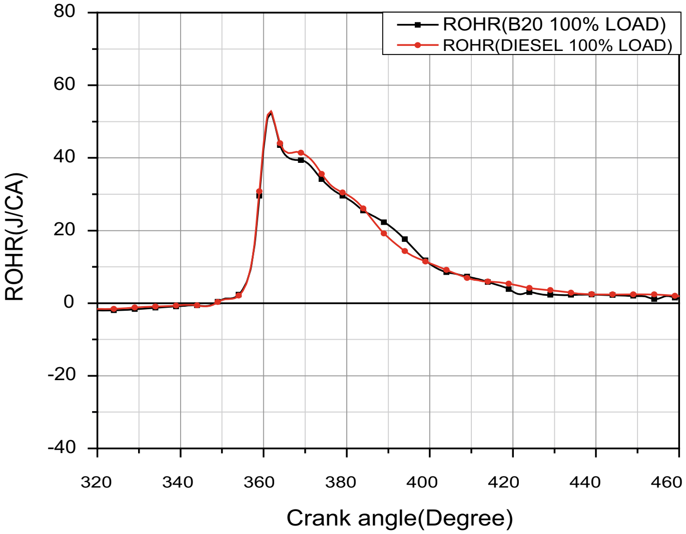

Fig. 16 Net Heat release rate versus crank angle at 100% load

loss and vice-versa. It can be noticed that CHR curve for B20 fuel blend showed the earlier fall and at all load conditions till the end of combustion stroke (Figs. 17 and 18).

Hence, there is maximum conversion of thermal energy into useful mechanical work by the engine. That is why B20 blend showed higher BTE and lower BSFC

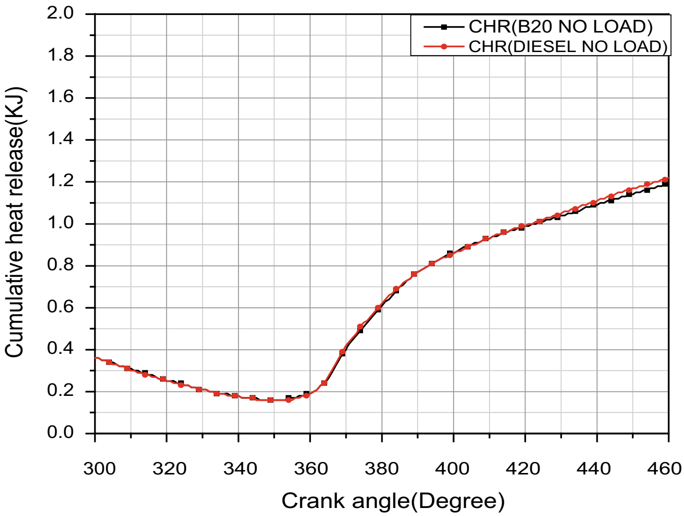

Fig. 17 Cumulative heat release rate versus crank angle at No load

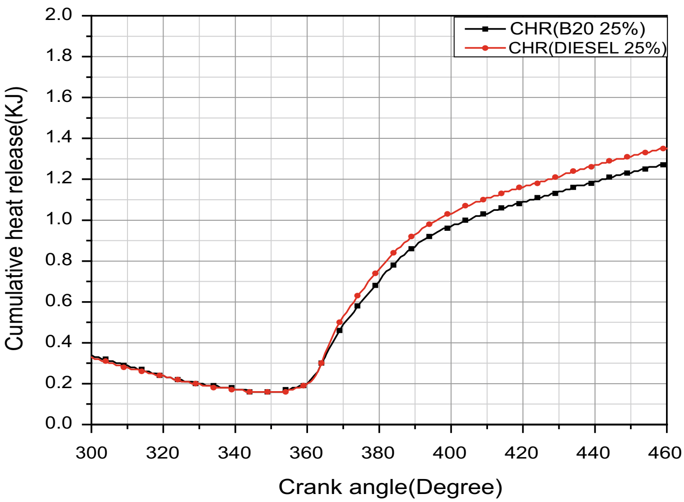

Fig. 18 Cumulative heat release rate versus crank angle at 25% load

even though it is having lower its lower calorific value as compared to mineral diesel (Figs. 19, 20 and 21).

The variation of cumulative heat release rate was shown for different loading condition at (No load, 25%, 50%, 75% and Full load) for both fuels diesel and biodiesel blend, MB20. It was observed that at No load, 25% and 50% load condition diesel has higher cumulative heat release rate compared to biodiesel and its blends with diesel, because diesel has high calorific value than biodiesel blend because of

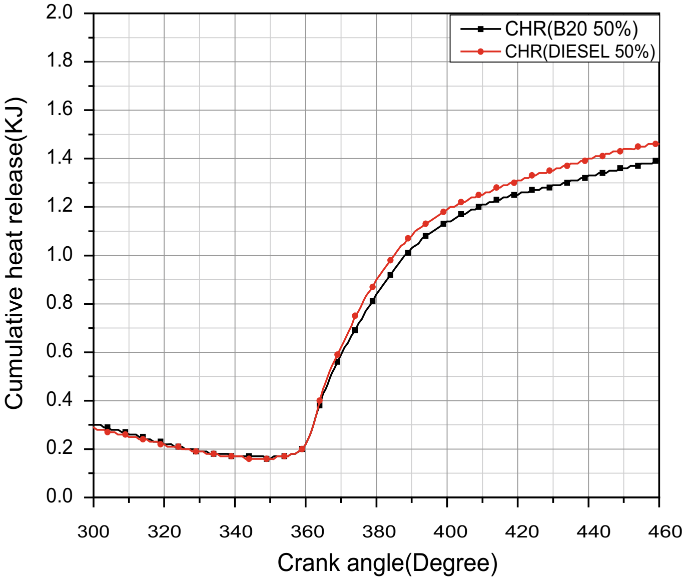

Fig. 19 Cumulative heat release rate versus crank angle at 50% load

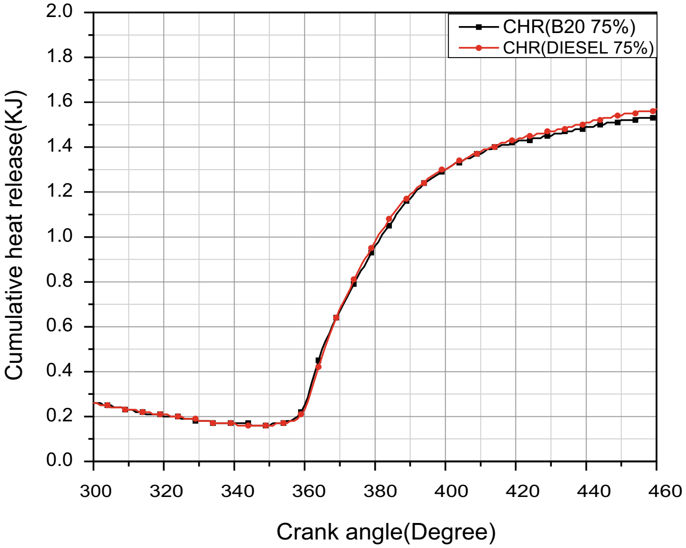

Fig. 20 Cumulative heat release rate versus crank angle at 75% load

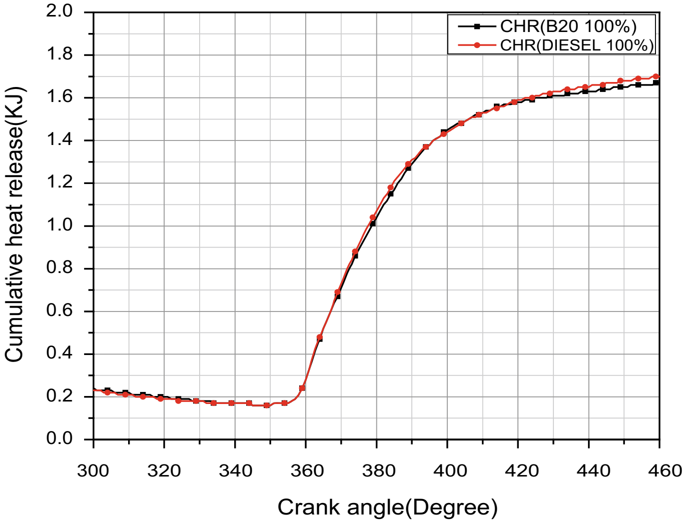

Fig. 21 Cumulative heat release rate versus crank angle at 100% load

better atomization of diesel at lower loads. At higher loading condition 75% and full load condition biodiesel blends have higher cumulative heat release rate than diesel. This is mainly due to more amount of fuel injected for biodiesel at higher loading condition and biodiesel have higher density and bulk modulus than diesel. Another factor contributing in this regard is more oxygen content in the fuel so combustion is better.

4.1.5 Mean Gas Temperature Versus Crank Angle

The mean gas temperature plays an important role in combustion analysis of fuel because mean gas temperature affects the NOx emission. High value of mean gas temperature leads to formation of more amount of NOx [9] so that mean gas temperature should be lower for less emission of NOx. The variation of mean gas temperature for different fuels and loads is shown below. At 75% and 100% load conditions, blends of biodiesel with diesel have higher value of mean gas temperature than diesel because of 10% more amount of oxygen contained in biodiesel than diesel so that better combustion takes place and high value of mean gas temperature was recorded [10]. It was also observed from Figs. 22, 23, 24, 25 and 26 that with increasing loading condition for all fuels more amount of fuel is injected which leads to high cylinder pressure and heat release rate ultimately leads to high mean gas temperature.

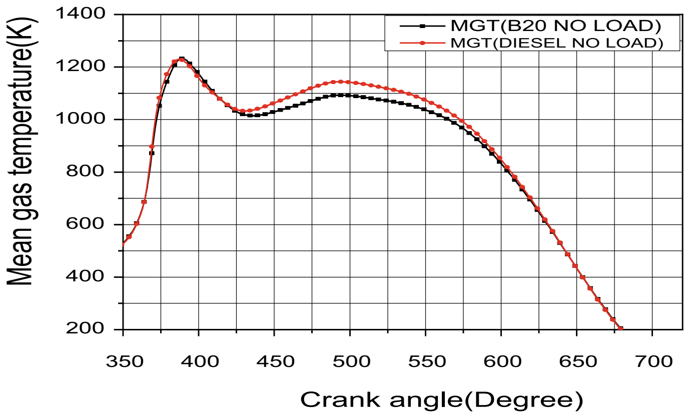

Fig. 22 Mean gas temperature versus crank angle at No load

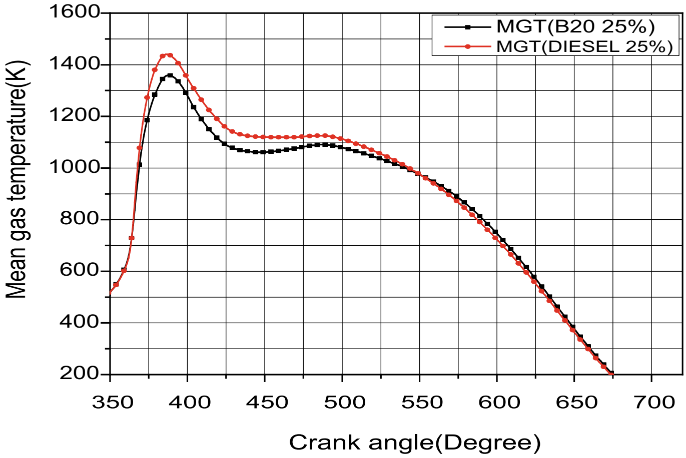

Fig. 23 Mean gas temperature versus crank angle at 25% load

4.2 Performance Characteristics

4.2.1 Brake Power

The variation of brake power for different fuels and different loads is as indicated below. Brake power is almost linear and comparable with respect to load for both diesel as well as B20 blend. As brake power is directly proportional to torque [3] and torque is directly related to load the variation of the curve is linear (Fig. 27).

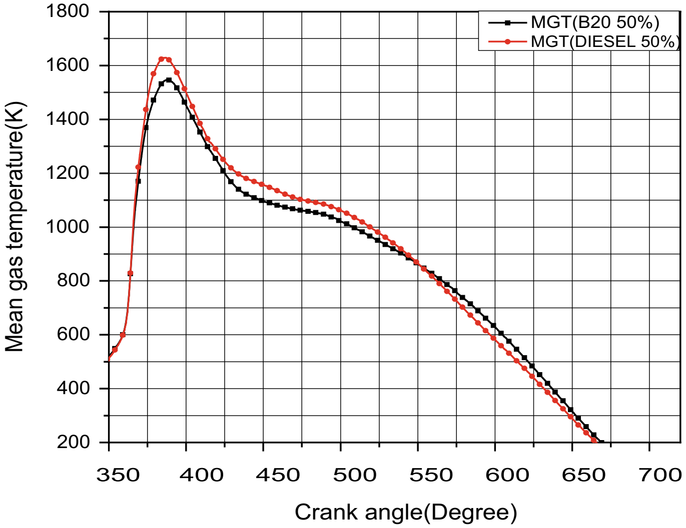

Fig. 24 Mean gas temperature versus crank angle at 50% load

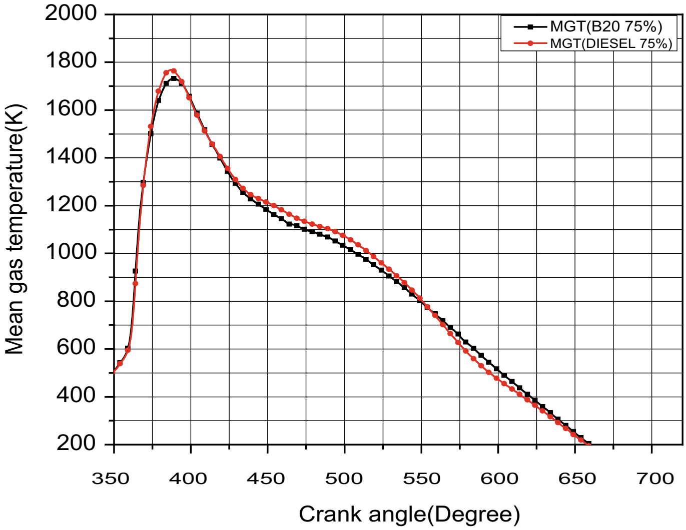

Fig. 25 Mean gas temperature versus crank angle at 75% load

4.2.2 Brake Specific Fuel Consumption

The variation of brake specific fuel consumption (bsfc) for different loads and fuels is shown in Fig. 28. The brake specific fuel consumption is estimated from the brake power output of the engine and mass flow rate of the fuel. At 25% load, diesel has

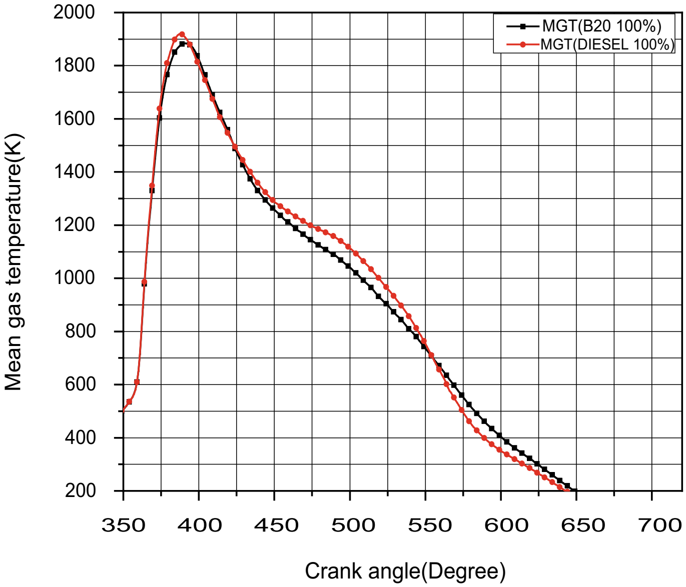

Fig. 26 Mean gas temperature versus crank angle at 100% load

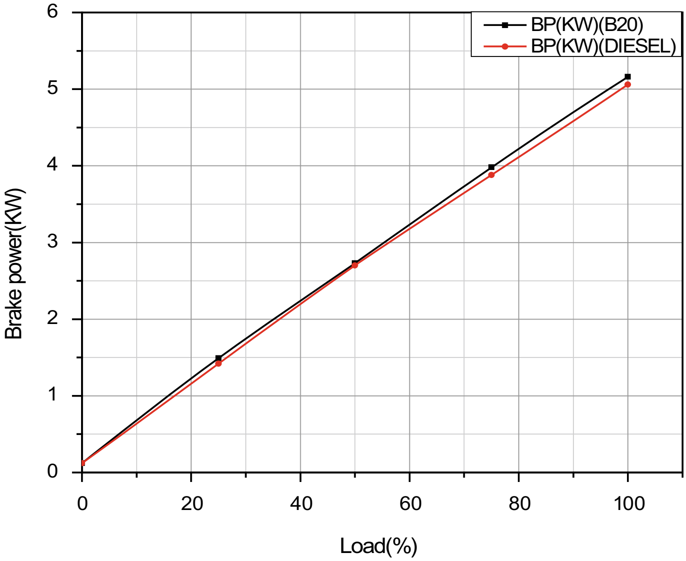

Fig. 27 Brake power versus load

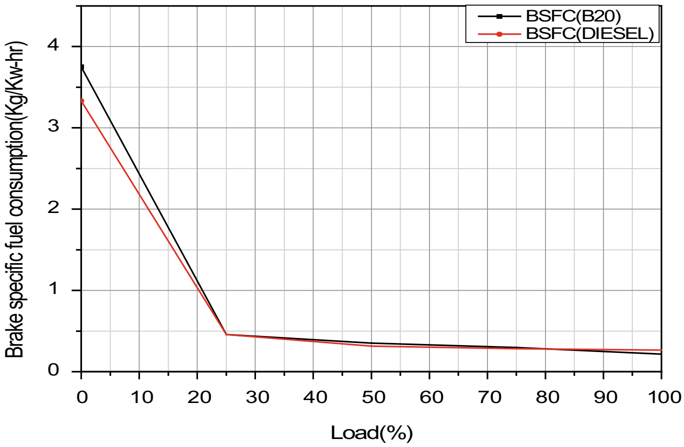

Fig. 28 Brake specific fuel consumption versus load

lower bsfc than biodiesel blend. At higher load condition diesel and bodiesel have comparable bsfc. This is due to the fact that although the calorific value becomes lower on adding the biodiesel in diesel which enhances the bsfc the better combustion on account of fuel bound oxygen and higher incylinder temperature at higher loads compensates the earlier effect.

4.2.3 Exhaust Gas Temperature

Exhaust gas temperature increases as the load is increased with increase in load and at 100% load the maximum value of temperature is approximately 300 degrees centrigrade. As load is increasing fuel consumption is also increasing and hence exhaust gas temperature is also increased. It can be seen that up to 25% load temperature difference is high but as the load is increasing this difference is reduced and at 100% load this becomes minimal as the combustion of the biodiesel blend is poor at lower loads and it is better at higher loads (Fig. 29).

5 Conclusion

In this study, the mustard oil was fed to transesterification reactor along with 260 ml methanol and 0.68 gm KOH which gave maximum yield of 96.16% biodiesel. NaoH did not work effectively as a catalyst for transesterification of mustard oil rather it turned into soap. Biodiesel blend (B20) was prepared by adding 20% of biodiesel to diesel on volumetric basis and it had slightly high viscosity as compared to diesel. At 75% load and 100% load condition for MB20, the cylinder peak pressure was higher

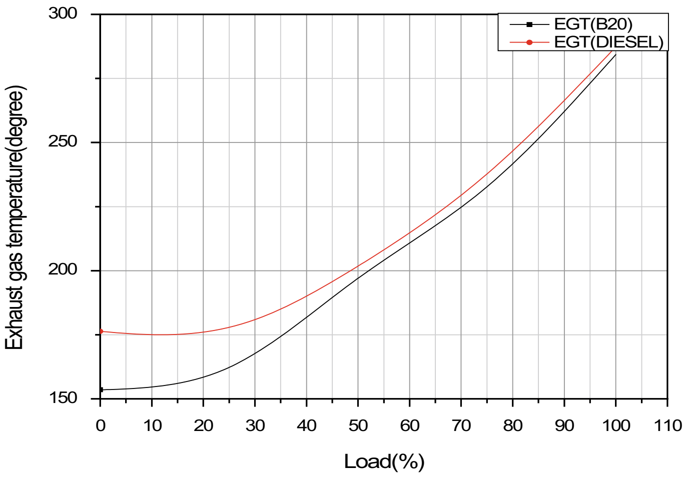

Fig. 29 Exhaust gas temperature versus load

as compared to diesel because at high loading condition MB20 due to its 7% to 8.1% more oxygen content its combustion is comparable to diesel. Rate of pressure rise for biodiesel is found to be less than 8 bar/CA which shows that the engine can work smoothly without vibrations. Cumulative heat release for the blend increases with load which means losses to the cylinder walls and crevices increase which minimizes the conversion of thermal energy into useful work. At full load conditions, diesel and bodiesel have comparable bsfc. This is due to the fact that although the calorific value becomes lower on increasing the biodiesel percentage in blends which should enhance the bsfc the better combustion of biodiesel on account of its fuel bound oxygen and higher incylinder temperature at higher loads compensated the earlier effect. The mean gas temperature also increased with load and brake power variation with load shows linear trend.

References

1. Encyclopedia of Energy. McGraw Hill Publication.
2. A. Thumann Handbook of Energy Engineering, The Fairmont Press Inc.
3. J.B Heywood, Fundamental of Engines
4. A.J.V.D.O. Débora De Oliveira, M. Di Luccio, C. Faccio, C.D. Rosa, J.A. Paulo Bender, N. Lipke, C. Amroginski, C. Dariva, Optimization of alkaline transesterification of soybean oil and castor oil for biodiesel production. Appl. Biochem. Biotechnol. **121** (2005)
5. J. Van Gerpen, Biodiesel processing and production. Fuel Process. Technol. **86**(10), 1097–1107 (2005)
6. B. Singh, J. Kaur, K. Singh, Production of biodiesel from used mustard oil and its performance analysis in internal combustion engine. J. Energy Resour. Technol. **132**(3), 031001 (2010)
7. M. Abdel, H.A. Farag, M.E. Ossman, Production of biodiesel from non-edible oil and effect of blending with diesel on fuel properties. An Int. J. (ESTIJ) **2**(4), 2250–3498 (2012)

8. A.B. Fadhil, W.S. Abdulahad, Transesterification of Mustard (Brassica nigra) seed oil with ethanol: purification of the crude ethyl ester with activated carbon produced from de-oiled cake. Energy Convers. Management. **77**, 495–503 (2014)
9. L. Lešnik, J. Iljaž, A. Hribernik, B. Kegl, Numerical and experimental study of combustion, performance and emission characteristics of a heavy-duty diesel engine running on diesel, biodiesel and their blends. Energy Convers. Manage. **81**, 534–546 (2014)
10. S.M. Palash, M.A. Kalam, H.H. Masjuki, M.I. Arbab, B.M. Masum, A. Sanjid, Impacts of NOx reducing antioxidant additive on performance and emissions of a multi-cylinder diesel engine fueled with Jatropha biodiesel blends

Chapter 21
Necessity of Ergonomic Intervention in Apparel Industry: A Case for Re-designing Steam Ironing Work Station

Ettishri B. Rajput

Pratitioner Summary: Work in the Apparel Industry is essentially classified as light work. It is important to draw attention of the international community to the fact that the design of the steam ironing table, one of the most ubiquitous piece of equipment needs rethinking in order to accommodate Human Factors. A cross sectional study was conducted across ten leading apparel manufacturing companies in India. The findings clearly indicate a high probability of WMSD's affecting the steam ironing operators considering the physical risk factors involved. There is a strong requirement to humanize the ironing job. Besides, the requirement of an amending Occupational Health legislation in order to review the current climatic and work conditions and specify minimum ambient air velocity and temperature and humidity requirements in line with Article 21 of the Indian Constitution and the ILO can not be ruled out.

1 Introduction

Apparel Industry is one of the most fragmented industries, but it is also one of the most globalized industries. There are generally three different competitive planks in the other wise fragmented apparel industry: Cost advantage (High Quality mass production, e.g. Giordano), Speed advantage (e.g. Mango, Tonywear, etc.), Competing on Brand Equity (the luxury market) [1]. A significant proportion of the Indian apparel manufacturing sector caters to the brands falling under the first plank. In FY19, total textile and clothing exports estimated to Rs 1.13 trillion (US$ 16.2 billion). Readymade garments (RMG) exports from India stood at Rs. 52,810.51 crore (US$ 7.53

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billion) during the same time. A majority of the manufacturing units in the ready made garments sector are medium to small scale. Ready made garments as an industry was de-reserved only as recently as 2001 in India and hence the apparel sector finds a preponderance of small sector units and higher proportion of informal labour [2]. The said structure of the garment industry is one of the factors that the sector has not realized the full potential of automation and accurate information systems.

The work in garment industry is necessarily categorized as light work. But, almost all tasks associated with garment assembly, ironing or finishing, exert *static loads* on the body. This is clearly evidenced as the industry largely follows assembly line approach with progressive bundle system of apparel manufacturing. Companies thrive on large volumes, which necessitates long working hours, minimum 8, and occasionally 2 additional hours of overtime. Also the nature of work is paced. The psychosocial factors weigh heavier if the operator is paid on per piece basis and has no job security or control on the job, especially the informal labour. Another factor that plagues the apparel production industry is the lack of job rotation, thus forcing overuse/underuse of the certain muscles on a daily basis. Anderson et al have concluded that a variety of disabling injuries or disorders of musculoskeletal tissues or peripheral nerves may ensue due to exposure to awkward postures and repetitive motions for prolonged periods.

Certain Musculoskeletal disorders are well established occupational diseases [3, pp. 15–16] and also afflict the productivity and attendance of operators.

The need of general purpose machinery in the apparel sector is influenced by the scale, frequent style changeovers, product type, all of which, here necessitate a batch production system which does not allow for rigid automation and hence a consideration for human factors is of utmost importance while considering design and interface of the machines used.

Medium and Small scale units usually purchase machinery that has a fairly high level of flexibility. Besides, the pressing and ironing operation requires the material to be manipulated and handled for more than 50% of cycle time. In such a scenario it is most essential to design machines and environment with human factors in consideration, given the fact that an average Indian apparel industry worker spends anywhere between 48 and 60 h per week at the workplace. Major factors that make the apparel industry operators prone to certain MSDs have been identified [4] as:

- Static loads
- No or little job autonomy
- Paced and repetitive work
- Long work hours with of only a certain set of muscles.

2 Method

2.1 The Study

For the purpose of this study, definition and key framework that is necessary to constitute a Healthy Workplace is that as proposed by the WHO [4]. The purpose of this study is to highlight the risk of work related musculoskeletal disorders among the steam ironing (pressing) operators in apparel manufacturing factories engaged in ironing a complete garment. The study focuses on the problems faced by operators working full time as ironing operators in the apparel industry and using an industrial steam ironing table equipped with a vacuum system.

The sample consists of 59 steam ironing/pressing operators who were engaged in ironing an entire garment for 8–10 h, 6 days of the week. The operators fall in the age range of 20–52 years old. Of the 59 operators, 55 operators were male and 4 operators were female. The operators had an experience in pressing for 2 years or more. Operators were working on either piece rate or time rate in the ten different garment manufacturing factories contacted. The 10 units were selected randomly. The factories were located in Ahmedabad (5 factories), Delhi NCR (3 factories), Bangalore (2 factories). The product being manufactured in the said factories were P1-Mens Formal Shirt, P2-Denim Trousers, P3-Coveralls, P4- Women's dress, P5-Women's Formal Shirt as under (Table 1).

2.2 General

2.2.1 Indian Context of MSDs

Currently the national and state labour laws do not completely address the problems regarding health and safety for labour, not fully so for the formal workers as well. Out of the five conventions of the ILO which are related to occupational health and safety (including musculoskeletal disorders), India has ratified only Convention. No. 127, Maximum Weight Convention, 1967 (ratified March 2010) [5].

The remaining conventions relating to MSD's not ratified by India are as under (Table 2).

Table 1 Factory wise products manufactured and the *mean cycle time observed in minutes: seconds (average of 5 cycles per operator observed)

Region	Ahmedabad					Delhi NCR			Bangalore	
Factory	A1	A2	A3	A4	A5	D1	D2	D3	B1	B2
Product	P1	P2	P2	P3	P3	P1	P4	P5	P1	P1
Work cycle*	1:35	1:25	1:41	3:36	3:23	1:57	2:55	2:08	1:52	1:45

Table 2 ILO conventions related to MSD's [6] and not ratified by India [5]

Convention	Topic	Ratified/not ratified
C148	Working environment (air pollution, noise and vibration)	Pending ratification
C155	Occupational safety and health	Pending ratification
C167	Safety and health in construction	Pending ratification
C184	Safety and health in agriculture	Pending ratification

The necessity for an occupational health and safety regulator can not be over emphasized. Though, time and again the Supreme Court of India has stepped in with guidelines for specific sectors. The social security concerns, to a great extent, have already been addressed by legislation such as the Minimum Wages Act, Payment of Wages Act, Maternity benefits Act, ESI Act, and other central legislations which have improved provision of social security and other benefits to the extent of implementation for the formal labour.

Even as '*share of unorganized labour has declined from 87 to 82.7%*', yet, there is no shrinking of the informal economy [7]. In fact, when considering labour conditions, even the organized sector has not fared too well. Growing informalisation, worsening working conditions for labour and absence of trade unions is widespread in the organized apparel industry [8]. The absence of an Occupational Health and Safety legislation to address WMSD's, a higher proportion of informal labour with little voice and the nature of work in the apparel industry together affect the occupational health in this sector.

The subject at hand is concerned with the physical demands of full time steam ironing work in apparel factories.

In absence of any specific ergonomic guidelines for the said industry at the state or central level, the NIOSH guidelines were followed in order to identify the risk factors and their intensity [4]

The following physical risk factors were considered for the purpose of the study (Table 3).

2.2.2 Method

The demographic profile of the workers studied was as under (Table 4).

The work conditions and dimensions of the work place were studied through observation. Type of ironing equipment was ascertained in order to understand the prevalence of industrial steam ironing table equipped with vacuum system in apparel industry. 1–2 steam ironing operators were videotaped in 5 factories. Video/photo recordings were not permitted in the remaining 5 factories. 5 Work cycles for 7 operators ($5 \times 7 = 35$ work cycles) of various factories were observed through video recordings and direct observations. Breaks/rest allowed for operators in the factories were two ten minute tea breaks and one half an hour lunch break. All

Table 3 Physical risk factors

Type of musculoskeletal disorder	Risk factor (s)
Neck MSD	Repetitive work (repetition with awkward neck posture)
	Forceful work (arms and hand movement generate force stress on the neck)
	Static awkward posture (tension-neck syndrome)
Shoulder MSD (shoulder tendinitis)	Repetitive work (repetition with awkward shoulder posture)
	Static shoulder load (contact stress)
	Overhead work
Elbow MSD (epicondylitis)	Forceful work (wrist generates force stress on elbow)
	Combined Risk Factors
	Force and repetition
	Force and posture
Carpal tunnel syndrome (CTS)	Combined Risk Factors
	Force and repetition
	Force and posture
	Force, repetition and posture
Hand/wrist tendinitis	Combined risk factors
	High repetition and forceful hand/wrist exertion
Hand-arm vibration syndrome	Intensity and duration to vibrational tools, e.g. vibrational level 5–36 m/s^2
Low-back MSDs	Heavy physical work
	Lifting and forceful movements
	Bending and twisting (awkward posture)
	Whole-body vibration (WBV)
	Static work posture

Table 4 Demographic profile

Indicators	Mean (SD)
Age	31.14(7.70)
Male/female	55/4
Non smokers (Smokers)	49(10)
Tobacco consumption	45
Languages spoken	Hindi, Gujarati, Kannada-English

workers performing the steam ironing operation were being paid on time rate, except for one factory making coveralls where the steam ironing/pressing operator was also paid on piece rate.

Heat Stress

A questionnaire on preliminary assessment on heat stress [5] was used for preliminary assessment of heat stress among steam ironing operators. The questionnaire in english was translated to the local language for the operators in order to record responses for heat stress questionnaire.

2.2.3 Data Management and Analysis

The work cycles (5*7) were analysed for the following:

(i) Awkward Postures
(ii) Repetitive work
(iii) Ease of movement
(iv) Restricted movement
(v) Heat Strain
(vi) Accidents if any.

The videos were analysed for cycle time, proportion of material handling time, number of times iron is lifted per work cycle. The heat strain questionnaire survey has been analysed on the Microsoft Excel Software by MS corp. The questionnaire gives a preliminary assessment of the heat strain level experienced by the workforce and classifies the said heat strain in to safe, alarm and danger levels [5]. The said heat stress questionnaire was administered only in the arid regions as per the Koppen classification (Ahmedabad area and NCR factories) as the heat stress study for plateau regions like Bengaluru would need a separate treatment. The heat stress was measured for a sample size of 45 persons (all males) working in the factories in Ahmedabad and National Capital Region.

2.3 Results

In terms of the physical risk factors that contribute to the development of WMSD's, the following have been observed to be especially influential:

(I) **Awkward Postures**: Of all the areas of work in the apparel industry, sewing and steam ironing, are the operations that require maximum manipulation by hands, raised shoulders, restricted foot movement. Companies involved in manufacturing finishing equipment have introduced finishing equipment like steam ironing table with vacuum, tunnel finisher, form finishers, bed bucks, buck presses, multiple types of irons depending on end use (weight of which may vary from 1200 to 1900 g), various shapes and sizes of ironing surfaces in order to best suit the garment to be finished, etc. But the most versatile equipment among the aforesaid is the Steam ironing table with vacuum attachment. In

Picture 1 Pictures from a Factory in NCR: Typical posture of a steam ironing operator; postural stresses affect knees, lower back, neck. Repetitive lifting of iron makes the postural stresses more severe. A major draw back of this machine design is the necessity to keep both the knees straight, all through the day lasting 8–10 h

fact, sticking to a conservative estimate, it was ascertained during the study, that on an average, for every 500–600 garments made, there would be one such ironing table and one full time ironing operator in a typical garment factory.

Besides, with a preponderance of medium and small scale units in this industry combined with the variety inherent in fashion business, a steam ironing table with vacuum is one which is indispensable for any apparel manufacturer.

Low back pain among standing workers is a well-researched topic. Lower back pain is common among standing workers. Bridger suggests that for work that requires standing, the workspace must be designed to prevent workers from having to stand with excessive lumbar lordosis or having to adopt forward flexed working positions [9]. The requirement of maintaining a standing posture with minimum muscular effort requires that the line of centre of gravity must fall through the major weight bearing joints and be equidistant from each foot [10] (Picture 1).

Out of the 59 respondents, 69.5% respondents reported pain in either arms, neck, shoulder, lower back, legs, heel or wrist. 55% of the respondents experienced pain in more than one of the above parts.

(II) Repetitive Strain: A combination of Force, repetition, posture and speed is studied in order to analyze any job. The steam ironing operators job is repetitive, in as much as, it comprises of continuously ironing the product for 8–10 h a day where the work cycle observed ranges from 1 min 25 s to 3 min 36 s.

The job comprises of continuous application of force and repetitive lifting of the steam iron. For example, in one complete cycle of pressing, the steam ironing operator lifts the iron around 13–15 times. The ironing cycle time depends on factors like urgency, complexity of the garment, operator trainning, whether the workers were paid on a piece rate, age and experience of the operator among others. Thus a typical scenario would be lifting the iron, the weight of which ranges from 1300 to 1950 grammes, atleast 8–10 times per minute. Though this is a lifting task, the redeeming factor is that the iron has to be lifted for a short distance as in repositioning, also the iron need not be lifted in order to terminate contact between the iron and the fabric, it can be simply slid off. It is obvious that the NIOSH lifting equation would help little given the assumptions that accompany the same. The right hand is involved in lifting of the iron while the left hand is continuously engaged in material handling. Around 80% of the subjects studied complained of wrist pain in the right hand. Besides, the proportion of material handling for different products ranged from 38.41 to 63.55%.

(III) **Ease of Movement**: The posture, as can be observed from the images involves continuous standing, raised shoulders, repetitive lifting of the iron by the right hand, bent neck and torso, upper and lower arm working away from the body as they are involved in manipulating the product to be ironed, constrained feet movement as the vacuum peddle is provided under the machine table and forcing the operator's feet to fall in line with the entire body, eliminating the luxury of placing the foot on a foot stand or taking turns to rest alternate feet or even bending alternate knees all through the 8–10 h of the day. Such restricted movement of the foot not only reduces the reach of the operator, but is also a source of additional fatigue resulting from non-neutral balancing of the body when pressing the vacuum lever. In such a situation muscles will fatigue rapidly even at low workloads [11].

Hence the steam ironing operator's low workload may become a persistent condition even as it is easy work, by the sheer fact that it generates static workloads for the legs, shoulder, neck, Spine. A very dangerous problem overall even in absence of large forces or heavy weights.

(IV) **Restricted Movement**: Steam ironing workstation has not undergone much change since 1946, though it can not be said that improvement efforts have not been made in this area. Studies on postural adaptation in standing workers have suggested workbench modifications for standing workers [12]. They suggest postural adaptation to task distance involves a trade-off between neck flexion and trunk flexion and that standing posture is largely dependent on foot position. The current pressing equipment restricts the foot movement and thus reduces the reach and comfort of the standing operator in a job that entails standing for 8 h (Picture 2).

(V) **Heat Strain**: Heavy Physical work in the heat imposes conflicting demands on the cardiovascular system and the cardiovascular system may be placed under considerable strain when a person is working in the heat as output rises to meet the demands of both physical and bodily cooling [9]. Human body tries to maintain the internal body temperature at around 37 °C. Air temperature, radiant temperature, air velocity, and humidity therefore are the four basic variables that should be quantified (measured/estimated) if one is considering human thermal environments [13]. The study was conducted in the month of June. The outside temperature was 33–36 °C. The WBGT could not be measured for the work area due to absence of a calibrated heat stress monitor (Table 5).

The sensitivity on heat stress and necessity of an amending legislation was realized during one of the regular factory visits to one of the factories manufacturing denim

Picture 2 From a factory in Bangalore

Table 5 HSSI as reported by respondents from factories in Ahmedabad and NCR; the Mean HSSI reported was 17.39 with a standard deviation of ±3.35

Heat strain index	Number of respondents (%)
Safe level	5 (11.9%)
Alarm level	19 (45.24%)
Danger level	18 (42.86%)
	(42 Respondents)

trouser. Usually, the finishing department in an apparel manufacturing industry is infamous for high temperature and heavy moisture laden air. Another area of work which has similar working environment is washing area, where a garment is washed in industrial washing machines with certain chemicals and hot water. It was so observed that an exhaust that was supposed to freshen up the air in the finishing area, actually opened in the washing area. The steam ironing operators were soaked in sweat for 6–7 h of the day ironing away denim trousers. But in the other factories the ironing tables were arranged along the windows side or anywhere in the manufacturing assembly line. Again the above observations were for the operators working in the arid, semi-arid regions only.

(VI) **Other Observations**: In an industry that boasts of having a large part of the workforce as females, it is a striking aberration that a majority of the steam ironing operators, in the 10 apparel manufacturing companies studied, were male. In the study, around 93% of the sample population studied were male. Accidental contact of steam iron with hands was also reported.

3 Discussion

As discussed above, one of the methods to better the workplace environment is through product design. Designing equipments, machines, interfaces, etc. with the user in mind is crucial. The following aspects may be considered when designing a workspace:

I. Having a gender neutral workplace is crucial today: More than ever before, and especially so in the garment industry, where we have, and even promote, a higher ratio of female operators. Achieving a worker friendly workspace necessitates user-friendly workstations. An attempt to create such a workspace should prod our understanding to the minutest details of the jobs, its elements, interface, controls, physical aspect and most importantly the humane aspect of work. Studies indicate that an improvement in the workspace design is positively associated with productivity.

II. Ergonomics as an essential ingredient to productivity improvement programs: While all productivity improvement programs and management paradigms are synced with Kaizen, Lean manufacturing, JIT, etc., ergonomics is usually left out. *Ergonomics is usually not a part of the primary business strategy*…. The waste of unnecessary motion is particularly related to ergonomics. Excess motion consists of bending, twisting, lifting, reaching and walking. These often become health and safety issues and should be dealt with as soon as they are recognized [14]. That significant improvement can be achieved as regards quality of goods in manufacturing has been established through various studies [15–17]. Studies have suggested a model for calculation of costs of poor assembly ergonomics in the automobile industry [18]. The necessity to re-design equipment and devices used by arc-welders in order to bring about a significant improvement in productivity and minimizing associated labour costs has also been established [19].

III. Ergonomic Interventions must take in to account local conditions: One of the major factors affecting productivity is weather conditions. Not only hot weather conditions in the temperate and arid zones cause loss in productivity, but are also detrimental to worker health. China's Heat allowance regulation helps factories ensure productivity but at best is comparable to the polluter pays principle which may not be the best policy for India.

IV. Ergonomics, an investment: Most of the factories consulted in the Gujarat area signify a dearth of knowledge in so far as ergonomic tools are concerned. At best ergonomics is equated to comfort and a penny here and pound there, what is missing is a holistic approach. Just as a piecemeal approach to lean implementation means doom for the organization, ergonomics too calls for a holistic approach and should not be treated as a favor owed to the subjects.

4 Limitations and Further Scope

In no way does this work claim to fulfill all conditions necessary and sufficient as '*the scientific evidence generally used for establishing a causal relationship between diseases and work*' [3]. Besides, the treatment to heat stress as given in the current work is limited to preliminary assessment and it is necessary to be studied in greater depth. Specific problems related to female steam ironing operators could not be studied in depth as the [1]proportion of such employees in the factories visited was extremely limited.

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References

1. A. Carugati, R. Liao, P. Smith, Speed-to-fashion: managing global supply chain in zara, in *2008 4th IEEE International Conference on Management of Innovation and Technology* (2008)
2. G. Kane, *Factos on India's Garment Industry* (Clean Clothes Campaign, 2015)
3. International labour Organization, *Meeting of Experts on the Revision of the List of Occupational Diseases (Recommendation No. 194)* (ILO, Geneva, 2009)
4. J. Hague, L. Oxborrow, L. Mc Atamney, *Musculoskeletal Disorders and Work Organisation in the European Clothing Industry* (2001)
5. WHO, *2nd International Consultation on Healthy Workplaces, Rome, 10–12 December* (Rome, 2012)
6. ILO, *Up-to-date Conventions and Protocols not ratified by India* (2017). Accessed 2 August 2017 http://www.ilo.org/dyn/normlex/en/f?p=1000:11210:0::NO:11210:P11210_COUNTRY_ID:102691
7. European Agency for Safety and Health at Work, *OSH in figures: Work-related musculoskeletal disorders in the EU—Facts and figures* (2010)
8. L. Bureau, *Indian Labour Year Book*, Ministry of Labour & Employment, Shimla (2015)
9. A. Mezzadri, R. Shrivastava, *Labour regimes in the Indian garment sector: capital-labour relations, social reproduction and labour standards in the National Capital Region* (Centre for Development Policy and Research, 2015)
10. R.S. Bridger, Introduction to Ergonomics, International ed., International Edition: McGraw Hill International Editions (1995)
11. R. Roaf, *Posture* (Academic Press London, London, 1977)
12. K. Kroemer, Human Strength, terminology, measurement and interpretation of data. Hum. Factors **20**, 481–497 (1970)
13. R.S. Whistance, L.P. Adams, B.A. Van Geems, R.S. Bridger, *Postural Adaptations to Workbench Modifications in Standing Workers*, vol. 38 (Ergonomics, 1995), pp. 2485–2503
14. K. Parsons, *Human Thermal Environments*, 2nd ed. (Taylor & Francis, London & Newyork, 2006)

15. R. Sharma, Conceptual framework for improving business performance with lean manufacturing and successful human factors interventions–a case study. Int. J. Qual. Res. **6**(3), 259–270 (2012)
16. O. Erdinc, O. Vayvay, Ergonomics interventions improve quality in manufacturing: a case study. Int. J. Ind. Syst. Eng. **3**(6) (2008)
17. L. Lin, C. Drury, S.-W. Kim, Ergonomics and quality in paced assembly lines. Hum. Fact. Ergon. Manuf. **11**4 (2001)
18. J.A. Eklund, Ergonomics and quality management—humans in interaction with technology, work environment, and organization. Int. J. Occup. Saf. Ergon. **5**(2), 143–160 (1999)
19. A.-C. Falck, M. Rosenqvist, A model for calculation of the costs of poor assembly ergonomics (part 1). Int. J. Ind. Ergon. **44**(2014), 140–147 (2014)
20. S. Das, Understanding hidden factors that influence costs of arc welding operations. Adv. Prod. Eng. Manag. **7**(4), 213–224 (2012)
21. ILOSTAT, *Informal Economy Indicators* (ILOSTAT, 2017)
22. ILO, *India Labour Market Update ILO Country Office for India* (ILO, 2016)
23. National Statistical Commission, *Report of the Committee on Unorganised Sector Statistics* (2012)
24. NCEUS, *Definitional & Statistical issues relating to workers in informal employment* (2008)
25. P. Sinha, I.B. Sinha, S.P. Shekhar, *Industrial Relations, Trade Unions and Labour Lagislation*, 3rd ed. ed by V. Goenka, S. Kansal (Pearson, 2017), p. 739
26. Y. Epstein, D.S. Moran, Thermal comfort and heat stress indices. Ind. Health **44**, 388–398 (2006)
27. T. Kjellstrom, I. Holmer, B. Lemke, Workplace heat stress, health and productivity–an increasing challenge for low and middle-income countries during climate change. Global Health Action (2009)
28. H. Dehghan, S.B. Mortzavi, M.J. Jafari, M.R. Maracy, Development and validation of a questionnaire for preliminary assessment of heat stress at workplace. J. Res. Health Sci. **15**(3), 175–181 (2015)
29. Veit, *Veit*. Accessed 22 August 2017 http://www.veit.de/en/ironing-and-pressing-garments/ironing-tables/veit-varioset-flat-top-table-s-b/
30. KPMG, *Textiles and Apparel: Market & Opportunities* (IBEF, 2008)
31. T. Economist, Made to Measure. *The Economist* (2015May)
32. L. McAtamney, E. Corlett, RULA: a survey method for the investigation of work-related upper limb disorders. Appl. Ergon. **24**(2), 91–99 (1993)
33. H. Signett, L. McAtamney, Rapid entire body assessment (REBA). Appl. Ergon. **31**(2), 201–2015 (2000)
34. ILO, Ilo.org. Accessed 6 August 2018 https://www.ilo.org/global/topics/working-conditions/lang--en/index.htm
35. O. Broberg, Integrating ergonomics into the product development process. Int. J. Ind. Ergon. **19**(4), 317–327 (1997)

Chapter 22
Whole Body Vibration Exposure Among Tractor Drivers: The Effect of Varying Subject, Speed and Posture Levels

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1 Introduction

In developing country like India, being an agrarian country agricultural tractors are widely used for both on-road and off-road operations and as well as transportation to towing goods, persons and animals. However, drivers are exposed to high levels of whole body vibration (WBV) during rough or uneven road or terrain interaction with tractor [1]. Continuous high WBV of tractor driver could be damages in form of psychologically, biologically, physiologically and mechanically [2]. WBV could also adversely effect on driver health and work performance [3]. Mostly, tractor driver work under the high WBV exposures for long duration and reported beyond exposure action value as per EU [4].

Therefore, it would be necessary to evaluate the effects of the exposure time and vibration dose on health during tractor operations and to maintain WBV exposures below the exposure limit level for reducing the probability of adverse health effects on the tractor operators.

Vibration transmitted from the road to the passengers (or driver) of a vehicle through the seat pan and seat backrest might interfere with activities, affect ride comfort and in some cases have a detrimental health effect [5]. Many studies have been performed in the laboratory or the field in which the objective and subjective responses of humans to vibration were investigated. The objectives of those studies varied from identifying factors affecting the sitting posture, backrest, and footrest to vibration to identifying factors affecting vibration-related discomfort and health

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issues [6]. In some studies, the independent variables (i.e. factors) studied were related to the characteristics of the vibration itself (i.e. direction, frequency, magnitude, waveform and duration). In other studies, the person posture (e.g. sitting with an erect, normal or slouched posture) or the seating conditions (e.g. with or without a backrest, seat surface angle, and backrest angle) were the independent variables [7]. Moreover, despite that there are many studies that looked at the effect of body posture and seating conditions on the biodynamic response of the human body to vibration, those studies were conducted under single axis vibration. The objective of this study is to investigate the effect of different seating conditions on the vibration received by the seat occupant from the seat pan and seat backrest. The factors considered in this paper are the use of a backrest, backrest angle, use of headrest, and lower leg position. Different sitting conditions means that the body will assume different sitting postures.

2 Methodology

A systematic methodology has been made as following:

Tractor and Terrain

A 2017 model and 55 hP tractor with double clutch mechanism and power steering has been selected for this study. The tractor has three-cylinder engine, wheel base 2045 mm and with negligible wear and tear of lugs tyres dimension was front tyre (6.0 × 16) and rear (14.9 × 28). A 7 km conglomerate bituminous road (Fig. 1) has been selected for this study in Punjab (India) region. There was no attachment towed with tractor during experimentation. A systematical process of data collection and analysis has been shown in flow chart (Fig. 2).

Fig. 1 A view of tractor and conglomerate bituminous road

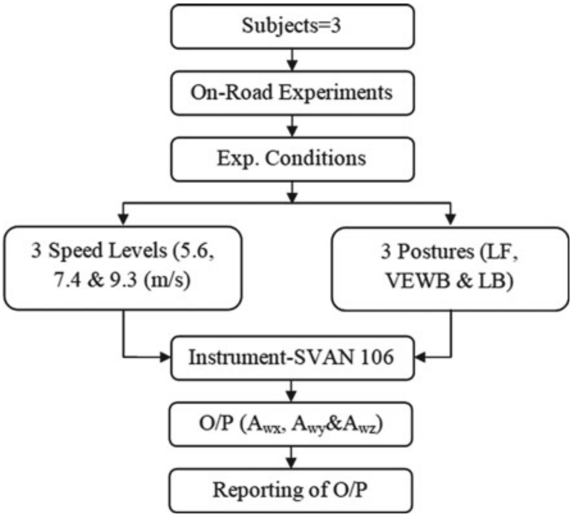

Fig. 2 Summary of data processing and analyzation

Subjects

Three tractor drivers have been selected for present study, having an average age 26.33 ± 2.05 years, weigh 77 ± 7.87 kilograms, stature 170.67 ± 4.03 centimeters basis on convenience sampling. The selected drivers have minimum 5 years' tractor driving experience. The purpose of this study already cleared to the drivers before experimentation. Drivers reported that no past sensitivity towards vibration.

Experimental Design

Experimental conditions include three selected forward speed levels (5.6, 7.4 and 9.2 m/s) and three postures levels (lean forward-LF, vertical erect with no backrest-VENB and lean with backrest-LB) as shown in Fig. 3. The drivers were instructed to maintain the selected postures as per their comfort and no instruments have been used for measure the posture [8].

Taguchi's L27 Orthogonal array was used for the design of the experiments. The array was chosen for getting the minimum number of experiments. Investigate and analyze the effects of forward speeds and postures in-terms of signal-to-noise (S/N) ratios. The 'S' indicates the actual effect of input factor on the output while 'N' indicates the undesirable response for response parameter. In present study objective function is to minimize the output response, therefore smaller-the-better option was chosen as per Eq. (1).

$$\left(\frac{S}{N}\right) = -10\log[1/R(y_1^2 + y_2^2 + \ldots\ldots.. + y_n^2] \tag{1}$$

Fig. 3 Sitting postures representation

where, $y_1, y_2, \ldots, y_n$ are the trial response with R times replications. Each experiment trail was replicated three times to determine the A_w (x, y and z axes). The orthogonal array consisted of 27 numbers of experiments and with three times replication total experiments were ($27 \times 3 = 81$) and each trail time was 60 s.

Instrument and Software

A tri-axial seat pad accelerometer acquire for the present study.

Seat pad accelerometer (SV 38 V) has been mounted on the tractor seat for measuring the whole body vibration in translational (fore-and-aft: x; lateral: y; vertical: z) axes simultaneously (Fig. 4). The data was acquired by SVAN 106 human vibration monitor having built weighting filter (w_d for x, y axes and w_k for z axis) and data sampling rate was 6 kHz. The data processed through SVANPC++ software for graphical analysis.

3 Results and Discussion

The weighted root mean square acceleration SNRs (signal-to-noise ratios) were computed for each experimental conditions by Taguchi's L27 orthogonal array. Each combination of experiment was replicated with three times (R1, R2 and R3) and mean of weighted root mean square acceleration was calculated are shown in Table 1.

The A_w levels were dominant along vertical (z) axis at seat as shown in Fig. 5. The S/N ratios were calculated for the optimal combination of experiments for obtaining a minimum A_w along translational axes.

The signal-to-noise ratios of A_w values for translational axes are shown in Figs. 6, 7 and 8 along average speed levels (5.6, 7.4 and 9.2 m/s) and driver body posture

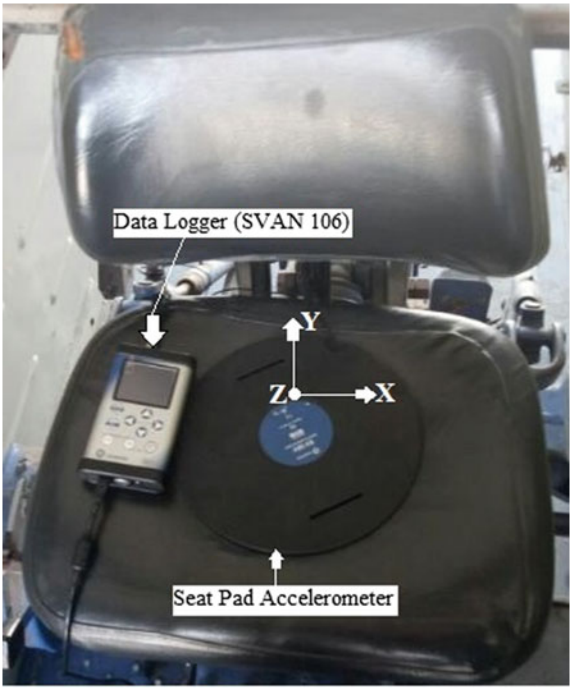

Fig. 4 Seat pad accelerometer (SV 38 V)

(lean forward (LF), vertical erect with no backrest (VENB) and lean with backrest (LB)). The optimal level is average speed, subject and posture as respectively 5.6 m/s, 86 kg and LF for the *x*-axis; 5.6 m/s, 81 kg and VENB for *y*-axis; 5.6 m/s, 81 kg and LF for *z*-axis. These are obtained from the means of S/N ratio plots by choosing the higher value of each input parameter. The mean of A_{wx} is first increasing with the increasing of average forward speed up to 7.4 m/s and afterward slightly decreasing up to 9.2 m/s; mean of A_{wx} is first slightly decreeing with increasing subject weight up to 81 kg and drastically increasing up to 84 kg and mean of A_{wx} is increasing drastically at LF posture and slightly decreasing at LBR posture as shown in Fig. 6.

The mean of A_{wy} is drastically increasing with increasing the average speed up to 7.4 m/s and afterward slightly decreeing with increasing the speed up to 9.2 m/s; mean of A_{wy} is slightly decreasing at subject weight up to 81 kg and slightly increasing with increasing the subject weight up to 84 kg and mean of A_{wy} very slightly decreeing from body posture LF to VENB and slightly decreeing up to LBR posture as shown in Fig. 7.

The mean of A_{wz} is increasing with the increasing of average forward speed up to 9.2 m/s; mean of A_{wz} first slightly decreeing with increasing the subject weight up to 81 kg and afterward drastically increasing up to 84 kg weight and mean of A_{wz} is slightly increasing at body posture VENB afterward very slightly decreasing at LBR body posture as shown in Fig. 8.

Table 1 Design and experimental results of L27 orthogonal array with replications

T. No	Input parameters			Output parameter (A_{wx})			M	S/N (dB)	Output parameter (A_{wy})			M	S/N (dB)	Output parameter (A_{wz})			M	S/N (dB)
	A	B	C	R1	R2	R3			R1	R2	R3			R1	R2	R3		
1	5.6	66	LF	0.15	0.23	0.19	**0.19**	**0.22**	0.14	0.16	0.18	**0.16**	**0.14**	0.59	0.63	0.64	**0.62**	**0.65**
2	5.6	66	LF	0.19	0.23	0.21	**0.21**	**–**	0.13	0.12	0.14	**0.13**	**–**	0.63	0.68	0.64	**0.65**	**–**
3	5.6	66	LF	0.24	0.26	0.28	**0.26**	**–**	0.12	0.16	0.14	**0.14**	**–**	0.65	0.69	0.67	**0.67**	**–**
4	5.6	81	VENB	0.2	0.25	0.21	**0.22**	**0.24**	0.08	0.12	0.1	**0.1**	**0.10**	0.6	0.63	0.66	**0.63**	**0.66**
5	5.6	81	VENB	0.26	0.24	0.22	**0.24**	**–**	0.11	0.09	0.13	**0.11**	**–**	0.62	0.69	0.64	**0.65**	**–**
6	5.6	81	VENB	0.29	0.25	0.27	**0.27**	**–**	0.09	0.07	0.11	**0.09**	**–**	0.67	0.69	0.71	**0.69**	**–**
7	5.6	84	LBR	0.29	0.33	0.31	**0.31**	**0.34**	0.14	0.13	0.12	**0.13**	**0.15**	0.7	0.75	0.71	**0.72**	**0.75**
8	5.6	84	LBR	0.32	0.36	0.34	**0.34**	**–**	0.16	0.14	0.15	**0.15**	**–**	0.75	0.77	0.73	**0.75**	**–**
9	5.6	84	LBR	0.4	0.33	0.38	**0.37**	**–**	0.16	0.14	0.18	**0.18**	**–**	0.76	0.79	0.82	**0.79**	**–**
10	7.4	66	VENB	0.37	0.41	0.39	**0.39**	**0.37**	0.23	0.25	0.27	**0.25**	**0.25**	0.8	0.81	0.82	**0.81**	**0.79**
11	7.4	66	VENB	0.35	0.39	0.34	**0.36**	**–**	0.24	0.25	0.2	**0.23**	**–**	0.75	0.77	0.79	**0.77**	**–**
12	7.4	66	VENB	0.4	0.35	0.36	**0.37**	**–**	0.27	0.31	0.26	**0.28**	**–**	0.76	0.81	0.8	**0.79**	**–**
13	7.4	81	LBR	0.37	0.34	0.31	**0.34**	**0.33**	0.21	0.23	0.19	**0.21**	**0.19**	0.74	0.76	0.78	**0.76**	**0.75**
14	7.4	81	LBR	0.32	0.31	0.3	**0.31**	**–**	0.21	0.19	0.17	**0.19**	**–**	0.74	0.72	0.73	**0.73**	**–**
15	7.4	81	LBR	0.35	0.33	0.34	**0.34**	**–**	0.14	0.16	0.18	**0.16**	**–**	0.73	0.75	0.77	**0.75**	**–**
16	7.4	84	LF	0.43	0.47	0.45	**0.45**	**0.44**	0.19	0.18	0.17	**0.18**	**0.23**	0.86	0.89	0.83	**0.86**	**0.86**
17	7.4	84	LF	0.41	0.4	0.45	**0.42**	**–**	0.24	0.25	0.23	**0.24**	**–**	0.82	0.83	0.87	**0.84**	**–**
18	7.4	84	LF	0.44	0.46	0.45	**0.45**	**–**	0.24	0.28	0.29	**0.27**	**–**	0.9	0.85	0.86	**0.87**	**–**
19	9.2	66	LBR	0.37	0.38	0.42	**0.39**	**0.35**	0.3	0.32	0.31	**0.31**	**0.20**	0.93	0.95	0.97	**0.95**	**0.92**
20	9.2	66	LBR	0.34	0.3	0.29	**0.31**	**–**	0.14	0.12	0.13	**0.13**	**–**	0.87	0.92	0.91	**0.9**	**–**

(continued)

Table 1 (continued)

T. No	Input parameters			Output parameter (A_{wx})			M	S/N (dB)	Output parameter (A_{wy})			M	S/N (dB)	Output parameter (A_{wz})			M	S/N (dB)
	A	B	C	R1	R2	R3			R1	R2	R3			R1	R2	R3		
21	9.2	66	LBR	0.34	0.39	0.35	**0.36**	–	0.16	0.14	0.18	**0.15**	–	0.91	0.92	0.93	**0.92**	–
22	9.2	81	LF	0.32	0.28	0.33	**0.31**	**0.27**	0.16	0.21	0.17	**0.18**	**0.22**	0.86	0.88	0.9	**0.88**	**0.83**
23	9.2	81	LF	0.2	0.25	0.24	**0.23**	–	0.23	0.28	0.24	**0.25**	–	0.78	0.76	0.83	**0.79**	–
24	9.2	81	LF	0.28	0.23	0.27	**0.26**	–	0.2	0.24	0.25	**0.23**	–	0.81	0.85	0.8	**0.82**	–
25	9.2	84	VENB	0.41	0.43	0.45	**0.43**	**0.44**	0.27	0.29	0.28	**0.28**	**0.22**	1.01	1.05	1.06	**1.04**	**1.03**
26	9.2	84	VENB	0.38	0.43	0.42	**0.41**	–	0.21	0.19	0.23	**0.21**	–	0.98	0.97	0.99	**0.98**	–
27	9.2	84	VENB	0.46	0.5	0.51	**0.49**	–	0.19	0.18	0.17	**0.18**	–	1.04	1.08	1.06	**1.06**	–

T. No: Trial Number; A: Average speed levels (m/s); B: Driver weight (kg); C: Driver body posture [(lean forward (LF), vertical erect with no backrest (VENB) and lean with backrest (LB)]; M: Mean of replication trail; (R1, R2 and R3): Replication of trail; S/N: Signal-to-noise ratio; dB: decibels

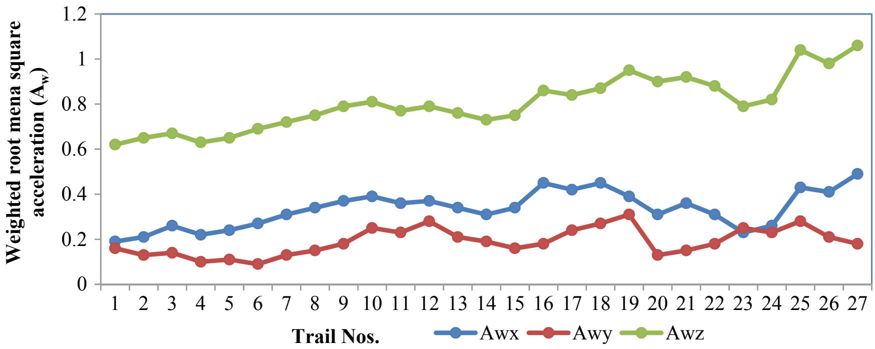

Fig. 5 Mean of weighted RMS acceleration translational axes wrt trails

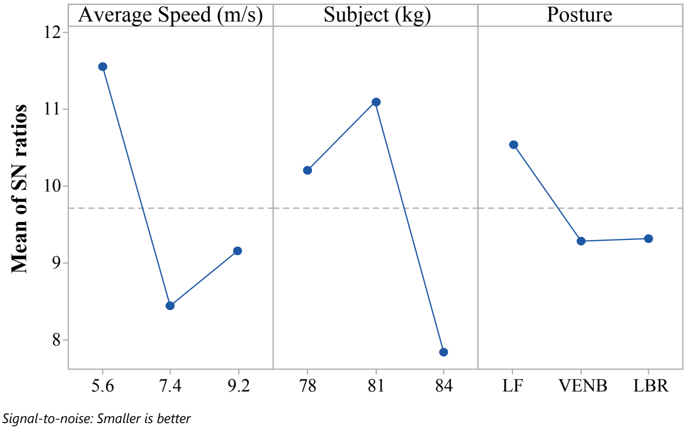

Fig. 6 Main effects plot for S/N ratios A_{wx}

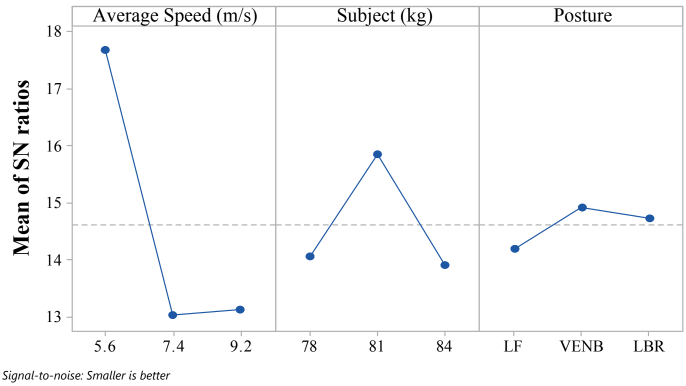

Fig. 7 Main effects plot for S/N ratios A_{wy}

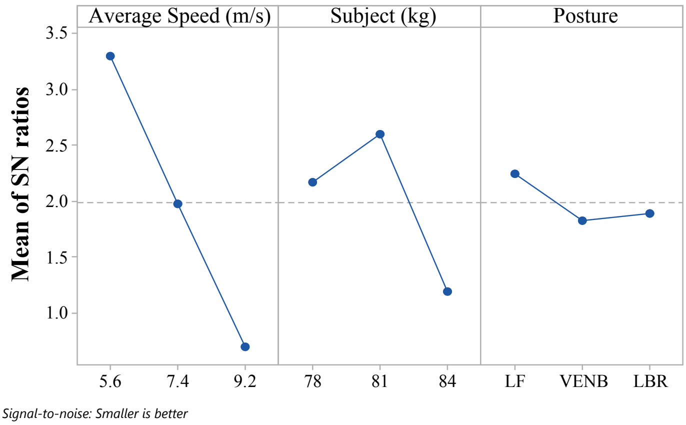

Fig. 8 Main effects plot for S/N ratios A_{wz}

Statistically, subjective discomfort responses for average speed and subjects were significant at 5% level with mean A_{wx}; insignificant at 5% level of selected factor for A_{wy} and all selected factors were significant for A_{wz} as shown in Table 2. Many study reported a significant association between subject and vibration exposure levels [1, 9].

Table 2 Analysis of variance (ANOVA) for translational axes

Weighted RMS acceleration	Source	Dof	Seq SS	Adj MS	F	P	P (%)	Rank
A_{wx}	Average speed (m/s)	2	0.021	0.0105	36.00	**0.027***	41.380	2
	Subject (kg)	2	0.026	0.0130	44.59	**0.022***	51.258	1
	Posture	2	0.003	0.0016	5.41	0.156	6.213	3
	Residual error	2	0.001	0.0003	–	–	1.149	–
	Total	8	0.051	–	–	–	100	–
A_{wy}	Average speed (m/s)	2	0.015	0.0075	8.38	0.107	77.621	1
	Subject (kg)	2	0.002	0.0010	1.10	0.476	10.182	2
	Posture	2	0.001	0.0003	0.32	0.760	2.928	3
	Residual error	2	0.002	0.0009	–	–	9.265	–
	Total	8	0.019	–	–	–	100	–
A_{wz}	Average speed (m/s)	2	0.087	0.0437	121.56	**0.008***	72.919	1
	Subject (kg)	2	0.028	0.0142	39.47	**0.025***	23.680	2
	Posture	2	0.003	0.0017	4.67	**0.0176***	2.802	3
	Residual error	2	0.001	0.0004	–	–	0.600	–
	Total	8	0.120	–	–	–	100	–

Asterisk(*) = Define the significance of the factor

The ride of tractor along translational axes affects tractor driver's comfort [10]. These affects excite vibrations because interaction of tractor-terrain along with different tractor speeds [11, 12]. Whole body vibration is evaluated in form of weighted root mean sqare acceleration along translational axes wrt different levels of speeds and driver body sitting posture conditions. The result depicts that A_w for z-axis was higher as compare to x and y axes. A study of Langer et al. [13] reported similar results effects of vibration exposure in respective axis. Such exposures may result in health-related disorder especially low back pain [14–16]. Similarly, a significant effect of postural variation on vibration exposure levels reported by Jack and Eger [17]. Therefore, tractors seat need more design efforts in form of seat material or cushion to damp such vibration exposures so as to enhance driver's ride comfort level and to increase the safe working ride.

4 Conclusion

The following conclusions have been drawn from the present study:

- The vertical axis has been observed as dominant among all the experimental conditions.
- Daily exposure found maximum under all sitting postures and exceeding exposure action value-EAV (ISO 2631-1-1997).
- Weighted RMS acceleration A_{wz} is found significant wrt average speeds, subjects and posture while A_{wx} is found significant wrt average speeds and subjects.

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References

1. A.J. Scarlett, J.S. Price, R.M. Stayner, Whole-body vibration: evaluation of emission and exposure levels arising from agricultural tractors. J. Terrramech. **44**(1), 65–73 (2007)
2. C.E. Goering, M.L. Stone, D.W. Smith, P.K. Turnquist, Human factors and safety, in *Chapter 15 in Off-Road Vehicle Engineering Principles* (ASAE, St. Joseph, MI, 2003). pp. 421–462
3. G.S. Newell, N.J. Mansfield, Evaluation of reaction time performance and subjective workload during whole-body vibration exposure while seated in upright and twisted postures with and without armrests. Int. J. Ind. Ergon. **38**(5–6), 499–508 (2008)
4. International Organization for Standardization (ISO 10326–1) (1997) ISO 2631–1 (E). Mechanical, Geneva, Switzerland
5. M.J. Griffin, *Handbook of Human Vibration.* 1st edn. (Elsevier, London, 1990)
6. N. Nawayseh, M.J. Griffin, Power absorbed during whole-body vertical vibration: Effects of sitting posture, backrest, and footrest. J. Sound Vib. **329**(14), 2928–2938 (2010)
7. W. Wang, S. Rakheja, P.É. Boileau, Effects of sitting postures on biodynamic response of seated occupants under vertical vibration. Int. J. Ind. Ergon. **34**(4), 289–306 (2004)

8. S.P. Harsha, M. Desta, A.S. Prashanth, V.H. Saran, Measurement and bio-dynamic model development of seated human subjects exposed to low frequency vibration environment. Int. J. Veh. Noise Vib. **10**(1–2), 1–24 (2014)
9. K.N. Dewangan, A. Shahmir, S. Rakheja, P. Marcotte, Vertical and fore-aft seat-to-head transmissibility response to vertical whole body vibration: gender and anthropometric effects. J. Low Freq. Noise Vib. Active Control **32**(1–2), 11–40 (2013)
10. M. Cutini, C. Costa, C. Bisaglia, Development of a simplified method for evaluating agricultural tractor's operator whole body vibration. J. Terrramech. **63**, 23–32 (2016)
11. A. Singh, L.P. Singh, S. Singh, H. Singh, C. Prakash, Investigation of occupational whole-body vibration exposure among Indian tractor drivers. Int. J. Hum Fact. Ergon. **5**(2), 151–165 (2018)
12. N. Prasad, V.K. Tewari, R. Yadav, Tractor ride vibration—a review. J. Terrramech. **32**(4), 205–219 (1995)
13. T.H. Langer, M.K. Ebbesen, A. Kordestani, Experimental analysis of occupational whole-body vibration exposure of agricultural tractor with large square baler. Int. J. Ind. Ergon. **47**, 79–83 (2015)
14. M.J. Griffin, Discomfort from feeling vehicle vibration. Veh. Syst. Dyn. **45**(7–8), 679–698 (2007)
15. N.J. Mansfield, *Human Response to Vibration* (CRC Press, 2004)
16. J. Village, C. Trask, Y. Chow, J.B. Morrison, M. Koehoorn, K. Teschke, Assessing whole body vibration exposure for use in epidemiological studies of back injuries: measurements, observations and self-reports. Ergonomics **55**(4), 415–424 (2012)
17. R.J. Jack, T. Eger, The effects of posture on seat-to-head whole-body vibration transmission. J. Low Freq. Noise Vib. Active Control **27**(4), 309–325 (2008)

Chapter 23
Workplace Environment and Its Impact on Polyhouse Workers

PromilaKrishna Chahal and Kiran Singh

1 Introduction

Polyhouse cultivation of vegetables is emerging as a specialized production technology to overcome biotic and abiotic stresses and to break the seasonal barrier to production. It also ensures round the year production of high value vegetables, especially, during off-season. Vegetable cultivation in polyhouse, not only increases the productivity but also, enhances the quality of vegetables and it is being practiced in more than fifty countries all over the world. However, in India, it is a new phenomenon and is still in its initial stage [1]. It is rather used to protect the plants from the adverse climatic conditions such as wind, cold, precipitation, excessive radiation, extreme temperature, insects and diseases. It is also of vital importance to create an ideal micro climate around the plants. This is possible by erecting a greenhouse, where the environmental conditions are so modified that one can grow any plant in any place at any time by providing suitable environmental conditions. Production of off-season vegetable nurseries under protected structure has become a profitable business. The main purpose of raising nursery plants in protected structure is to get higher profit and disease free seedlings in off season to raise early crop in protected condition or/and open field condition. The environment parameters inside polyhouses are higher than outside due to controlled condition. The temperature inside the poly house is 6–10 °C higher than outsides [2]. High temperature (up to 40 °C) and humidity (70–80%) exhibits a significant influence on the rate of photosynthesis. Generally, the higher the temperature and humidity, assuming CO_2 and light are abundant, the faster the photosynthesis takes place. By warming the air immediately around crops, polyhouses effectively extend the growing season and allow the cultivation of crops from lower latitudes [3]. The cost of the polyhouse structure plays the decisive factor for adoption and sustainability of vegetable

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production. Vegetables need very high levels of temperature with a peak of 40 °C and 80% of relative humidity, but these levels cannot be considered favorable to operators who work in this environment. The polyhouse cannot be considered a very suitable place for work operators especially in hot season. During summer time, in polyhouses, when air temperatures are already high, elevated humidity levels can increase people's risk for heat-related illnesses. Symptoms of overheating include heat cramps, heat fainting, heat exhaustion and heat stroke. Workers are forced to work in unfavorable conditions and exposed to harmful effects [4]. So keeping these problems in mind the present study was conducted to find out the environmental condition in polyhouses as well as effects of polyhouse environment on workers' health.

2 Methodology

The present study was conducted at indo-Israel project on vegetable, Karnal. Four types of polyhouses viz; Hi-tech polyhouse, Naturally Ventilated polyhouse, Walk-In-Tunnel and Anti Insect net shade house were selected for research. For Phase-I, environmental parameters including temperature, humidity and carbon-dioxide were taken from all types of polyhouses as well in conventional farming. Data was collected during working time and three replicas of each parameter were taken during research (see Tables 1 and 2).

Regarding Phase-II, 15 female workers were selected which were working 8 h daily in polyhouses. Their working pattern was studied including type of work, duration of work, age etc. Their physiological parameters were studied including heart rate, blood pressure, and lung function capacity. The effect of environmental parameters on physiological parameters was also studied. Occupational health hazards were studied in terms of physical, activity and physiological parameters associated with environmental parameters (temperature, humidity, and carbon-dioxide) of different polyhouses workers. The data was statistically analyzed by using ANOVA

Table 1 Environmental parameters

Parameters	Name of instrument
Temperature	Air quality monitor
Humidity	
Carbon-dioxide	

Table 2 Physiological parameters

Parameters	Name of instrument
Heart rate	Polar heart rate monitor
Lung function	Spirometer
Blood pressure	Sphygmomanometer and stethoscope

and response surface methodology. **In phase-I** ANOVA was used on environmental parameters to find out the significant different in environmental parameters in different polyhouses. **Regarding phase II**, response surface methodology was used to find out the effect of environmental parameters (temperature, humidity and CO_2) on workers' physiological responses (Heart rate, Blood pressure and Lung function capacity).

3 Results

According to present study, in Haryana State 614 different types of polyhouses were found under the area of 17,71,121 m^2. The total area under polyhouse farming was 0.49% of total cultivated area in Haryana State. In Haryana on polyhouse production, 50% subsidy is provided by Government of India and 15% by Government of Haryana, so the total 65% subsidy of total cost in provided to the farmers. Findings explain that financial assistance on polyhouse was varying from technology to technology.

Data in Table 3 represent the temperature of different polyhouses in different months. Results show that the temperature in conventional farming and AINSH polyhouse was found similar in all months. The temperature of AINSH was observed significantly higher to temperature in conventional farming in Jan, April and August with critical difference of 9.7, 8.7 and 10.1, except for these months, the temperature was similar in all months in AINSH and conventional farming. Alongside in NVPH and WIT the temperature was significantly higher in all months from conventional farming temperature. In the months of January, Feb., March, Nov. and Dec., the temperature of NVPH (26.0, 31.0, 33.4, 37.4 and 28.0 °C) and WIT (29.5, 33.6, 35.1, 41.5 and 31.5 °C) was found to be similar. The peak temperature was observed in WIT polyhouse in the month of May i.e. 53 °C.

Table 3 Comparison of temperature (°C) in different polyhouses of Karnal district (month wise)

Month	CF	AINSH	Hi-tech	NVPH	WIT	CD
January	17.4[a]	18.1[a]	**22.4**[b]	**26.5**[c]	**29.5**[c]	9.7
February	24.1[a]	25.4[a]	26.6[a]	**31.0** °C	**33.6**[c]	10.8
March	27.6[a]	28.0[a]	31.6[a]	33.4[b]	35.1[b]	11.4
April	32.6[a]	33.7[a]	**38.6**[b]	42.1[b,c]	**44.2**[c]	8.7
May	38.6[a]	39.7[a]	43.7[a,b]	47.8[b]	**53.9**[c]	9.2
August	37.1[a]	38.3[a]	**42.3**[b]	44.5[b,c]	**49.6**[c]	10.1
September	33.9[a]	35.5[a]	38.6[a]	41.7[a,b]	45.1[b]	7.8
October	31.6[a]	33.5[a]	36.3[a]	39.3[a,b]	42.5[b]	6.8
November	29.5[a]	30[a]	**33.4**[b]	**37.4**[c]	**41.5**[c]	8.4
December	24.0[a]	24.7[a]	26.0	**28.0**	**31.7**	9.1

CF: *conventional farming*

Table 4 Comparison of humidity (%) in different polyhouses of Karnal district (month wise)

Month	CF (°C)	AINSH (°C)	HI-TECH (°C)	NVPH (°C)	WIT (°C)	CD
January	50.8[a]	70.1[a]	55.2[a]	**81.4**[b]	**90.4**[b]	18.3
February	47.8[a]	64.9[b]	48.7[a]	78.9[b,c]	**88.1**[c]	17.2
March	44.2[a]	65.2[b]	46.3[a]	**75.1**[b]	**82.0**[b]	16.1
April	44.5[a]	62.6[b]	45.8[a]	72.1[b,c]	**78.4**[c]	12.7
May	33.1[a]	44.9[b]	35.6[a]	**61.3**[c]	**65.0** °C	17.4
August	40.8[a]	55.5[b]	42.6[a]	**67.1**[c]	**70.2**[c]	13.4
September	39.2[a]	59[b]	41.4[a]	69.1[b,c]	**73.0** °C	12.2
October	42.8[a]	58.1[b]	44.8[a]	**71.4**[c]	**78.3**[c]	13.7
November	45.7[a]	62.9[b]	48.7[a]	**76.3**[c]	**82.6**[c]	11.4
December	55.9[a]	72.5[b]	60.8[a]	82.7[b]	**92.1**[c]	12.4

CF: *conventional farming*

Results in Table 4 reflect the humidity level in different polyhouse in different months. Finding in table reveals that the level of humidity in conventional farming and hi-tech polyhouse was significantly ($p < 0.05$) similar in all months. Regarding AINSH, the level of humidity was significantly ($p < 0.05$) higher to conventional farming level of humidity with critical difference 18.3, 17.2, 16.1, 12.7, 17.4, 13.4, 12.2, 13.7, 11.4 and 12.4 in the months of Jan., Feb., March, April, May, Aug. Sept. Oct., Nov., and Dec., respectively. Results in table elucidate that the humidity in NVPH and WIT was significantly higher to conventional farming, AINSH and Hi-tech with critical difference of 18.3, in Jan., 12.7, in April, 17.4 in May, 13.7 in Oct., 11.4 in Nov. and 12.4 in Dec. As per data, the level of humidity in NVPH and WIT polyhouses was significantly higher than other types of polyhouses as well as to conventional farming.

Data in Table 5 represent the level of CO_2 in different polyhouses in comparison to conventional farming. Findings in table disclose that the level of CO_2 in Hi-tech polyhouse was found to be similar to conventional farming with a few variations in months of April, May, Aug., Nov. and Dec. The level of CO_2 in AINSH, NVPH and WIT was found to be significantly ($p < 0.05$) increasing to conventional farming level. The level of CO_2 in WIT was observed to be high in all months with level of 15.4.1 ppm (Jan.), 1166.5 ppm (Feb.), 955.9 ppm (March), 833.5 ppm (April), 739.3 ppm (May), 7008.4 ppm (Aug.), 704.3 ppm (Sept.), 840.7 ppm (Oct.), 1047.8 ppm (Nov.) and 1585.9 ppm (Dec.), respectively in comparison with conventional farming and other polyhouses (Hi-Tech, AINSH and NVPH) (see Tables 6, 7 and 8).

Table 5 Comparison of CO_2 (ppm) in different polyhouses of Karnal district (month wise)

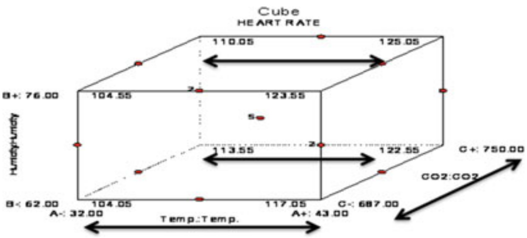
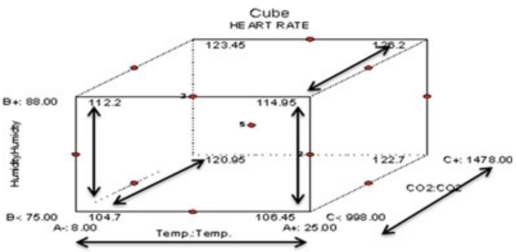
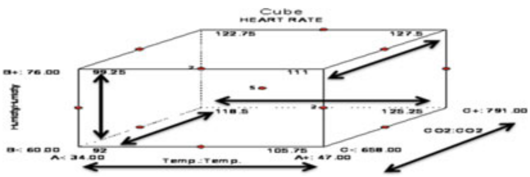
Month	CF	HI-TECH	AINSH	NVPH	WIT	CD
January	327.1[a]	488.2[b]	879.9[c]	1072.1[c,d]	**1504.1**[d]	10.7
February	313.4[a]	451.2[b]	628.8[c]	**962.6**[d]	**1166.5**[d]	17.1
March	325.8[a]	414.5[b]	606.4[c]	831.8[c,d]	**955.9**[d]	15.4
April	315.8[a]	358.5[a]	536.2[b]	762.7[b,c]	**833.5**[c]	18.1
May	379.5[a]	397.3[a]	571.8[b]	**717**.0 °C	**739.3**[c]	14.8
August	359.7[a]	394.1[a]	588.7[b]	**673.4**[b]	**708.4**[b]	20.2
September	347.4[a]	441.2[b]	626.0 °C	**687.8**[c]	**704.3**[c]	16.6
October	316.5[a]	418.5[b]	686.3[c]	**812.3**[c]	**840.7**[c]	21.6
November	352.6[a]	442.9[a]	802.9[b]	**907.5**[b]	**1047.8**[b]	24.2
December	366.3[a]	453.7[a]	892.5[b]	**1118.1**[b]	**1585.9**[b]	25.4

CF: *conventional farming*

4 Summary and Conclusion

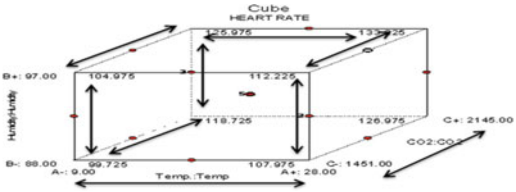
In study it was found that high level of environmental parameters were found in all type of polyhouses, especially in WIT and NVPH. Findings explain that temperature was found higher in WIT polyhouses, especially in the month of May i.e. above 50 °C. Temperature was observed more than 25% higher in WIT polyhouses and more than 18% in NVPH in comparison to conventional farming throughout the year. The reason may be air tight structure of polyhouses without any ventilation. Without ventilation and cooling system the temperature within the polyhouse can increase to more than 45 °C [5]. Average temperature differences between inside and outside was 10 °C and 18 °C in winter and summer season, respectively. In WIT polyhouse, temperature was found higher at noon time (10:00 am–5:00 pm) in both seasons i.e. above 25 °C in winter and above 40 °C in summer season [6]. The concentration of humidity was also higher in WIT and NVPH polyhouses, about 40% higher humidity in comparison to conventional farming in all month with maximum in months of January, February, November and December. The level of humidity was found above 90% at the time of 11:00 pm to 5:00 am in both the seasons i.e. summer and winter. Relative humidity above 70% is optimum for plant growth. Humidity in polyhouses is controlled by stopping ventilation; because higher humidity reduces the evapotranspiration, hence the water requirement of plant in polyhouses also reduces [7]. Concentration of CO_2 was found significantly higher in WIT and NVPH polyhouses. In WIT polyhouse, CO_2 concentration was more than 50% higher in comparison to conventional farming and as well as from other polyhouses also. The maximum increase in CO_2 concentration was observed at

Table 6 Association between environmental parameters and heart rate workers **n = 15**

Environmental parameters	*NVPH (summer)*
A (temperature)	52.57**
B (humidity)	Ns
C (carbon-dioxide)	8.11*
	Figure 1 gives a clear picture of association between environmental parameters and heart rate level of workers. Data reflect that increasing level of temp. (A), CO_2 (C), A^2 (temp.^{2}) and BC (humidity: CO_2) were significantly (F = 52.57, 8.11, 13.83 and8.22) increasing the heart rate of workers i.e. from 104.05 b^{-min} to 117.05 b^{-min}, from 117.05 b^{-min} to 112.55 b^{-min}, from 113.55 to 122.55 b^{-min} and from 110.05 b^{-min} to125.05 b^{-min}, respectively
Environmental parameters	*NVPH (winter)*
A (temperature)	106.48**
B (humidity)	28.08**
C (carbon-dioxide)	575.24**
	Figure 2 illustrates the association between environmental parameters and heart rate of NVPH workers. Data reflect that increasing level of temperature (8–25.8 °C), humidity (75–88%), CO_2 (998–1478 ppm), temp: humidity and $CO_2{}^2$ was significantly (F = 106.48, 28.8, 575.24, 5.89, 7.62 and 7.29) increasing the heart rate i.e. from 104.7 b^{-min} to 106.45b^{-min}, from 104.7 b^{-min} to 112.2b^{-min}, from 106.47 to 120.95 b^{-min} and from 114.95 b^{-min} to 126.2 b^{-min}, respectively
Environmental parameters	*WIT (winter)*
A (temperature)	18.86**
B (humidity)	117.90**
C (carbon-dioxide)	24.3**
	Results in Fig. 3 revealed that increasing level of temp. (A), humidity (B), CO_2 (C) AB (temp.: humidity) A^2 (temp.^{2}) and C^2 ($CO_2{}^2$) were significantly (F = 18.86, 117.90, 24.3, 42.5, 10.29, 8.85) associated with heart rate of WIT workers in summer season

(continued)

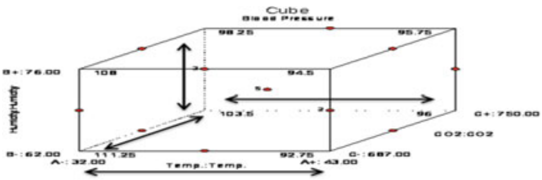
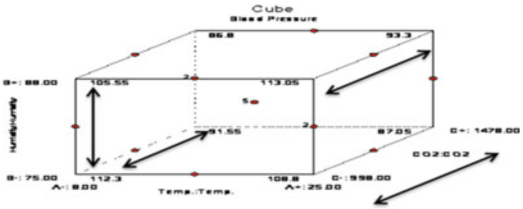
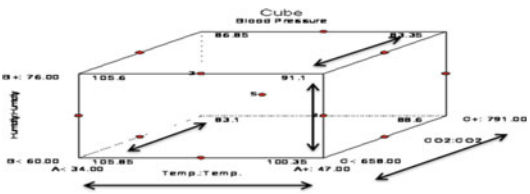
Table 6 (continued)

Environmental parameters	*WIT (winter)*
A (temperature)	28.1**
B (humidity)	58.92**
C (carbon-dioxide)	28.3**
	Data in Fig. 4 give a clear picture of findings that all the environmental parameters (A, B, C, AB, AC, AB, A^2, B^2, C^2) were significantly (F = 28.18, 58.92, 28.3, 36.8, 16.7, 7.28, 8.92, 21.73, 6.91) associated with heart rate of WIT workers

night time (11:00–5:00) i.e. up to 2500 ppm in winter and up to 1600 ppm in summer season, because polyhouses were air tight, trap CO_2 released by plant during the night and make it available during the day time. Mulching and soil respiration also increases the CO_2 level in polyhouses. Optimum CO_2 level in polyhouses should be 5–10 times higher than conventional farming i.e. 1500–3000 ppm. Similar result was reported that high level of temperature (up to 40 °C) and humidity (70–80%) exhibits a significant influence on the rate of photosynthesis, generally the higher temperature and humidity, assuming CO_2 and the faster photosynthesis takes place by warming the air immediately around the crops. That's why polyhouses effectively extend the growing season and allow the cultivation of crop from lower latitude [8].

Carrying out prolonged physical activity in a hot, humid environment increases the risks of heat exhaustion and heat stroke [9]. The effect of environmental parameters (temperature, humidity and CO_2) on physiological parameters (heart rate, blood pressure and lung function capacity) of the workers was probed out. According to a study the potential effects of heat exposure on occupational health and safety are both direct and indirect. Exposure to high ambient temperatures causes an increase in body temperature, which translates into cutaneous vascular dilation, sweating, and increased heart rate [10]. Carrying out prolonged physical activity in a hot, humid environment increases the risks of heat exhaustion and heat stroke. The presented data clarifies the association between environmental parameters (temp., humidity and CO_2) and physiological health of workers in different types of polyhouses (Hi-Tech, AINSH, NVPH and WIT). Regarding NVPH, in summer high concentration of temperature, humidity:CO_2 and temp.: humidity) were significantly decreasing the lung function capacity (1.696–0.82 l/s, 1.56–1.01 l/s and 1.69–1.25 l/s) of NVPH workers. A study on 21 subjects of polyhouse farming was conducted to test the lung function capacity of workers by spirometry immediately before and after a 4-h work

Table 7 Association between environmental parameters and blood pressure of workers **n = 15**

Environmental parameters	*NVPH (summer)*
A (temperature)	101.21**
B (humidity)	Ns
C (carbon-dioxide)	Ns
	Results in Fig. 5 viewed that increasing concentration of A (temp.), AB (temp.:humidity), A^2 (temp.^{2}) and B^2 (humidity^2) were significantly ($F = 101.21, 9.7, 12.08, 63.90$) deacresing the blood pressure of workers i.e. 111.25 mmHg–92.75 mmHg, 111.25 mmHg–103.5 mmHg, 103.5 mmHg–96 mmHg and 103.5 mmHg–98.25 mmHg, respectively
Environmental parameters	*NVPH (winter)*
A (temperature)	Ns
B (humidity)	4.24
C (carbon-dioxide)	81.30**
	Data pertaining effect of environmental parameters on blood pressure of workers shows that high concentration of humidity (B), CO_2 (C), temp.: humidity (AB), C^2 ($CO_2{}^2$) were observed significantly decreasing blood pressure of NVPH workers; 112.3 mmHg–105.55 mmHg, 108.8 mmHg–87.05 mmHg, 112.3 mmHg–91.55 mmHg and 113.05 mmHg–93.3 mmHg, respectively
Environmental parameters	*WIT (winter)*
A (temperature)	9.31*
B (humidity)	Ns
C (carbon-dioxide)	501.39**
	Figure 7 cleared that blood pressure of workers was found to be associated with A, C, AB, AC, C^2. Data reflect that blood pressure was significantly decreasing with increasing rate of temperature, carbon-dioxide, temperature: humidity, temperature: CO_2 and $CO_2{}^2$

(continued)

Table 7 (continued)

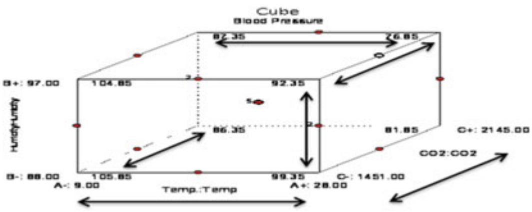
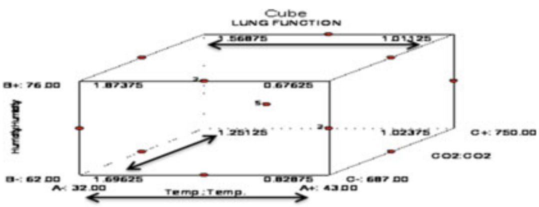
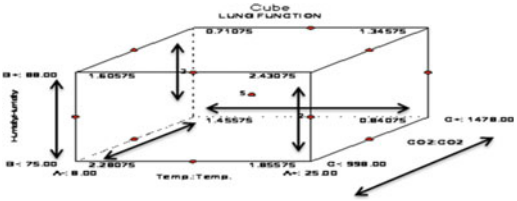
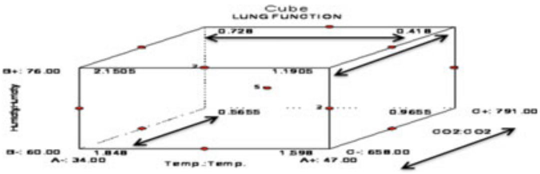
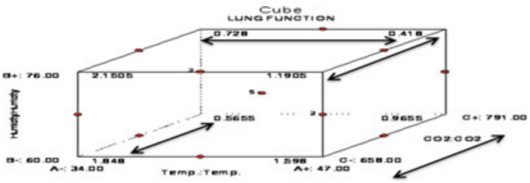
Environmental parameters	*WIT (winter)*
A (temperature)	12.68*
B (humidity)	Ns
C (carbon-dioxide)	53.73**
	Findings in Fig. 8 revealed that increasing level of temp. (9–28 °C) CO_2 (1451 ppm–2145 ppm), temperature: humidity, temp.:CO_2, humidity: CO_2, CO_2^2 were significantly decreasing the blood pressure of workers i.e. from 105.85 mmHg to 99.35 mmHg, from 99.99.5 mmHg to 81.85 mmHg, from 105.85 mmHg to 86.35 mmHg, from 99.35 mmHg to 92.35 mmHg from 87.35 mmHg to 76.85 mmHg and from 92.35 mmHg to 76.85 mmHg, respectively

Table 8 Association between environmental parameters and lung function capacity of workers **n = 15**

Environmental parameters	*NVPH (summer)*
A (temperature)	27.07**
B (humidity)	Ns
C (carbon-dioxide)	Ns
	Findings in Fig. 9 illustrate that high concentration of temperature (A), BC (humidity: CO_2) and AB (temp.: humidity) were significantly decreasing the lung function capacity (1.696–0.82 l/s, 1.56–1.01 l/s and 1.69–1.25 l/s) of NVPH workers
Environmental parameters	*NVPH (winter)*
A (temperature)	Ns
B (humidity)	9.2
C (carbon-dioxide)	40.98**

(continued)

Table 8 (continued)

	Figure 10 illustrates that lung function capacity of NVPH workers was significantly ($F =$ 9.2, 40.98, 23.2, 3.36 and 7.83) affected by humidity, CO_2, AB (temp.: humidity), A^2 (temp.^{2}),and B^2 (humidity^2)
Environmental parameters	*WIT (winter)*
A (temperature)	Ns
B (humidity)	Ns
C (carbon-dioxide)	110.9**
	Results in Fig. 11 represent the association between environmental parameters and lung function capacity of WIT workers. Fig. shows that increasing value of CO_2, AB (temperature: humidity) and C^2 ($CO_2{}^2$) were significantly decreasing the lung function capacity from 1.59 l/s to 0.96 l/s, from 1.84 l/s to 0.56 l/s and 1.19 l/s to 0.41 l/s, respectively
Environmental parameters	*WIT (winter)*
A (temperature)	18.71**
B (humidity)	Ns
C (carbon-dioxide)	15.91*
	Figure 12 divulges the association of lung function capacity of workers with environmental parameters (temperature, humidity, CO_2). Findings explain that CO_2, AB, BC, C^2 were significantly affecting lung function capacity of WIT workers in winter season

period. Workers had statistically significant decrements in flow rates ranging from 3.3% (mean FVC) to 11.9% (mean FEF25–75) [11]. So, the environmental condition of polyhouses was significantly deteriorating the health of workers.

References

1. D.S. Murthy, B.S. Prabhakar, S.S. Hebbar, V. Srinivas, M. Prabhakar, Economic feasibility of vegetable production under polyhouse: a case study of capsicum and tomato. J. Hortic. Sci. 4(2), 148–152 (2009)
2. R.K. Yadav, P. Kalia, H. Choudhary, Z. Husain, B. Dev, low-cost polyhouse technologies for higher income and nutritional security. Int. J. Agric. Food Sci. Technol. **5**(3), 191–196 (2014)
3. N. Patel, S. Rajput, Environment monitoring and estimation of water requirement inside a polyhouse through (2010)
4. C.J. Portier, A human health perspective on climate change: a report outlining the research needs on the human health effects of climate change. Research Triangle Park, NC: Environmental Health Perspectives/National Institute of Environmental Health Sciences (2012). www.niehs.nih.gov/climatereport
5. J. Calpas, Components of the greenhouse system for environmental control. Agriculture and rural development (2003). http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/opp2892#1
6. A. Gusman, A. Marucci, L. Salvatori, Control of the climate parameters inside greenhouses to defende workers Health, in *International Conference: Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems*, Ragusa, Italy (2008)
7. B. Singh, B. Singh, B. Kumar, L.M. Chadha, Working group report on development of protected cultivation in Haryana. Government of Haryana, Haryana Kisan Ayog CCS Haryana Agricultural University Campus, Hisar (2007)
8. R.C. Upadhyaya, Socio-economic implications and opportunities for women in floriculture (2009). http://www.floriculturetoday.in/socio-economicimplications-opportunities-for-women-infloriculture.html
9. T. Kjellstrom, The 'Hothaps' programme for assessing climate change impacts on occupational health and productivity: an invitation to carry out field studies. Glob Health Action **2**, 10–17 (2009)
10. R.D.I. Adam-Poupart, M. Palotas, G. Vetro, I. Csolle, M. Nehez, M. Zimanyl, A. Ferke, E. Huszta, L. Nagymajtenyl, Biological monitoring and health surveillance of a group of greenhouse pesticides sprayers. Toxicol Lett. **33**, 91–105 (2013)
11. J. Kelley, M.S. Donham, C. Donald, M.D. Zavala, J. Merchant, Acute effects of the work environment on pulmonary functions of swine confinement workers. Am. J. Ind. Med. **5**(5), 367–375 (2007)

Chapter 24
Occupational Strain of Grinders in Foundry

Das Chandan, Banerjee Debamalya, Bhattacharyya Bidyut Kumar, and Samanta Amalendu

1 Introduction

In ergonomist device work system encourages the work personnel to perform their activity without excessive fatigue, so that at the end of the workday not only can they recover from work-induced fatigue for returning to work on the next day but also they will be able to enjoy their off duty time [1, 2]. The body's response to physical workload coupled with thermal load involves musculoskeletal and cardio-respiratory system [3, 4].

Any kind of muscular activity demand energy which creates load on the body system leading to increase in heart rate, body temperature, oxygen consumption, etc. [5–7]. Physiological criteria for selecting thermal limits for everyday works have been extensively investigated. The thermal limit value for heat stress should be set as corrected effective temperature (CET) of 30 °C, in case of acclimatized worker engaged in moderate types of activities [8]. Physiological gradation of different activities has been proposed by different researchers with respect to the physiological response at work [9, 10]. Many authors have attempted to establish an optimum work limit expressed in terms of percentage of maximum aerobic power of the worker appropriate to a specific occupational task [11, 12]. Several studies have been carried out in the past in different activities in different workplaces like iron

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and steel industries, cotton jute, soap and detergent industries, glass and ceramic industries [13–15]. The grinding job which is common to many workplaces has not been studied systematically. The present paper is a brief account of the physical strain of a group of grinders in a foundry on a regular basis.

2 Methodology

In the present investigation, it was decided to examine the physical strain of two types of grinders (Figs. 1 and 2) over a period of a day shift work and accordingly workers were observed over a period of five spells where three spells were before lunch and two were after lunch.

A foundry is a place where metal is melted and formed into particular shapes. Grinding is one of the activities involved in finishing different products.

Sites of WorkPlace: The study was conducted in the district of Howrah, West Bengal, India, where large number of foundries were located. The present study was conducted in three different foundries where the products were similar in nature. Two types of grinding activities were examined and they were heavy grinding and pencil grinding.

Fig. 1 Heavy grinding operation

Fig. 2 Pencil grinding operation

Table 1A Physical characteristics of heavy grinder

Sl. no	Operation	Height (m)	Weight (kg)	Age (year)	BSA (m^2)	BMI (kg/m^2)	Experience (year)
1	Grinding (heavy)	1.6	48	22	1.47	18.75	3
2	Grinding (heavy)	1.63	55	28	1.58	20.7	10
3	Grinding (heavy)	1.66	52	18	1.56	18.87	2
4	Grinding (heavy)	1.6	59	23	1.61	23.05	4
5	Grinding (heavy)	1.68	72	35	1.81	25.51	15
6	Grinding (heavy)	1.62	47	24	1.47	17.91	5
7	Grinding (heavy)	1.69	70	36	1.8	24.51	16
8	Grinding (heavy)	1.63	67	32	1.72	25.22	14
9	Grinding (heavy)	1.63	54	24	1.57	20.32	6
10	Grinding (heavy)	1.65	57	25	1.62	20.94	6
Mean		1.64	58.10	26.70	1.62	21.58	8.10
SD		0.03	8.85	5.91	0.12	2.81	5.24

Table 1B Physical characteristics of pencil grinder

Sl. no	Operation	Height (m)	Weight (kg)	Age (year)	BSA (m^2)	BMI (kg/m^2)	Experience (year)
5	Grinding (pencil)	1.67	48	22	1.52	17.21	4
7	Grinding (pencil)	1.63	50	38	1.52	18.82	19
8	Grinding (pencil)	1.65	68	53	1.75	24.98	33
11	Grinding (pencil)	1.65	52	26	1.56	19.1	7
13	Grinding (pencil)	1.62	61	33	1.64	23.24	12
Mean		1.64	55.80	34.40	1.60	20.67	15.00
SD		0.02	8.44	12.10	0.10	3.28	11.55

Table 2A Working heart rate (HR) in different spells of heavy grinding operation

Sub. no	TWA (1st spell)	TWA (2nd spell)	TWA (3rd spell)	TWA (4th spell)	TWA (5th spell)
1 h (bpm)	118.60	122.60	126.60	120.60	124.60
2 h (bpm)	111.61	113.61	116.61	112.61	116.61
3 h (bpm)	128.41	130.41	133.42	125.92	128.41
4 h (bpm)	123.39	126.39	130.39	124.39	129.39
5 h (bpm)	123.98	126.98	130.98	125.98	130.98
6 h (bpm)	117.05	120.05	125.05	119.05	125.05
7 h (bpm)	123.30	126.30	131.30	125.30	131.30
8 h (bpm)	122.68	124.68	127.68	123.68	127.68
9 h (bpm)	122.07	124.07	129.06	123.07	129.06
10 h (bpm)	116.87	119.87	123.87	118.87	124.87
Mean (HR)	120.80–121	123.50–124	127.50–128	121.95–122	126.79–127
SD (HR)	4.77	4.72	4.84	4.22	4.32

Table 2B Working heart rate (HR) in different spells of pencil grinding operation

1 HR (bpm)	96.44	99.44	102.44	98.44	101.44
2 HR (bpm)	96.13	99.13	103.14	97.14	102.14
3 HR (bpm)	96.00	98.00	102.00	97.00	103.00
4 HR (bpm)	116.00	119.00	123.00	117.00	124.00
5 HR (bpm)	102.92	105.92	109.92	104.92	109.92
Mean (HR)	101.50–102	104.30–104	108.10–108	102.90–103	108.10–108
SD (HR)	8.70	8.87	9.02	8.61	9.61

Table 3A Energy expenditure (EE) in different spells of heavy grinding operation

Sub. no	TWA (1st spell)	TWA (2nd spell)	TWA (3rd spell)	TWA (4th spell)	TWA (5th spell)
1 EE (KCal)	4.3	4.7	5.7	4.5	5.5
2 EE (KCal)	4.6	5.0	5.3	4.9	5.2
3 EE (KCal)	5.2	5.7	6.2	5.5	6.0
4 EE (KCal)	4.9	5.2	5.5	5.0	5.8
5 EE (KCal)	5.6	5.9	6.2	5.7	6.0
6 EE (KCal)	5.3	5.7	6.0	5.5	5.8
7 EE (KCal)	4.8	5.3	5.8	5.0	5.5
8 EE (KCal)	5.4	6.0	6.6	5.6	6.3
9 EE (KCal)	4.8	5.3	5.8	5.0	5.6
10 EE (KCal)	4.6	5.1	5.4	4.9	5.3
Mean (EE)	4.9	5.4	5.9	5.2	5.7
SD (EE)	0.42	0.43	0.41	0.40	0.33

Table 3B Energy expenditure (EE) in different spells of pencil grinding operation

Sub. no	TWA(1st Spell)	TWA (2nd spell)	TWA (3rd spell)	TWA (4th spell)	TWA (5th spell)
1 EE (KCal)	2.9	3.4	4.0	3.1	3.7
2 EE (KCal)	2.8	3.0	3.3	3.0	3.2
3 EE (KCal)	2.7	3.0	3.4	2.8	3.2
4 EE (KCal)	4.0	4.2	4.4	4.1	4.3
5 EE (KCal)	3.0	3.3	3.6	3.2	3.5
Mean (EE)	3.1	3.4	3.7	3.2	3.6
SD (EE)	0.5	0.5	0.5	0.5	0.5

Subjects: After the selection of sites, extensive interaction was carried out with grinders. During these interactions grinders were motivated to cooperate as required by the design of the study, After careful and repeated follow-up, a total number of 15 grinders engaged in two categories of grinding activities were selected for the study.

Grinding Operation: Castings obtained from knockout table have uneven surface, which is to be cleaned and smoothed as far as possible. They are put on a floor and kept on working Table 4; a grinding machine weighing 5.5 kg was used for the removal of uneven surface. But in case of pencil grinding machine weighting 3 kg was used for the removal of small items of uneven surface. After that, the components get ready for necessary machining work.

Height, Weight, BMI And BSA: Weight of the subjects were measured in kg by a sensitive human weighing balance and heights were measured in centimetres using an anthropometric rod. Body mass index (BMI) was expressed in $kg \cdot m^{-2}$ and body surface area (BSA) was expressed in m^2 [7].

Field Investigation: Each of the subjects was investigated during work shifts of the day, when he was engaged in grinding activities. Measurements were taken in order, not to disturb the normal work pace of the subjects. No instructions were given

Table 4 ANOVA analysis of heavy grinder (shapiro wilk assumption)

ANOVA

		Sum of squares	df	Mean square	F	Sig.
TWAHR	Between groups	347.123	4	86.781	4.126	0.006
	Within groups	946.451	45	21.032		
	Total	1293.574	49			
TWAEE	Between groups	5.816	4	1.454	8.976	0.000
	Within groups	7.289	45	0.162		
	Total	13.105	49			

Significant differences were found among the spells (p <0.05) by one way anova to the grinders to control their work method as it may interfere with the primary exploratory objective of the study. The grinders maintain their habitual pattern for works, work-rest regimen and normal work pace.

The following measurements were taken.

Working Heart Rate and Estimated Energy Expenditure: The heart rate of grinders during grinding was registered continuously throughout the work shift involving five different work spells by Suunto Ambit 3 Peak heart rate (HR) monitor. The Suunto Ambit 3 Peak HR monitor has been designed to monitor the energy expenditure (cost) continuously converting heart rate to energy expenditure (EE) (cost) as Kcal/min.

Tympanic membrane thermometer: In this temperature of grinders were recorded by Barun thermoscan 5.

Environmental Heat Load: Dry bulb (DB), weight bulb (WB), natural wet bulb and radiant heat were measured using asman hygrometer. Radiant heat was measured by Globe Thermometer (GT). Natural wet bulb temperature was recoded as per guideline by ACGIH [14] and WHO [8], and Air velocity (AV) was measured to determine the cooling time of a Blue Kata thermometer. From the Kata factor of the thermometer used and the already determined dry bulb temperature, the velocity of the air movement was calculated using the appropriate nomogram.

Heat Stress Index: Wet bulb Globe Temperature (WBGT) and corrected effective temperature (CET). WBGT and CET are worked out as Index of thermal stress. The measurements were made at frequent intervals to get an average picture of the heat load throughout the shift.

Scale of heaviness of workload was assessed based on working heart rate and energy expenditure (cost).

Parameter Classification of workload.

Parameter	Classification of work load	
Working heart rate $\left(\text{beats}\cdot\text{min}^{-1}\right)$		
	Light	<90
	Moderate	$<90-110$
	Heavy	$>110-130$
	Very Heavy	$>130-150$
	Extremely Heavy	>150
Energy Expenditure $\left(\text{Kcal}\cdot\text{min}^{-1}\right)$		
	Light	$1-2.5$
	Moderate	$<2.5-4$
	Heavy	$>4-6$
	Very Heavy	$>6-8$
	Extremely Heavy	>8

Ramanathan et al. [4] and Astrand [11].

Experimental Details

Observations were made over a period from March 2018 to July 2018 involving five spells of work.

Thermal Environment: Different thermal environment parameters were monitored and expressed as WBGT and CET. The instruments required are assman hygrometer, natural wet bulb temperature, globe thermometer and Kata Thermometer. A stand was required to suspend those thermometers that were placed near the subject who was performing work.

Parameter measurement: The physiological variable studied included heart rate estimated energy expenditure and they were monitored continuously with the aid of Suunto Ambit 3 peak HR and body temperature recorded in the form of tympanic membrane thermoscan 5. The data analysis has been done using IBM SPSS Version 24 software including treatment of data for descriptive statistics and appropriate statistical significance test.

A. *Result*

The physical characteristics of the two groups of grinders are summarized in Tables 1A and 1B.

It was evident from the table that mean age, height, BMI and BSA of the heavy and pencil grinders were 26.7 years, 1.64 m, 21.58 kg/m^2 and 1.62 m^2 and 34.4 years, 1.64 m, 20.67 kg/m^2 and 1.6 m^2, respectively. The result of 't' test with respect to different parameters of two groups yield no significant variation at an α level of >0.05. Therefore these two group of workers with respect to their physical characteristics appears to be homogeneous in nature. Physical strain and in grinding activities.

Heart rate responses: The TWA working heart rate profile of two different groups of workers in five different spells of work before and after lunch are present in Tables 2A and 2B.

It can be seen from Table 2A that the average heart rate increased from 121 to 128 bpm before lunch and again from 122 to 127 bpm after the lunch break. Similarly in the case of pencil grinder the heart rate of different spells were also found to be increased from 102 to 108 bpm before lunch and from 103 to 108 bpm after lunch. The physical strain of grinders (Heavy) in terms of estimated energy cost from one spell of works to others, before lunch it varied from 4.9 to 5.9 kcal/min but after lunch it varied between 5.2 and 5.7 kcal/min as can be seen from Tables 3A and 3B.

The variable (heart rate and energy expenditure) studied in the present investigation were normally distributed as per Shapiro Wilk assumption, where the *p* value was at a level of <0.05. The one-way ANOVA was performed among the five different spells of two different parameters. The results are depicted in Table 4.

All the variables were normally distributed as per Shapiro Wilk assumption ($p <$ 0.05). One-way ANOVA was performed among the spells.

Significant differences were found among the spells ($p < 0.05$) by one-way ANOVA.

Table 5 ANOVA analysis of heavy grinder (robust test)

Robust tests of equality of means		
		Sig.
TWAHR	Welch	0.017
	Brown Forsythe	0.006
TWAEE	Welch	0.000
	Brown Forsythe	0.000

[a]Asymptotically F distributed
Scheffe's post hoc analysis states the inter-group significant differences individually ($p < 0.05$)

It can be seen from the table that an increase in heart rate and energy expenditure from one spell to the other were statistically significant in both the parameters at a level $p < 0.05$. The robust test (Welch and Brown Forsythe) as shown in Table 5 were performed to evaluate the homogeneity of variance. Robust tests (Welch and Brown Forsythe) were performed to evaluate the homogeneity of variances. They were significant at $p < 0.05$.

Similar statistical tests were performed in the case of pencil grinder. The result of statistical analysis is showed similar to that described in Tables 6 and 7 and they are found to be significant at a level of $p < 0.05$.

Table 6 ANOVA analysis of pencil grinder (shapiro wilk assumption)

ANOVA						
		Sum of squares	df	Mean Square	F	Sig.
TWHR	Between groups	181.864	4	45.466	0.576	0.683
	Within groups	1,577.692	20	78.885		
	Total	1,759.556	24			
TWAEE	Between groups	1.362	4	0.340	1.389	0.274
	Within groups	4.904	20	0.245		
	Total	6.266	24			

Scheffe's post hoc analysis states the inter-group significant differences individually ($p < 0.05$)

Table 7 ANOVA of pencil grinder (robust test)

Robust tests of equality of means		
		Sig.
TWAHR	Welch	0.753
	Brown Forsythe	0.683
TWAEE	Welch	0.390
	Brown Forsythe	0.274

[a]Asymptotically F distributed

There are significant differences found among the spells ($p < 0.05$) by one-way ANOVA. Robust tests (Welch and Brown Forsythe) were performed to evaluate the homogeneity of variances. They were significant at $p < 0.05$.

Robust tests (Welch and Brown Forsythe) were performed to evaluate the homogeneity of variances. They were significant at $p < 0.05$.

The result of average rise in body temperature in the form of tympanic temperature before and after just end of the shift were found to be 98.36 and 99.56 °F for heavy grinders and 98.4 and 99.5 °F for pencil grinders as shown in Table 8.

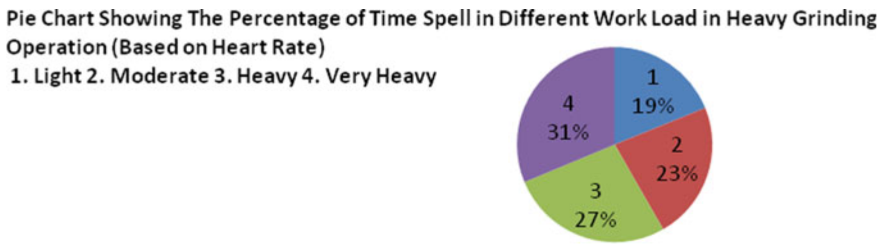
The 't' test was performed between pre- and post-working temperature in both the groups. The results are presented in Table 8 and they are statistically significant at a level $p < 0.05$.

Pie Charts 1 and 2 for heavy grinder and Pie Charts 3 and 4 for pencil grinder have been drawn based on heart rate and energy expenditure showing in percentage distribution of workload (based on working heart rate and energy expenditure) in relation to percentage of time spent in five different spells for both the grinding

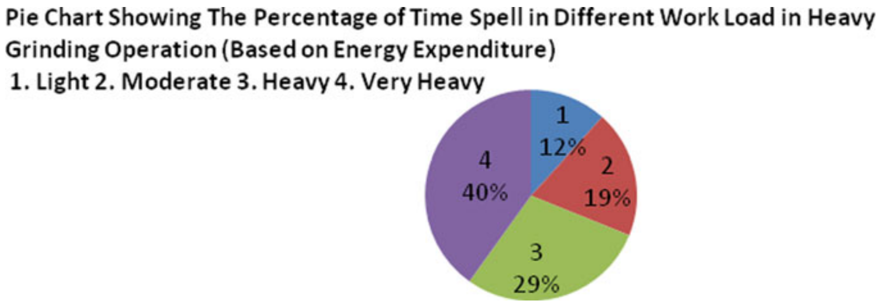
Table 8 Tympanic temperature of heavy grinder

Sl no	Operation	Pre working ear temperature (°F)	Post working ear temperature (°F)
1	Grinding (heavy)	98.32	99.64
2	Grinding (heavy)	98.28	99.98
3	Grinding (heavy)	98.42	99.46
4	Grinding (heavy)	98.40	99.32
5	Grinding (heavy)	98.32	99.62
6	Grinding (heavy)	98.34	99.46
7	Grinding (heavy)	98.44	99.58
8	Grinding (heavy)	98.32	99.32
9	Grinding (heavy)	98.36	99.58
10	Grinding (heavy)	98.40	99.66
Mean		98.36	99.56
SD		0.05	0.19

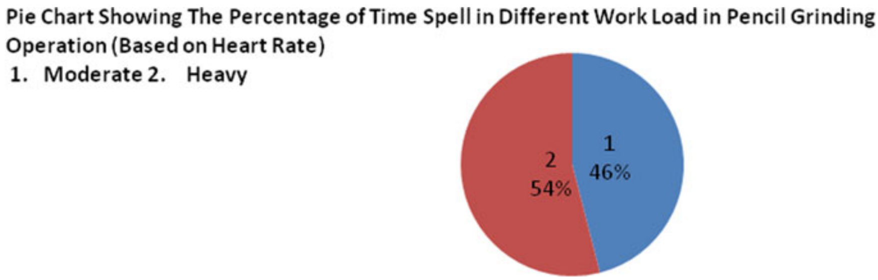
Statistical analysis of heavy grinder



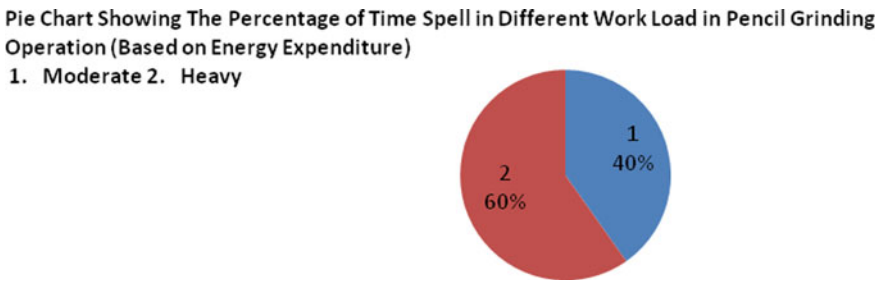
Pie Chart 1 Heavy grinder



Pie Chart 2 Heavy grinder



Pie Chart 3 Pencil grinder



Pie Chart 4 Pencil grinder

task. It can be seen from both the Pie Chart diagrams the percentage distribution of workload in relation to percentage of time spent in different spells are found to be more or less uniform throughout the shift for heavy grinder and they found to vary between light to very heavy. It can also be seen from these figures that more or <60% of time in each spell was found to engage in heavy to very heavy workload and rest of the time the workload varied between light to moderate. In case of pencil grinding, the percentage distribution of workload was found to be between moderate to heavy and they are in the proportion of more or <45% of moderate and more or <55%

Table 8A t-Test analysis of heavy grinder (ear temperature)

Independent sample test			
	t-Test for equality of means		
	T	df	Sig. (two-tailed)
EarTemp	−19.081	18	0.000

There is a significant difference found at $p < 0.05$

Table 9 Tympanic temperature of pencil grinder

Sl no.	Operation	Pre working ear temperature (°F)	Post working ear temperature (°F)
1	Grinding (pencil)	98.46	99.54
2	Grinding (pencil)	98.34	99.54
3	Grinding (pencil)	98.38	99.68
4	Grinding (pencil)	98.48	99.36
5	Grinding (pencil)	98.52	99.44
Mean		98.44	99.51
SD		0.07	0.12

Table 9A t-Test analysis of pencil grinder (ear temperature)

Independent sample test			
	t-Test for equality of means		
	T	df	Sig. (two-tailed)
Ear Temp	−17.013	8	0.000

There is a significant difference found at $p < 0.05$

heavy and the result of statistical analysis of Tympanic Temperature (Ear) showed in Tables 11, 12, 13 and 14.

t-Test was performed between the Pre working ear temp and Post working ear temp for Pencil Grinders ($n = 5$).

t-Test was performed between the Pre working ear temperature and Post working ear temperature for Heavy Grinders ($n = 10$).

t-Test was performed between the Pre working ear temperature and Post working ear temperature for Pencil Grinders ($n = 5$).

The thermal environmental condition at workplace. Table 10 depicts the thermal environmental scenario in two different working areas. It is seen that whatever variations do exist in different areas with respect to thermal environmental parameters do not reveal any statistically significant variation. Therefore it can be assumed that the thermal environment does not affect the elicited physiological response of the grinders in two different ways. keeping this point in mind the average picture of environmental heat load experienced by the grinders is represented in Table 10. This illustrates that the close proximity of DB (33.1 °C), WB (28.4 °C) and GT (38.2 °C)

Table 10 Prevalence thermal environment of workplace

Sl. no	Parameters	Heavy grinders	Pencil grinders
1	DB (°C)	33.1	32.8
2	WB (°C)	28.4	28.3
3	NWB (°C)	29.3	29.4
4	GT (°C)	38.2	37.9
5	RH (%)	82	74
6	Air velocity (m/min)	14.4	15.24
7	WBGT (°C)	31.6	31.2
8	CET (°C)	31.5	31.3

Thermal environmental difference of grinders

in the work sites reflects the high RH (82%) where the velocity of air in the work exhibit 14.4 m/min, the mean WBGT and CET are observed to be 31.6 and 31.3, respectively.

Discussion: The main element of grinding activity includes cutting in which metal is removed by a grinding wheel containing abrasive grains. This activity involves different types of posture with movements of arms above or below the shoulder level by handheld electric grinder machine. But in case of pencil grinder, this activity demands static muscular exertion for maintaining postural balance. However, shifting machine to other area involves dynamic excretion. Therefore, these activities are a mixed type involving both static and dynamic workload. Since, time for grinding constitute major portion of the different spell, it is expected that the heart rate and energy expenditure would rise once they start grinding and would drop a bit in between moving time to other direction. The continuous rising trends during grinding along with occasional drooping of heart rate and energy expenditure is quite evident. This cycle pattern of work where predominance static load is quite clear represent a non-steady work phase in different spell and might prevent them to achieve proper recovery between one spell to another as evidenced from Tables 1A, 1B, 2A and 2B, where it can be seen both heart rate and energy expenditure in both types of grinding activities remained at an elevated level making the workload become heavy to very heavy in case of heavy grinding and moderate to heavy for pencil grinding. This finding conveys the fact that cumulative stress becomes evidence among both the groups for whatever time they gets involved in the activity, where the rest might not be adequate enough as it required to be while grinding. This is in conformity with the finding of Scholz [1] who has observed that the extent of physical demands of foundry worker is not dependent on the extent of degree of mechanization of foundry equipment.

The present study has indicated a high thermal load on the grinders during their work shift. The values of WBGT and CET were estimated to be after connected with clothing level of acclimatization, and heaviness of activity around 28 and 30 °C [8, 14] and their value including occupational strain among the worker are high. This high load is accounted for with a combined effect of workload and thermal load, coupled with climatic load.

It is pertaining to mention here that workload as obtained from the Suunto Ambit 3 peak HR in the form of different gradation of workload along with percentage of time matched with heaviness scale [4, 11]. Lind [2, 3, 6] has suggested that upper limit of ET as 25 °C for moderately heavy work. Job performance depends on the personal reaction and severity to heat [12, 13, 15] has showed that high heat exposure and heavy workload adversely affect the workers' health and reduce the work capacity. Therefore the present study indicates that there is comparatively high thermal stress placed on the worker. The present investigation has shown that their rest pauses are either not sufficient to recover from the effect of the fatigue in between the spell they are not properly planned or both. Lehmann [16] has pointed out that distribution of rest pauses over work period is as important as the length of the pause. It is observed in the study that the pause between one spell to other is not voluntary rest pause indicating workers are not truly resting as their lack of spaces of resting area arrangement for ventilation or sufficient air movement.

3 Conclusion

The grinding activities in foundry (private) are completely different in several ways than usual foundry owned by Government. The average duration of work in privately owned foundry is significantly far more than Government establishment. For relatively homogeneous group of grinders the occupational strain vary widely from one category of grinders to the other owing to the varying demand of the nature of assigned tasks performed by the grinders. Moreover methodology adopted for executing two different tasks also contribute to this wide variation and resulted in comparatively uneven workload inspite of thermal exposure level remains same. Heavy grinders encountered workload coupled with thermal load varying between heavy and very heavy, whereas pencil grinder has to endure moderate to heavy. This if continued may bound to pose deleterious effect on health of the grinders.

Implementation of well-planned job rotation scheme as well as job organization along with implementation of mechanization has been recommended as preventive measures to combat with stressful work situation.

References

1. H. Scholz, Changing physical demand of foundry workers in the production of medium weight casting. Ergonomics **1**, 30–35 (1957)
2. A.R. Lind, A physiological criteria for selecting thermal limits for everyday work. J. Appl. Physiol. **18**, 51–56 (1963a)
3. A.R. Lind, Physiological effects of continuous or intermittent work in heat. J. Appl. Physiol. **18**, 57–60 (1963b)

4. N.L. Ramanathan, S.R. Dutta, B.N. Roy, A. Chatterjee, L.N. Mullick, Energy cost of different muscular test performed by Indian subject. Indian J. Occupat. Health **10**, 253–261 (1967)
5. I. Astrand, Degree of stain during building work as related in individual work capacity. Ergonomics **10**, 293–303 (1967)
6. A.R. Lind, Effect of individual variation on upper limit of prescriptive zone of climates. J. Appl. Physiol. **28**, 57–62 (1970)
7. A. Key, F. Fidanza, M.J. Karhovan, Indices of relative weight and obesity. J. Chronocal Disease **25**, 329–343 (1972)
8. World Health Organization, Health factor Involve in working condition of heat stress. Technical report series 413'WHO, Geneva, Switzerland (1969)
9. PN. Saha, S.R. Dutta, P.K. Banerjee, G.G. Nrayane, An acceptable workload for worker. Ergonomics 2, 1059–1071 (1979)
10. W.J. Evans, F.R. Winsman, K.B. Pandolf, R.F. Goldman, Self place hard work comparing man and woman. Ergonomics **7**, 613–621 (1980)
11. P.O. Astrand, Rodhal, A Test of Book of Work Physiology (Mc Graw Hill, New York, 1986)
12. I. Vasmatzidis, An investigation of heat stress effect on time sharing performance. Ergonomics **45**(3), 218–239 (2002)
13. Hancock P, Vasmatzidis I, Effects of heat stress on cognitive performance: the current state of knowledge. Health Science **19**(3), 355–372 (2003)
14. ACGIH (2010) The American conference of governmental industrial hygienists. Threshold limit value and biological exposure indices, **7**, 3–272
15. M. Krishnamurthy, P. Ramalingam, Occupational heat stress impacts on health and productivity in a steel industries in southern India. Saf Health Work **8**, 99–104 (2017)
16. G. Lehmann, Physiological measurements as a basis of work organization in industry. Ergonomics **1**, 328–344 (1958)

Chapter 25
Analysis of Train Driver Seat Whole Body Vibration

Syed Imran Shafiq and Faisal Hasan

1 Introduction

The WBA exposure is assessed by:

- Evaluation of the vibration exposure that an operator experiences during an 8 h shift and
- Comparison of this vibration dose with values that are considered a health risk.

The health issues of most concern are related to damage of the lumbar spine and connected nervous system after long-term exposure with high-intensity WBV. Acceptable levels of vibration dose are referred to in recognized standards and documents. AS 2670.1-2001 (hereafter called AS 2670) [1] is the relevant WBV standard and is now identical to International Standard ISO 2631-1:1997 [2], Mechanical vibration and shock-evaluation of human exposure to whole body vibration, Part 1: General requirements. AS 2670 specifies a measurement and analysis method for operator WBV, but only provides guidance for the assessment of the severity of WBV.

The standards require that acceleration be measured in three directions [3]. These acceleration measurements are scaled differently depending upon the frequency of vibration and direction of vibration (considering a different human position as well), in order to represent human sensitivity. For the majority of equipment, the vertical direction is usually the critical direction.

It is well understood that injury can be caused by a rough ride during a single once-off event. The standard does not fully address once-off events like hitting potholes at speed but it does allow for the measurements of jolts and jars; however, these must

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occur regularly to strongly influence measurement results. Therefore, site representatives responsible for OH&S should realize that machinery that passes evaluation of the WBV standards might cause operator injury during once-off or irregular impact events. The maximum peak acceleration, which indicates the maximum vibration that an operator is exposed was measured.

Two evaluation methods defined in AS 2670 are usually referenced. The Basic Evaluation of AS 2670 requires a single acceleration value called the Overall Weighted RMS Acceleration. For operator vibration that is not consistent in magnitude over time, the fourth power Vibration Dose Value (VDV) is defined as an alternative measurement option and is the Additional Evaluation of AS 2670. This method is considered relevant to operator vibration that has shocks (jolts) or transient vibration. The VDV is more sensitive to vibration peak values than the basic evaluation method. Only basic evaluation method, as the crest factor for each case was <9 and refer Appendix was considered.

Understanding the duration of vibration exposure to operators is very important as 2670 applies to regular exposure over years. The standard to consider the operator vibration averaged over a year at work was interpreted. AS 2670 and other references define a daily exposure limit value and a daily exposure action value. This "value" as an acceptable daily number of hours of vibration exposure that corresponds to the actual operator vibration is reported. The limit value represents a health risk indicator and should not be exceeded. The action value (also called a caution value) represents an indicator that actions be taken to reduce vibration exposure risks. AS 2670 defines a "health guidance caution zone" between the action and limit values.

2 Instrumentation

The following instrumentation was used to conduct the vibration tests:

- **2-Triaxial Transducers**: Accelerometer, Seat Pad (S/N: 22,726 and 22,730).
- **DEWE-MDAQ-PCI-16**: 16 channel 24-bit data-acquisition system

The measuring instruments were calibrated in the laboratory prior to site measurements. This system was calibrated using known accelerometer sensitivities. The order of accuracy of measurement is better than ±5%.

3 Whole Body Vibration

The health issues of most concerns are related to damage of the lumbar spine and connected nervous system after long-term exposure with high-intensity WBV. Acceptable levels of vibration dose are referred to in recognized standards and documents. AS 2670 is the relevant WBV standards and are now identical to International Standard ISO 2631-1:1997, "*Mechanical vibration and shock—Evaluation of* *human exposure to whole body vibration, Part 1: General requirements*". AS 2670 specifies a measurement and analysis method for operator WBV, but only provides guidance for the assessment of the severity of WBV. For the majority of equipment the vertical direction is usually the critical direction. It is well understood that injury can be caused by a rough ride during a single once-off event [4]. The standard does not fully address once-off events like hitting potholes at speed but it does allow for the measurements of jolts and jars; however, these must occur regularly to strongly influence measurement results. Therefore, site representatives responsible for OH&S should realize that machinery that passes evaluation of the WBV standards might cause operator injury during once-off or irregular impact events. We measured the maximum peak acceleration, which indicates the maximum vibration that an operator is exposed. To measure the vibration, a seat pad (constructed internally with three accelerometers in three directions) was placed between the seat and driver. The vibration signals were simultaneously measured at three orthogonal directions as shown in Fig. 1. Figure 2 shows the seat pad accelerometer mounted on the driver seat.

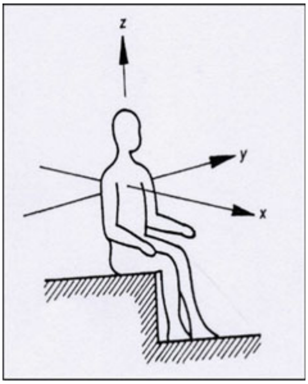

Fig. 1 Tri-axes of the human body

Fig. 2 Seat pad accelerometer

Fig. 3 Test route

The measurements were taken during "normal" train operating conditions on the rail track highlighted in Fig. 3 in red color.

AS 2670 Evaluation of Human Exposure to Whole Body Vibration provides designers, operators and relevant authorities with methods for the measurement of periodic, random and transient vibration transmitted to the human body as a whole from the supporting surfaces and provides guidance on the possible effects of the vibration on health, comfort and perception and motion sickness. The client was specifically interested in getting fatigued and safety (health) limits.

So AS standard is used to distinguish between two criteria and to depict two levels of limiting values:

- *The criterion of the maintenance of efficiency* (fatigue-decreased proficiency boundary—**F/D**). A decisive factor in this criterion is working efficiency (proficiency).
- *The criterion of safety* (exposure limits—**S/H**). Protection against damage to health is the main criterion in this category, i.e. the *Ceiling limit*.

4 Measurements

Two-seat pad tri-axial sensors were installed, one on the floor and the other on the driver seat (shown in Fig. 2). Data was continuously recorded when train was in motion. Vibration data has been recorded in eight measurements and each of this

Table 1 Boundary exposure assessment for worst-case short duration

S. no	Direction	Boundary exposure limit (hours)
1	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	5.51
	Y Right to Left (S/H)	15.07
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24

data has been analyzed and presented in this report which includes going to city from Hurstbridge station and back to Hursbridge station via the city loop.

Please note that the GPS hardware was not working while the measurements were being done from Hurstbridge to the city but it was working on the way back from City (after the tunnel) to Hurstbridge station.

5 Analysis of Data and Results

After measuring the acceleration in three orthogonal directions. **Two types of data** were analyzed according to the guidelines given in AS2670.

One was the worst-case—high vibration for a short duration, and the other eight cases for the normal operating conditions where the train from start-up acceleration to constant speed, then deceleration to stop.

The results are presented in Tables 1 and 2, respectively. For each case, boundary exposure limits were obtained for fatigue and health criteria's as presented below.

6 Conclusion

Results from Whole Body Vibration analysis can be concluded as:

- The Fatigue Decreased Proficiency time limit as normal service conditions for the average case was found to be 7.31 h (measurement from train start-up, braking, acceleration, maximum speed, braking and deceleration-slow down).
- The safety and health factor criteria time limit as normal service conditions found to be >20.28 h.
- Even for worst-case in a short period:
- The Fatigue Decreased Proficiency time limit for the worst-case was found to be 5.51 h (measurement duration approximately 60 s)
- The safety and health factor criteria time limit for worst-case were found to be 15.07 h.

Table 2 Boundary exposure assessment for normal assessment

S. no	Direction	Boundary exposure limit (hours)
1	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	13.04
	Y Right to Left (S/H)	>24
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24
2	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	8.42
	Y Right to Left (S/H)	22.40
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24
3	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	> 24
	Y Right to Left (S/H)	>24
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24
4	X Back to Chest (F/D)	> 24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	>24
	Y Right to Left (S/H)	>24
	Z Foot to Head (F/D)	> 24
	Z Foot to Head (S/H)	>24
5	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	13.04
	Y Right to Left (S/H)	>24
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	> 24
6	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	10.44
	Y Right to Left (S/H)	23.89
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24

(continued)

Table 2 (continued)

S. no	Direction	Boundary exposure limit (hours)
7	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	11.00
	Y Right to Left (S/H)	>24
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24
8	X Back to Chest (F/D)	>24
	X Back to Chest (S/H)	>24
	Y Right to Left (F/D)	7.31
	Y Right to Left (S/H)	20.28
	Z Foot to Head (F/D)	>24
	Z Foot to Head (S/H)	>24

- The dominant vibration is at a frequency range from 1.6 to 2.5 Hz, the directions are in lateral and vertical direction.

7 Recommendations

Based on the above conclusions, we have the following recommendations:

- It is recommended that individual drivers must not spend over a maximum of **7.3112** h **continuously** per day operating.
- The whole body vibration levels on the train should be re-measured following any significant modifications that would affect ride quality.

The properly designed isolation for driver seat from frequency range **(1.6–2.5 Hz)** can be done to further improve ride quality.

Appendix

The measured whole body vibration levels against the Fatigue Decreased Proficiency time for worst vibration for shorter duration and normal operating (reading 1) are presented in this Appendix.

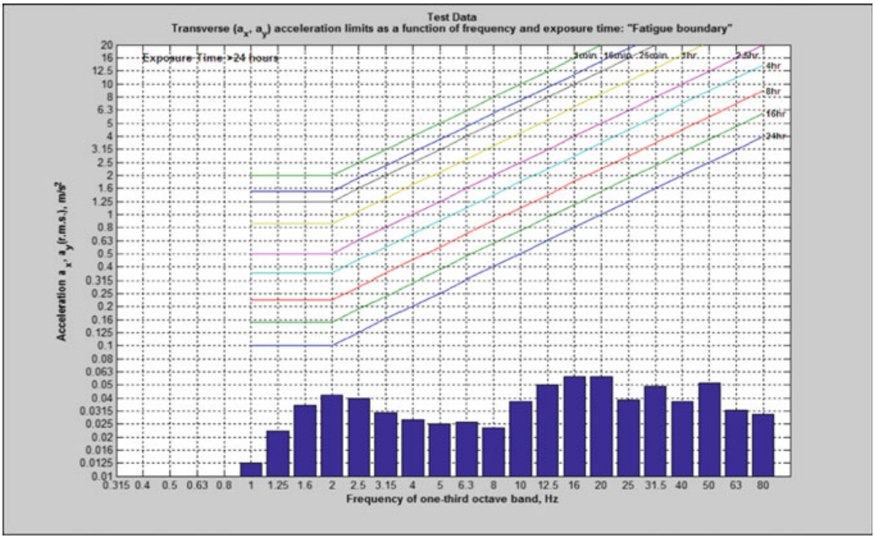

Fig. 4 Overall RMS acceleration values graph in the time domain for worst-case

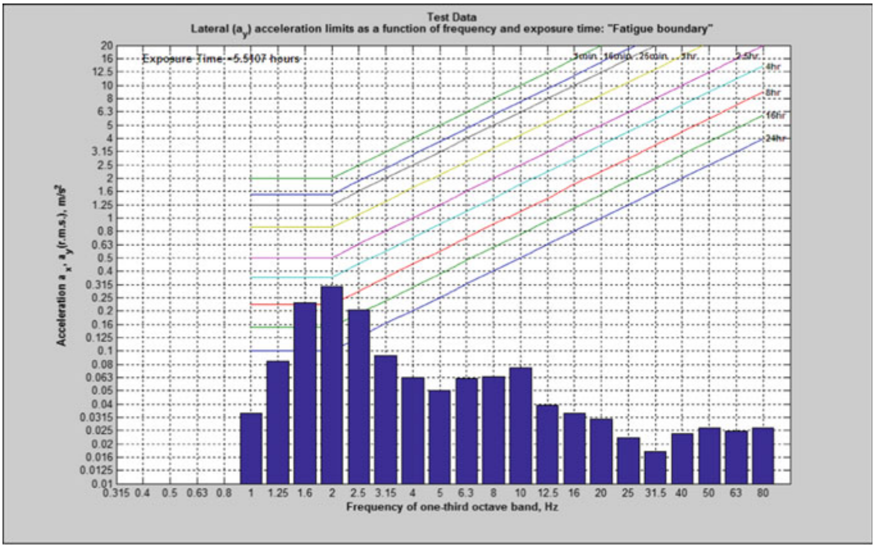

Fig. 5 The whole body vibration levels against F/D limits in X direction for worst-case

Reduced Fatigue Boundary Limit and Overall RMS Acceleration Plots For Worst-Case

See Figs. 4, 5 and 6.

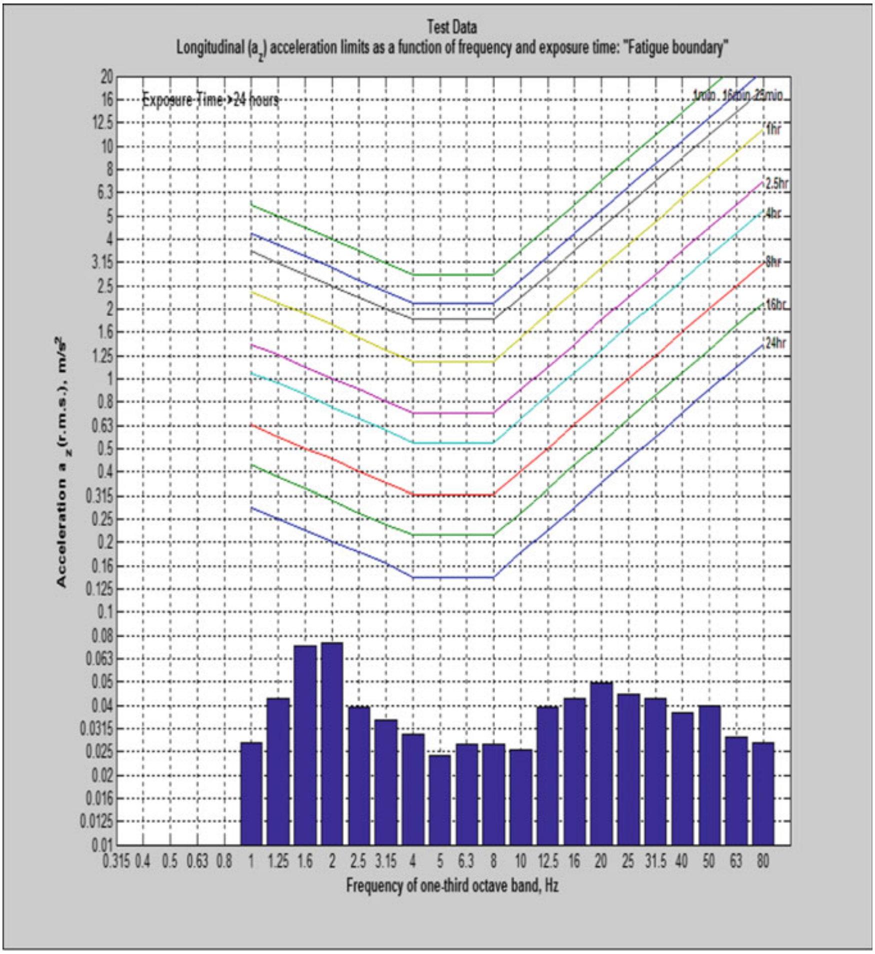

Fig. 6 The whole body vibration levels against F/D limits in Z direction for worst-case

The overall RMS value of acceleration for normal operation (Reading 8) is plotted along with the speed in Fig. 10 and Fatigue limits from Figs. 7, 8, 9 and 10.

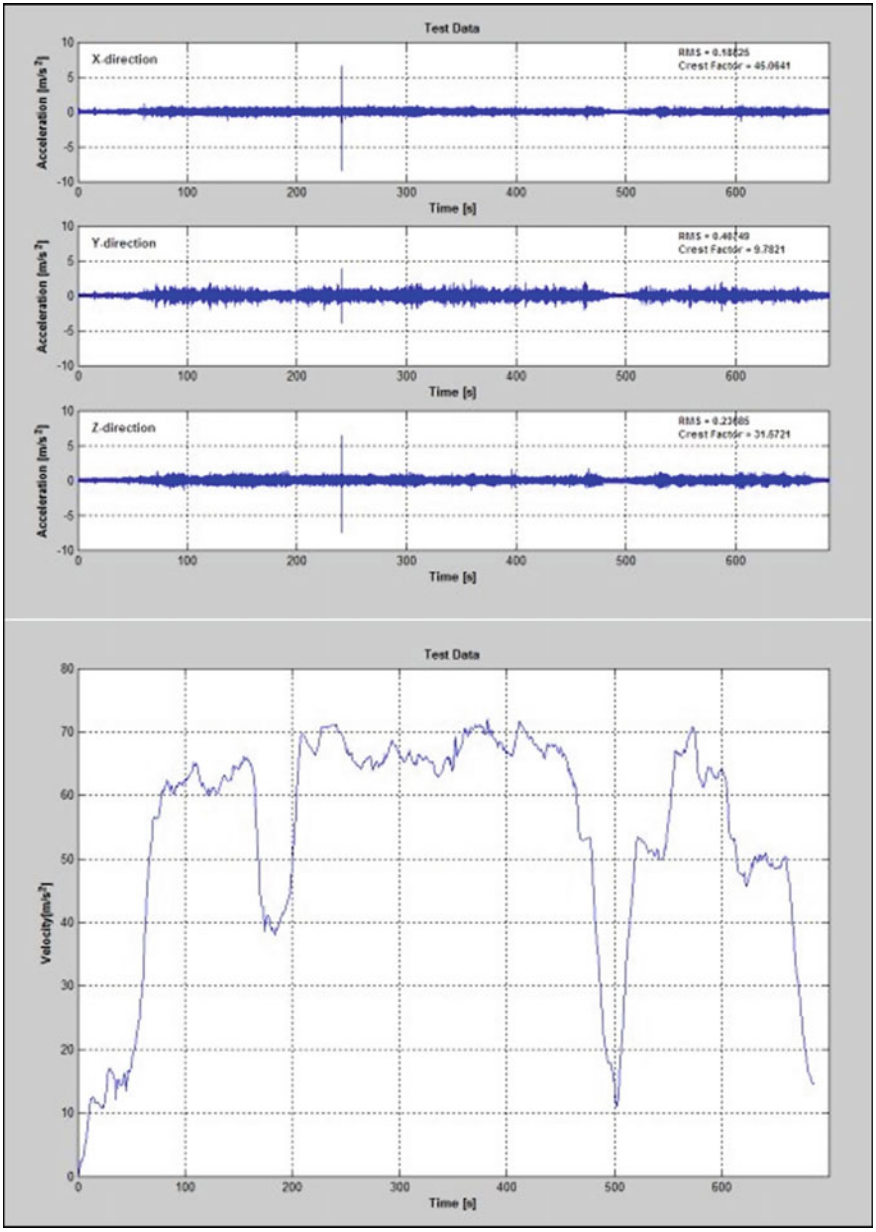

Fig. 7 The overall RMS value of acceleration for Reading 8

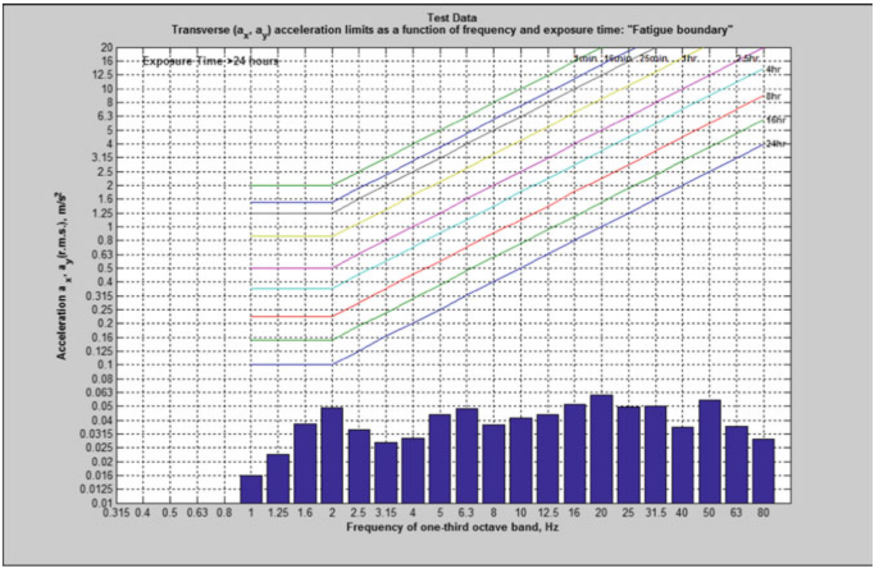

Fig. 8 The whole body vibration levels against F/D limits in X direction for Reading 8

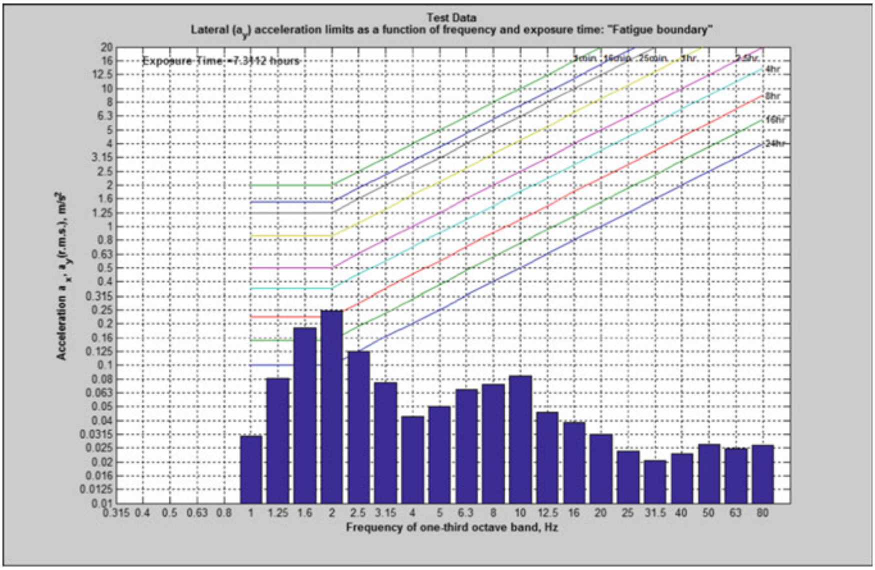

Fig. 9 The whole body vibration levels against F/D limits in Y direction for Reading 8

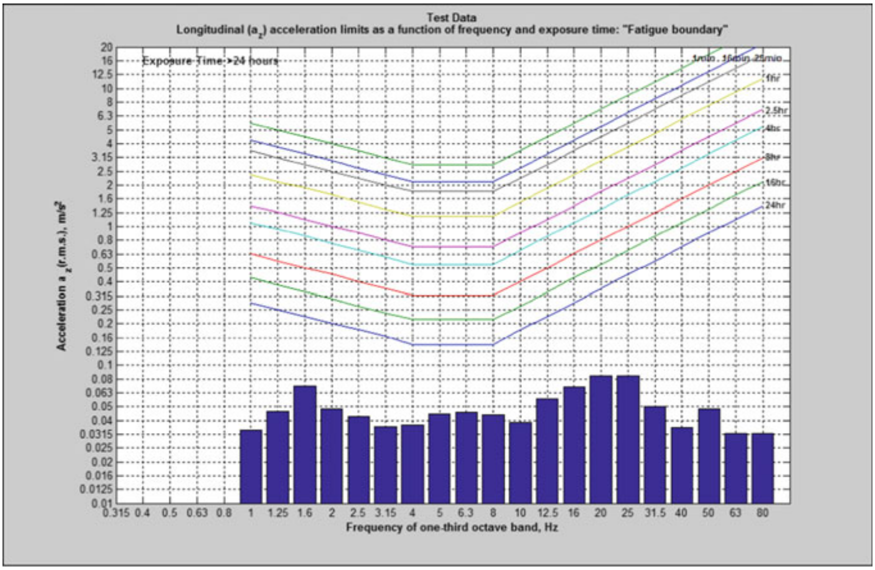

Fig. 10 The whole body vibration levels against F/D limits in Z direction for Reading 8

References

1. Evaluation of human exposure to whole-body vibration—General requirements. AS 2670.1-2001. Standards Australia International. ISBN 0 7337 4153 3
2. Mechanical vibration and shock—Evaluation of human exposure to wwlhole-body vibration—Part 1: General requirements. International Standard ISO 2631-1 (1997)
3. M.J. Griffin, *Handbook of Human Vibration* (Elsevier Ltd., London, 1990)
4. G.S. Paddan, M.J. Griffin, Effect of seating on exposures to whole-body vibration in vehicles. J. Sound Vibr. **253**(1), 215–241 (2002), ISSN 0022–460X, https://doi.org/10.1006/jsvi.2001.4257

Chapter 26
Respiratory Muscle Strength Training and Pulmonary Function Changes in Subjects with Chronic Neck Pain

M. Balaganapathy and Twisha S. Kansara

1 Introduction

Chronic neck pain, which has been considered common throughout the world, has shown a considerable impact on the individual, families, societies, communities, healthcare and business. In general population, the overall prevalence of neck pain ranges between 0.4% and 86.8%. There is a higher rate of incidence of neck pain among the women between the ages 35 and 49 and moreover it has been found that the prevalence is more in higher income countries compared to middle and low-income countries [1]. The risk is also higher in urban areas when compared to the rural areas. Among the region of Gujarat, India, the prevalence of non-specific neck pain was found to be 47% among computer workers [2].

The patients with chronic neck pain experiences the adaptation in the posture of the neck. As a result of that the neck muscles go into shortening or tightening and the patients exhibit different motor functions and there is also inhibition of the deep cervical flexor muscle activation which leads to restriction in cervical spine mobility. Studies have also shown that with an increase in neck pain, there is also an increase in the forward head posture and disturbance in sensorimotor function [3].

Many studies have shown that there are evidences for the respiratory pressures and pulmonary functions are getting impaired which leads to respiratory dysfunction in patients with chronic neck pain. One of the evidences has suggested that there is a reduction in MVV as well as Pi_{max} and Pe_{max} and thereby stated that there is also an association of isometric neck extensor muscle strength and forward head posture. Therefore, breathing training leads to clinically important changes in pain and function [3]. According to one study, the decrease in the MVV, Pi_{max} and Pe_{max}

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might result from the changes in ribcage mechanism. The mechanism occurs when the stability of the cervical and thoracic spine is reduced and when the force—-length curve of sternocleidomastoid is altered. Hence, when the intervention for the respiratory muscles is given, there is improvement in reducing the respiratory dysfunction in patients with chronic neck pain [4].

2 Methodology

This experimental study has conducted at Ashok & Rita Patel Institute of Physiotherapy. **Sampling method**: convenient sampling. **Sample size**: Forty subjects with 20 in each group. **Inclusion criteria**: Age group ranging from 30 to 50 years, both male and female, neck pain more than three months, non-radiating pain to upper limb, NPRS >5, Chronic neck pain diagnosed by orthopedic doctor. **Exclusion criteria**: Neck pain of traumatic origin, Surgery of thoracic cage or vertebral column, Inflammatory spinal pathology, Neurological deficits, Benign or malignant tumor around the neck area. **Procedure**: A total of 40 subjects were screened according to inclusion and exclusion criteria. Randomization was done using envelope method in which 20 subjects were allocated in control group and the other 20 were allocated in experimental group. The consent has been taken before participation. The Numerical Pain Rating Scale (NPRS) and Neck Disability Index of subjects with both the groups were assessed. The subjects of both the groups (control and experimental) participated in the assessment of Pulmonary Function Tests and Respiratory Muscle Strength. Experimental group was given treatment which included the respiratory muscle training using Inspiratory Muscle Trainer (IMT) device and Positive Expiratory Pressure (PEP) device and the standard treatment which included Interferential Current therapy and stretching of neck muscles like upper trapezius, sternocleidomastoid and scalene. The Control group subjects only received treatment with interferential current and stretching of neck muscles like upper trapezius, sternocleidomastoid and scalene.

Pulmonary Function Testing (Fig. 1): Pulmonary functions were tested according to standard recommendations (American Thoracic and European Respiratory Society 2002; Miller et al. 2005) [31]. Pulmonary function testing included Forced Vital Capacity (FVC), Peak Expiratory Flow Rate (PEFR), Forced Expiratory Ratio (FEV_1/FVC), Slow Vital Capacity (SVC) and Maximum Voluntary Ventilation (MVV). All these parameters were measured with a spirometer (RMS Helios 702) and were recorded with RMS Helios 702 software version 3.1.85 using a laptop.

Forced vital capacity was tested with a subject (Fig. 2) in a sitting position and the mouthpiece was placed in the mouth wearing a nose clip. The subject was asked to inhale completely and rapidly with a pause of 1 s at TLC and exhale maximally through the mouthpiece until no more air can be expelled while maintaining an upright posture. Slow vital capacity (SVC) was tested with the patient in a sitting position wearing a nose clip with no air leak between mouth and mouthpiece. The

Fig. 1 Pulmonary function testing device

Fig. 2 Assessment of pulmonary functions

subjects were asked to be relaxed and to inhale and exhale three breaths regularly and followed by one deep inhalation and exhalation. The test was measured till 12 s. Maximal voluntary ventilation (MVV) was tested with the subjects in a sitting position wearing a nose clip. Subjects were asked to make an airtight seal around the mouthpiece and were asked to breathe as rapidly and deeply as possible till 12 s.

Respiratory Pressure Meter Testing (Fig. 3): The respiratory pressure meter is a handheld device which is designed to measure the maximal inspiratory pressure and maximal expiratory pressure. The tests were performed in a sitting position with a mouthpiece sealed with both the lips. For $Pi_{max,}$ subjects were asked to inhale maximally from residual volume against the resistance for at least 1 s. For $Pe_{max,}$ subjects were asked to exhale maximally from total lung capacity against a resistance for at least 1 s. Tests were repeated three times and a best trial was recorded (Fig. 4).

Treatment by IMT (Fig. 5) and PEP (Fig. 6): The inspiratory muscle training was given with the subjects in a sitting position. Mouthpiece was sealed between the lips.

Fig. 3 Respiratory pressure meter device

Fig. 4 Assessment of Pi_{max} and Pe_{max}

Subjects were asked to inhale as deeply as possible through the mouthpiece. The device had an adjustable resistance settings by which the resistance was adjusted and increased at a normal respiratory rate. The subjects were then asked to exhale keeping the device out of the mouth so that he/she can go for the next breath. The test was repeated for four to six times, once a day for four weeks.

The training for expiratory muscles was given using a positive expiratory pressure device. For PEP, subjects were asked to assume a sitting position. Mouthpiece was sealed between the lips. The subject was asked to inhale deeply and exhale through the PEP mouthpiece as forcefully as can. The test was repeated for four to six times, once a day for four weeks.

Fig. 5 Use of IMT

Fig. 6 Use of PEP

Stretching and Interferential current: For stretching maneuver, subjects were asked to be in the sitting position on a chair. The stretching maneuver for upper trapezius, scalene and sternocleidomastoid muscles were given with three repetitions and 15 s hold daily for four weeks. The interferential current therapy was given to the subjects with the patient in a sitting position. The electrical current was applied to the affected part of neck region using four electrodes using two channels such that the two channels cross each other in affected area. It was given for 15 min.

Table 1 Demographic details

Variable	Total ($n = 40$)	Control group ($n = 20$)	Experimental group (20)
	Mean ± SD	Mean ± SD	Mean ± SD
Age	40.90	39.30 ± 8.19	42.50 ± 7.25
Height (cm)	1.63	1.59 ± 0.06	1.67 ± 0.70
Weight (kg)	69.70	64.70 ± 8.39	74.70 ± 16.39
BMI	26.02	25.33 ± 2.92	26.72 ± 6.38

Table 2 Demographic details

Variable	Total		Control group		Experimental group	
	Frequency	Percentage	Frequency	Percentage	Frequency	Percentage
Male	26	65.0	14	70.0	12	60.0
Female	14	35.0	6	30.0	8	40.0

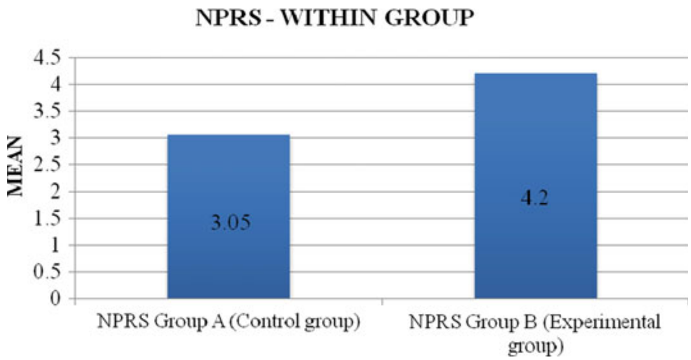
3 Results

The objective of the study was to find out the changes in respiratory muscle strength and pulmonary functions in subjects with chronic neck pain. The results were analyzed on the data obtained pre and post intervention using NPRS, NDI, MIP, MEP and pulmonary functions like FVC, FEV1/FVC, PEFR, SVC and MVV. The data was entered into an excel spread sheet, tabulated and subjected to statistical analysis.

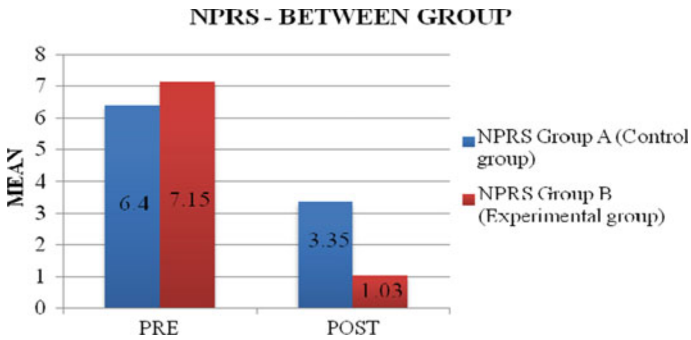
Data were analyzed using SPSS version 24.0. Descriptive statistics for all outcome measures were expressed as mean and standard deviation. For the test of significance, t-test was used. Paired t-test was used for comparing data within each group and independent t-test was used for comparing data between the groups (control and experimental). The confidence interval was set as 95% and data was considered statistically significant with $p < 0.05$ and highly significant with $p < 0.01$ (Tables 1, 2 and Graphs 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17 and 18).

4 Discussion

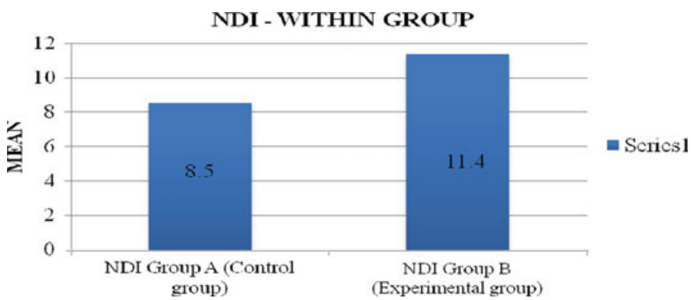
A total of 40 subjects were screened according to inclusion and exclusion criteria and the study was carried out to observe the changes in pulmonary functions and respiratory strength of patients with chronic neck pain. Two groups were assessed priorly. Both the groups were assessed for NPRS, NDI, Pi_{max}, Pe_{max}, FVC, FEV1/FVC, PEFR, SVC and MVV. One group (control group) received treatment with interferential current therapy and stretching of neck muscles. Experimental group received



Graph 1. Numerical Pain Rating Scale (NPRS) - WITHIN GROUP

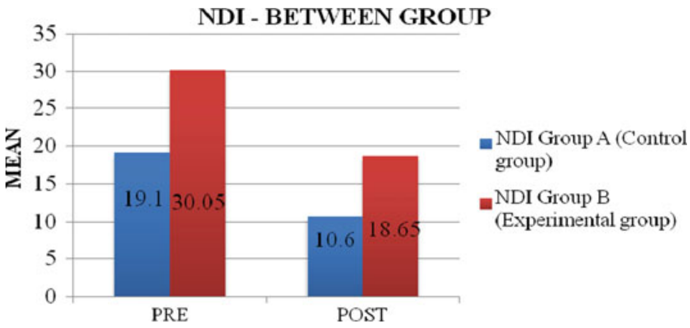


Graph 2. Numerical Pain Rating Scale (NPRS) - BETWEEN GROUP

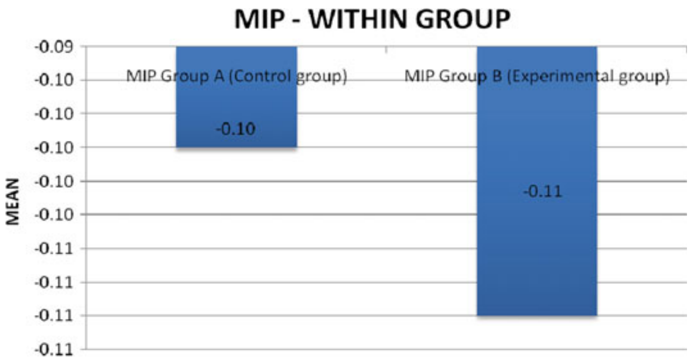


Graph 3. Neck Diability Index (NDI) - WITHIN GROUP

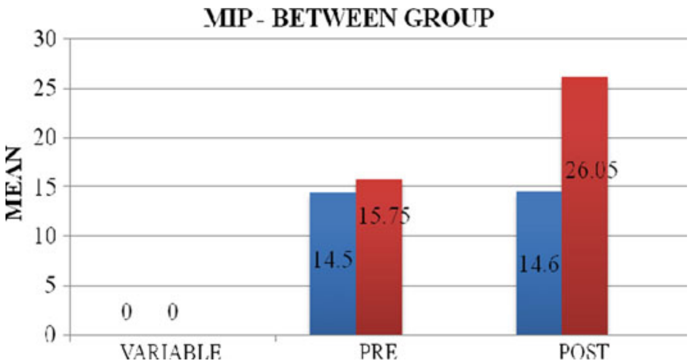
treatment with interferential current therapy, stretching of neck muscles and in addition to it was given respiratory training with the use of inspiratory muscle trainer (IMT) and positive expiratory pressure (PEP). When analysis was done with the help of SPSS version 16, it showed that both the control group and experimental group



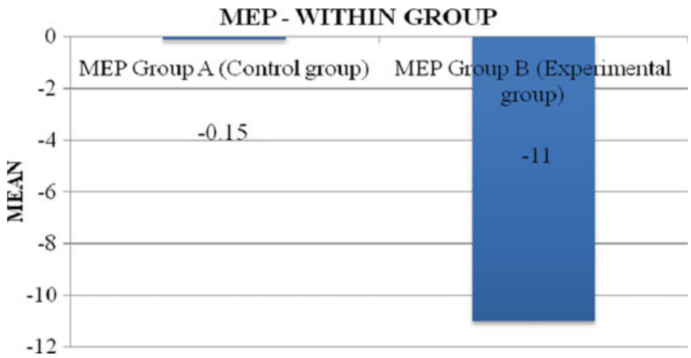
Graph 4. Neck Disability Index (NDI) - BETWEEN GROUP



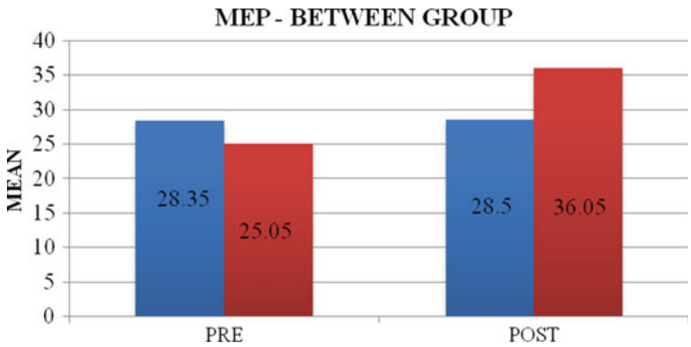
Graph 5. Maximum Inspiratory Pressure (MIP) - WITHIN GROUP



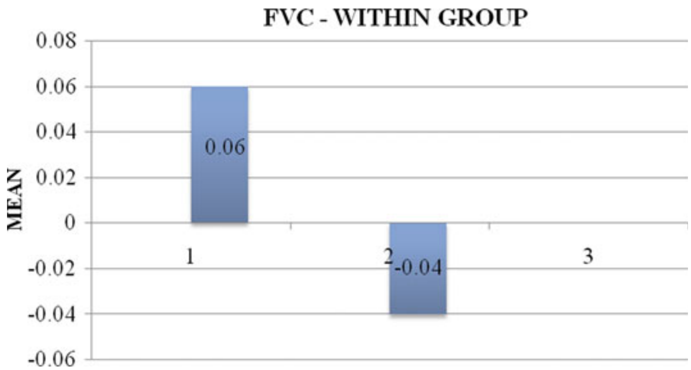
Graph 6. Maximum Inspiratory Pressure (MIP) - BETWEEN GROUP



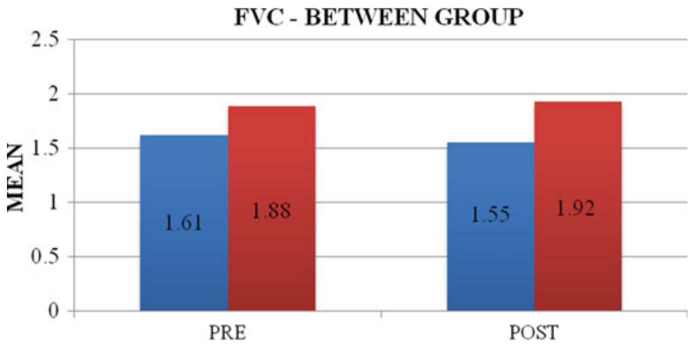
Graph 7. Maximum Expiratory Pressure (MEP) - WITNIN GROUP



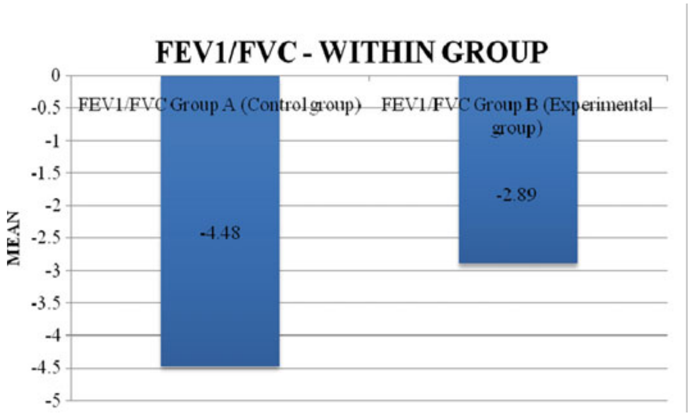
Graph 8. Maximum Expiratory Pressure (MEP) - BETWEEN GROUP



Graph 9. Forced Vital Capacity (FVC) - WITHIN GROUP

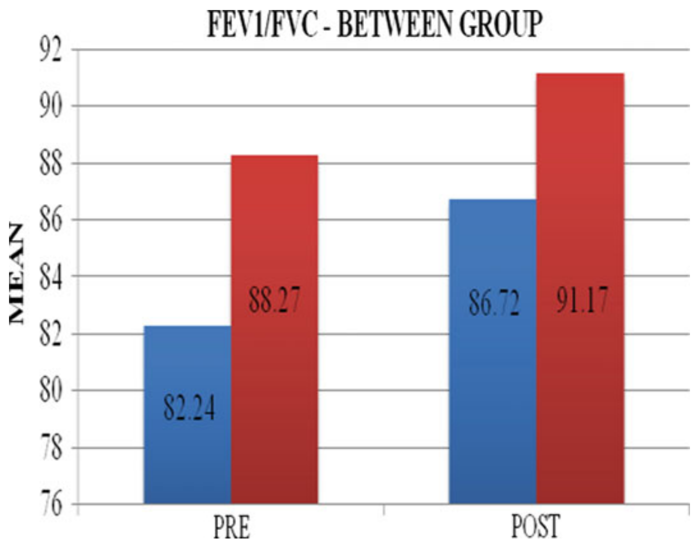


Graph 10. Forced Vital Capacity (FVC) - BETWEEN GROUP

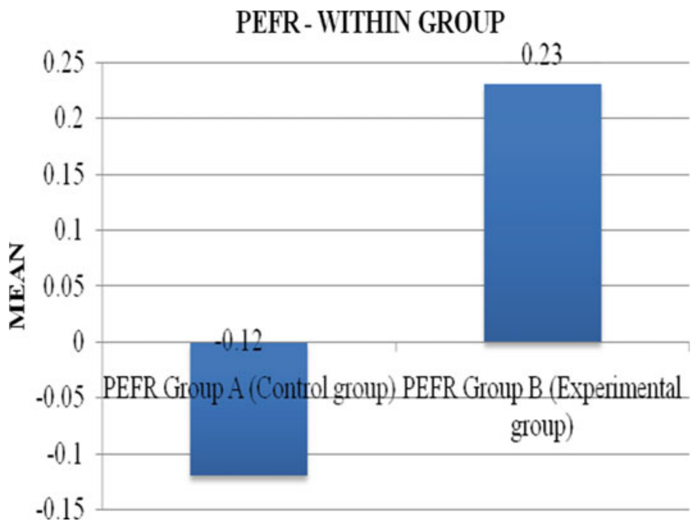


Graph 11. FEV1/FVC - WITHIN GROUP

were improved in terms of pain and disability. Both the groups showed a p value of 0.000 when compared with both the groups and between the groups. Respiratory muscle strength parameters included Pi_{max} and Pe_{max}. Intragroup comparisons showed that the control group showed no significance for MIP ($p = 0.60$) and MEP ($p = 0.60$) and experimental group showed a significant value for MIP ($p = 0.000$) and MEP ($p = 0.000$). Intergroup comparison of pre-value for MIP ($p = 0.274$) and of post MIP ($p = 0.000$). Similarly for pre MEP ($p = 1.58$) and post MEP was ($p = 0.000$). Hence, the respiratory parameters (MIP and MEP) showed a significant value. FVC parameters were assessed before and after the treatment for both the groups. Intragroup comparisons showed that for a control group, there was no significance for FVC ($p = 0.67$) and experimental group also did not show a significance for FVC ($p = 0.80$). When intergroup comparisons were made, it showed that the pre-value for FVC was $p = 0.24$ and post value was $p = 0.09$ which showed that there was no significance of FVC in between the control and experimental group. FEV1/FVC was also assessed during the assessment of FVC. The intragroup comparison showed

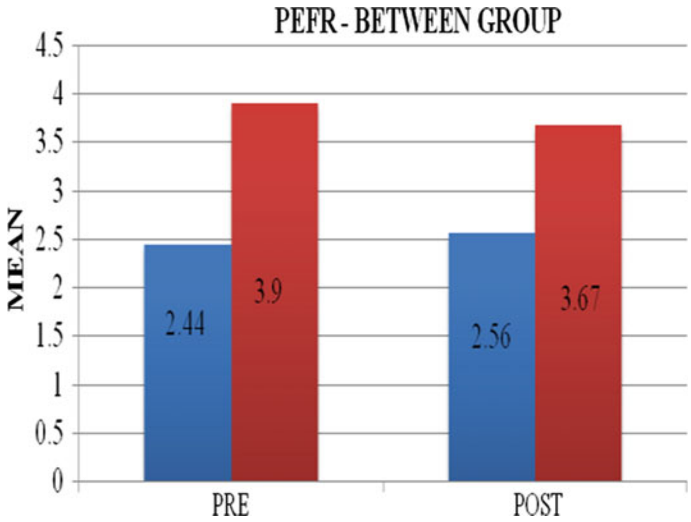


Graph 12. FEV1/FVC - BETWEEN GROUP

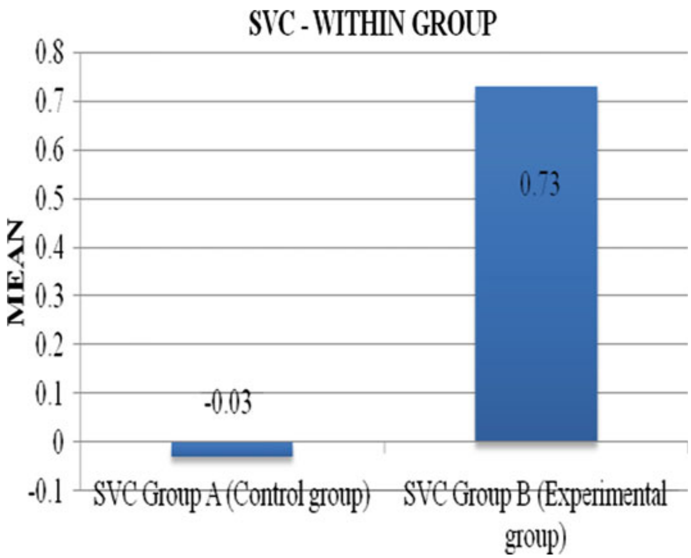


Graph 13. PEFR - WITHIN GROUP

that control group showed no significance for FEV1/FVC ($p = 0.34$) and similarly experimental group also did not show significance for FEV1/FVC ($p = 0.31$). When comparison was made between the two groups (intragroup), pre-value for FEV1/FVC was $p = 0.26$ and post value for FEV1/FVC was $p = 0.40$. Hence FEV1/FVC parameter did not show a significant value in intragroup as well as intergroup. Zachiarias

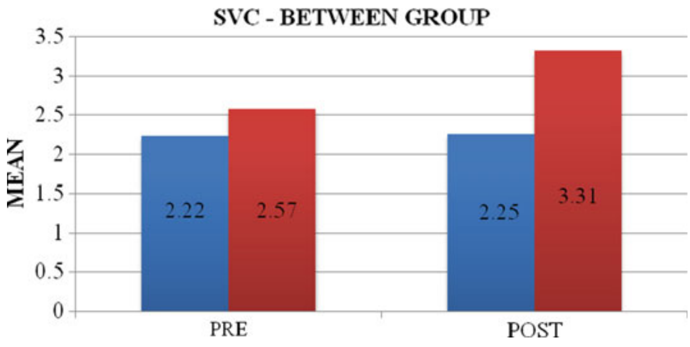


Graph 14. PEFR - BETWEEN GROUP

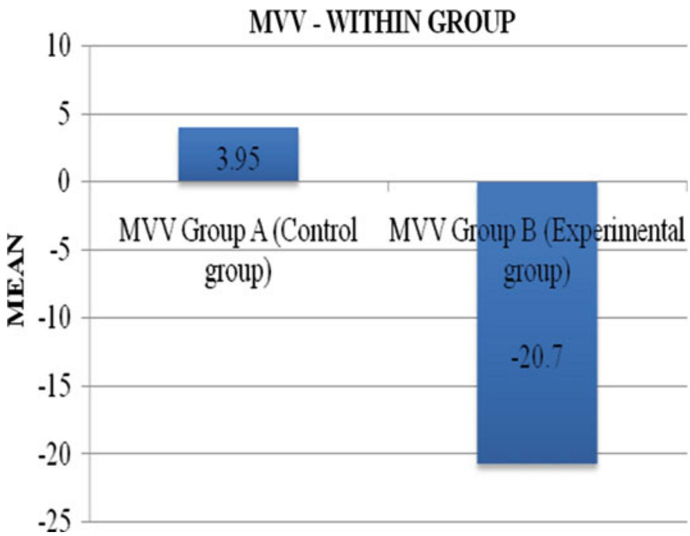


Graph 15. SVC - WITHIN GROUP

Dimitriadis et al. showed in their study that FEV1/FVC ratio was not found to be affected but FVC and VC were found to be affected. But FVC and VC were found to be reduced in patients with chronic neck pain [5]. Peak expiratory flow rate (PEFR) is a maximum speed of expiration that is included in FVC as well. Intragroup comparison showed that control group did not show a significant value ($p = 0.53$) and also

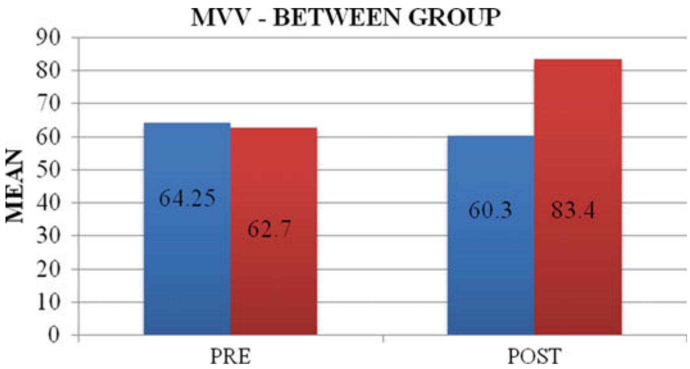


Graph 16. SVC - BETWEEN GROUP



Graph 17. MVV- WITHIN GROUP

for experimental group there was no significant value ($p = 0.57$). When comparison was made between the groups it showed no significant value for PEFR ($p = 0.33$). Slow vital capacity measures the volume of gas on a low complete expiration after a maximal inspiration without forced effort. When analyzed within the groups (intragroup comparison), it showed that there was no significant difference in SVC in control group ($p = 0.81$), whereas experimental group showed a significant value for SVC ($p = 0.000$). Intergroup comparisons showed that the pre-value for SVC was found to be ($p = 0.175$) and when post measurement was taken it showed a significant value of ($p = 0.001$). Hence, SVC was found to have a significant value in between the two groups. Maximal voluntary ventilation (MVV) measures the volume of air expired in a specific period during repetitive effort. Intragroup comparison showed



Graph 18. MVV - BETWEEN GROUP

that control group did not showa significant value ($p = 0.29$), whereas experimental group showed a significant value of $p = 0.000$. Intergroup comparisons showed a significant value of MVV ($p = 0.008$).

5 Conclusion

Respiratory parameters are found to be reduced in patients with chronic neck pain. Respiratory parameters include pulmonary functions and respiratory muscle strength. When respiratory training was imparted using the inspiratory muscle trainer and positive expiratory pressure devices the respiratory parameters like maximal inspiratory pressure, maximal expiratory pressure, slow vital capacity and maximum voluntary ventilation were found to be improved. Also the NPRS and NDI scores were decreased indicating a good quality of life for patients with chronic neck pain. Forced vital capacity (FVC), FEV1/FVC and PEFR did not show any improvement. Therefore, along with the standard treatment, respiratory assessment and respiratory training must be implemented by each and every clinician or therapist in clinical practice to reduce pain and improve quality of life in patients with chronic neck pain.

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Conflict of Interests Statement None.

References

1. D. Pierre Cote, J. David Cassidy, L. Carroll, The epidemiology of neck pain: what we have learned from our population-based studies, 284–290 (2003)
2. S.A. Shah, P.R. Patel, Prevalence of neck pain in computer operators. J. Med. Sci. **4**(1), Jan 2015
3. S. Hogg–Johnson et al., The burden and determinants of neck pain in the general population. Eur. Spine J. S39–S51 (2008)
4. MicroRPM (Respiratory Pressure Meter)—An operating manual by Carefusion, Feb 2010.
5. R.W. Ostelo, Minimal clinically important change of the neck disability index and numerical pain rating scale for patients with neck pain (2013)

Chapter 27
Ergonomic Application to Dental Scaling Tasks

Vibha Bhatia, Jagjit Singh Randhawa, Ashish Jain, and Vishakha Grover

1 Introduction

Musculoskeletal Disorders commonly associated with injury of human support system are believed to be developed with a single event or may develop gradually over time with repeated physical trauma [1]. Ergonomics can be effectively applied not only to reduce but to prevent the occurrence of MSDs.

Literature is evident of the fact that there is higher prevalence of MSDs in dentistry as compared to the other occupations [2–5]. Due to the limited work area (mouth cavity of patient), it becomes difficult for the dentists to adjust the body according to an optimally safe body posture. In consequence of not being able to do that, makes them susceptible to MSDs. Researchers have shown much interest in analyzing dental postures worldwide [6–8].

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Enumerable studies have been done evaluating dental postures using various qualitative and quantitative techniques. High muscle forces (21% greater than MVC) were observed in muscles when electromyography was used as a tool to measure the muscle strength while doing dental work [9]. RULA was used to assess the Indian dental practitioners and risk associated with upper body postural assessment was found out [10]. Biomechanical analysis was done using virtual prototyping methods (use of DELMIA software) and OCRA, work cycle optimization was suggested in order to have minimum risk [11]. REBA method used in a study had indicated that dentists were prone to medium to high risk and among the dental population pedodontsts, periodontists and oral and maxiofacial surgeons are prone to maximum risk [12].

Studies have been done in which ergonomic tools have been used to assess the posture of the dentists. But limited studies have been done till now to use multiple techniques to relate the results within different techniques. The current study aims at using multiple ergonomic evaluation techniques like Rapid Upper Limb Assessment (RULA), Strain Index (SI) and Threshold Limit Value for Hand Activity Level (TLV for HAL) in the assessment of dental postures with the aim of deducing comparative results. General ergonomic evaluation was carried out by experts to evaluate the working habits of dentists depending upon their suitability to dental environment.

2 Methodology

A. *Subjects*

Ten healthy dentists (five females and five males) from the local dental clinic had volunteered for the study. The volunteers had mean age: 28 years, mean height: 170 cm, mean weight: 66 kg. All participants used right hand as their dominant hand. Experimentation steps and the protocol for the study were explained to the volunteers in advance. Participant's written consent was taken on the consent form prior to the study.

B. *System Overview*

For the current study high-quality videography still camera SONY, HDR-XR550 was used to record image streams. The image streams were captured at the frame rate of 30 fps.

C. *Experimental Design*

All the recordings were done in an actual dental environment when the dental practitioner performed the scaling task on the patients. The readings were taken from both front and side view so that each body angle can be captured correctly. Also, the camera was kept at a distance of 4 m from the center of the chair on which the patient is lying. Each recording was done for the period of 10 min. All the ten dentists were recorded once for next three days. Required job physical exposure data was collected through dentists' interviews which included (a) duration of each dental procedure, length of dental work shift (b) peak hand forces sheet (BORG SCALE datasheet).

D. *Data Processing and Analysis*

The recorded videos were analyzed frame by frame to determine body angles, force ratings, temporal exertion needed, postures of hand/wrist and speed with which work is done. Different temporal exertion needs were evaluated: (a) HAL score using verbal anchor scale, (b) Number of efforts per minute and (c) percentage duration of exertion.

Thirty frames from each video recording with maximum awkward posture were selected at random for the study. The ergonomic evaluation tools like RULA, SI and TLV for HAL were evaluated for each selected frame.

The evaluated data was tabulated and was analyzed. For all the 30 frames, respectively, selected from the recordings of three days for ten dentists, RULA scores were evaluated. Final RULA scores were demarcated into groups as Acceptable posture, Further investigation, change may be needed, Further investigation, change soon and Investigate and implement change for 1–2, 3–4, 5–6 and 7 as their respective final RULA scores. The frequency percentage value for each group of final RULA score obtained was calculated.

The strain index values for all the ten dentists for three-day data were found out. To evaluate SI final values overall force rating, percentage duration of exertion, efforts per minute, speed of work and duration of task parameters were used. SI value ≤ 6.1 is categorized as low-risk value and SI >6.1 comes under high-risk value.

The TLV for HAL values was computed to find the physical exposure levels of dentists while working. Physical exposure level above the TLV was considered as the most unsafe working postures. The AL was considered threshold safety limit of effect of combination of upper limit force and repetitions. Therefore, NPF value for HAL existing below AL was considered as safe. The resulted dental postural analysis done using the RULA, Strain Index, TLV for HAL of all the dentists for the consecutive three days were plotted on the same graph. The results obtained from the three ergonomic techniques were compared and analyzed.

Using the American Conference of Governmental Industrial Hygienists [ACGIH] Worldwide (2002) methodology, TLV for HAL score was calculated as: score ¼ [analyst peak force rating on borg CR-10 Scale/(10–HAL rating)]. TLV for HAL values were treated as continuous variables. TLV for HAL values were categorized into three categories: if score <0.56 (below the action limit), if score is between 0.56 and 0.78 (between AL and TLV) and if the score is above 0.78 (above the TLV).

To find the correlation among the results obtained using two techniques (Strain Index and TLV for HAL) on three consecutive days, Pearson's Correlation Coefficients (r) and Concordance Correlation Coefficients (r_c) were found out. The values of correlation coefficients are represented in tabular form as shown in Table 1.

The methodology followed in the experimentation procedure is shown in Fig. 1.

Table 1 Correlation coefficient (r) and concordance correlation coefficient (r_c) between SI and TLV for HAL techniques

Correlation coefficients among data obtained using SI and TLV for HAL techniques	DAY 1	DAY 2	DAY 3
Pearson's correlation coefficient (r)	0.972	0.983	0.983
Concordance correlation coefficient (r_c)	0.976	0.923	0.988

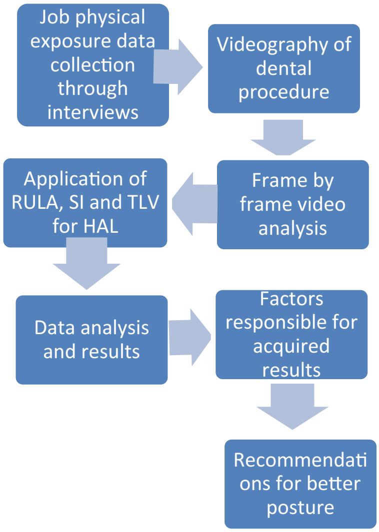

Fig. 1 Flow chart of the experimental procedure

3 Results and Discussion

The results obtained for RULA, SI and TLV for HAL were plotted on three different graphs for three respective days of data collection for each of the ten dentists.

The results obtained in DAYS 1–3 using three techniques are shown in Figs. 2, 3 and 4, respectively. RULA score results for all the three days mostly fluctuated between 3 and 6 which corresponds to further investigation, change may be needed (3–4) and further investigation, change soon (5–6) inferences. Observation and analyses of the image frames having higher RULA scores by expert resulted in following inferences:

- For 28% of dental postures, trunk and neck movements were the root cause of high RULA scores because the dental movements while working involve trunk's forward-leaning with the head almost above the patient's oral cavity.
- For 18% of the times awkward wrist posture (bent and twisted) resulted in higher RULA scores. Dental procedure needs dexterity in handling instruments while working. Relatively inexperienced dentists tend to bend and twist their wrist more

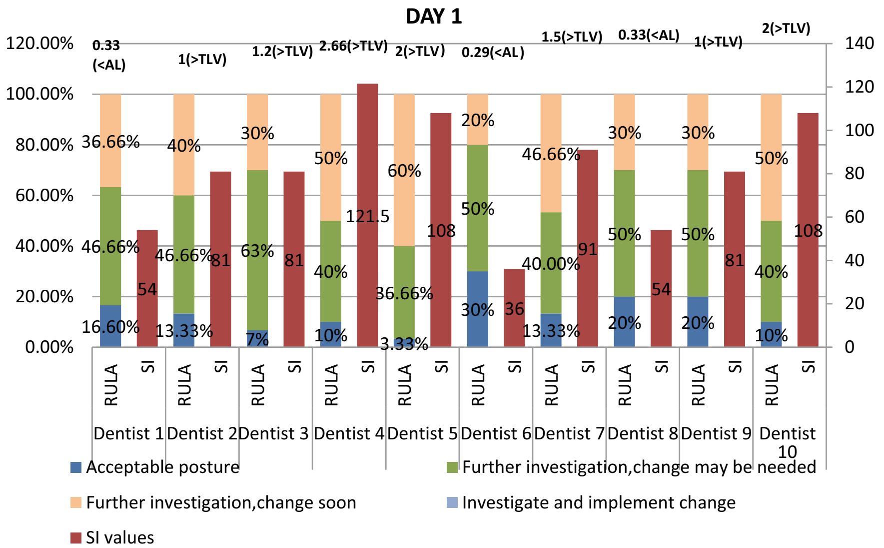

Fig. 2 Plots showing percentages of RULA score frequencies, absolute SI values and TLV for HAL values for ten dentists on DAY 1

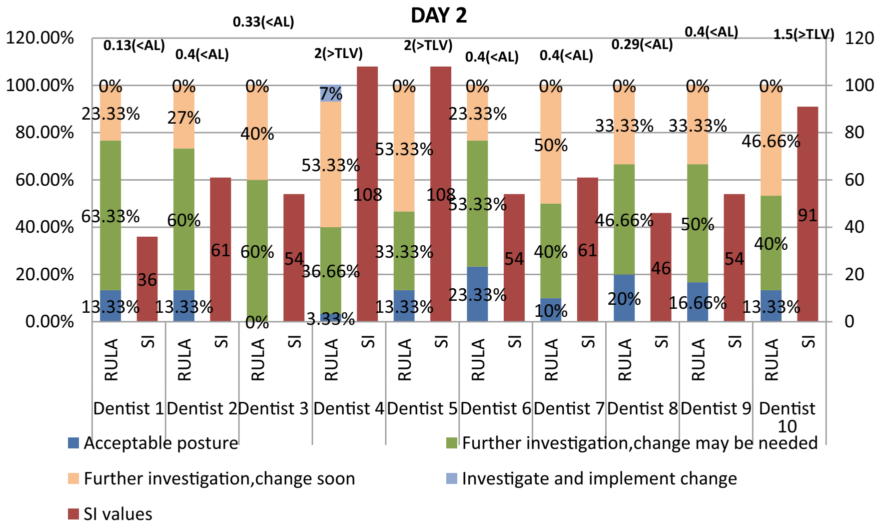

Fig. 3 Plots showing percentages of RULA score frequencies, absolute SI values and TLV for HAL values for ten dentists on DAY 2

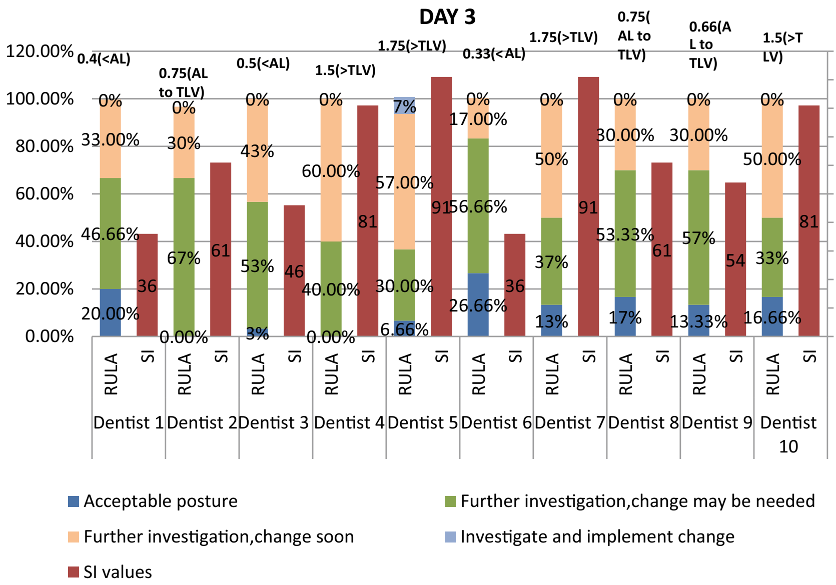

Fig. 4 Plots showing percentages of RULA score frequencies, absolute SI values and TLV for HAL values for ten dentists on DAY 3

often so as to get access to mouth's part which will otherwise need a different dental work position.

- For 15% of the cases trunk's bending and twisting was responsible for high RULA scores as the dentists tend to perform complete procedure being fixed to one sitting position instead of adopting the correct sitting clock position as the dental task demanded.
- For 10% of the times lower arm was lying out of the midline alignment of dentist's body. This lead to high RULA scores as dentists were habitual to extend the arm reach to have access to mouth which might otherwise require change in sitting work position.

For all three days, the Strain Index values were much >7 (job is probably hazardous) and was treated as continuous parameter for ergonomic analysis. On DAYS 2 and 3, for one dentist, the RULA score was seven for seven percent of the times indicating the urgency of implementing change. The strain index values were no <36 and ranged up to 121.5 which is much higher. Seven, three and four dentists on DAY 1, DAY 2 and DAY 3, respectively, had Normalized Peak Force values for HAL values higher than the acceptable limit that is Threshold Limit Value. The values of TLV for HAL came out to be higher which is probably due to the repetitive and continuous effort along the tooth surface while maintaining the awkward wrist postures in order to reach the tough areas of mouth.

It can be observed from the plots that values of Strain Index showed positive agreement with the RULA scores on all the days of data recording in almost all the dentists. Pearson's correlation coefficients and Concordance correlation coefficients between SI and TLV for HAL method results were on the higher side, inferring positive correlation between both technique results. This can also mean that both the techniques were able to produce similar results after analysis and providing strong evidence for existence of awkward postures in dentistry. The unacceptable ranges of RULA score, SI and higher values in TLV for HAL technique were observed in dentists 4, 5 and 10 in all the recordings of three days.

General observational inferences on dentist's work were made ergonomically after observing the awkward postures in the videos which might be responsible for prevalence of MSDs in long run. Dentists were prompted to bend over the patient in order to have a clear view of the work area. This upper body forward posture of dentists while working was responsible for bent and twisted neck, shoulders, back and spine. The height of patient and dentist's chair was not accurate which might be the reason for hindrance in dentist's movement around the patient resulting in awkward postures. The placement of the dental instruments was not ergonomically sound and was mostly placed out of the maximum reach of the dentist's arm. To pick up the dental tool in far proximity dentist had to side bend the body. The forward bend posture also resulted in blockage of illumination of work area.

4 Conclusion

Validity of each ergonomic technique used in experimentation was done against each other and resulted in a positive relationship among them. The prevalence and associated risk factors were identified to determine the likelihood of current postural problems faced by dentists in real work environment. In future, efforts will be made to put more emphasis on quantitative methods rather than current observational ergonomic techniques.

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References

1. C. Graham, Ergonomics in dentistry. Part 1. Dent Today **21**(4), 98–103 (2002)
2. G. Waddel, Biopsychosocial analysis of low back pain. Ballieres Clinical Rheum **6**, 523–527 (1992)
3. D.R. Fish, D.M. Morris-AlleN, Musculoskeletal disorders in dentists. NY State Dent. J. **64**, 44–48 (1998)
4. A.L. Nachemson, Spinal disorders. Overall impact on society and the need for orthopedic resources. Acta Orthop. Scand. Suppl. **241**, 17–22 (1991)
5. Z.R. Navah, T. Yaros, A. Mizlik, T. Kanner, Musculoskeletalsymptoms among dentists in relation to work posture. Work **15**, 153–158 (2000)

6. L. Finsen, H. Christensen, M. Bakke, Musculoskeletal disorders among dentists and variation in dental work. Appl. Ergon. **29**(2), 119–125 (1998)
7. B. Rundcrantz, B. Johnsson, L. Moritz, Occupational cervicobrachial disorders among dentists: analysis of ergonomics and locomotor functions. Swed. Dent. J. **15**(5), 105–115 (1991)
8. B.L. Rundcrantz, B. Johnsson, U. Moritz, Cervical pain and discomfort among dentists. Epidemiological, clinical and therapeutic aspects. Part 1. A survey of pain and discomfort. Swed. Dent. J. **14**, 71–80 (1990)
9. M. Djurić-Jovičić, N. Miljković, D. Marković, Evaluation of ergonomic risks during dental work. Balk. J. Dent. Med. **20**, 33–39 (2016)
10. V. Golchha, P. Sharma, J. Wadhwa, D. Yadav, R. Paul, Ergonomic risk factors and their association with musculoskeletal disorders among Indian dentist: a preliminary study using Rapid Upper Limb Assessment. Indian J. Dent Res. **25**, 767–771 (2014)
11. F. Bruno, R. Califano, R. Greco, G. Ricco, M. Vallone, N. Valter, Virtual ergonomic analysis and redesign of dentist's workcycle. J. Eng. Appl. Sci. **11**(21), 12371–12379 (2016)
12. F. Jahanimoghadam, A. Horri, N. Hasheminejad, N.H. Nejad, M.R. Baneshi, Ergonomic evaluation of dental professionals as determined by rapid entire body assessment method in 2014. J. Dent. (Shiraz) **19**(2), 155–158 (2018)

Chapter 28
Performance and Emission Characteristics of VCR Diesel Engine Fueled with Blends of Babassu Oil Methyl Esters and Diesel

Satishchandra Ragit, Krishnendu Kundu, and Aman Sharma

Nomenclature

CO	Carbon Monoxide
EGT	Exhaust Gas Temperature
HC	Hydrocarbons
BB	Babassu Biodiesel
BOME	Babassu oil methyl ester
BOME	BB
BOME 10	BB 10
BOME 20	BB 20
BOME 30	BB 30
BP	Brake Power
BTE	Brake thermal efficiency
SFC	Specific Fuel Consumption
NOx	Oxides of nitrogen

1 Introduction

Demand for the fuel, with the rising deterioration of natural conditions has increased concern for environmental problems and energy crisis. Babassu biodiesel (methyl

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ester) is one of the capable selections as substitute fuels for Compression ignition engines. Due to rapid industrialization and urbanization, demand for energy has sky rocketed. Among all the primary sources of energy, fossil fuels still top the list. According to the latest report, it is believed that that global energy consumption will increase by 30%. China and India will both account for an increase in energy demand up to 45% by 2020 and oil consumption will soar up in future. Report also showed an increase in coal consumption up to 30% by 2020 [1]. Babassu is a palm native to the Amazon forests and can be found in South American region and some parts of south India. Babassu nut contains around 62% of oil. Moreover, babassu palm is resistant to drought having extraordinary oil rate of production (1,541 kg oil ha^{-1}). The oil is light pale yellow colored has low FFA value. Babassu oil is a clear light yellow vegetable oil extracted from the seeds of the babassu palm (Attalea speciosa), which grows in most areas of South America. It is about 70% lipids, with 50% of lauric composition. Among all feasible vegetable oil to cultivation and to oil extraction, this study employed the babassu, a generic name given to palm oil belonging to the Palmae family and members of the genera Orbignya and Attalea. The babassu oil constitutes 66% of kernel weight, and its composition is mainly saturated (83% of the grease composition) which makes it an excellent alternative for biodiesel production. Non-edible oils contain some toxic components in their feedstock rendering them unfit for human consumption. Biodiesel obtained from babassu (*Attalea speciosa*) is excellent non-edible source of biodiesel production [2]. It had been very important to study alternative sources of fuel for diesel engine because of availability and price of petroleum-based fuels. The performance and emission of babassu oil methyl ester and its respective blends tested in VCR Engine have been presented in this research paper. These experiments were conducted at three different blending ratio's 10, 20, and 30% of BOME with diesel. The outcomes of the experiments were compared with standard diesel fuel. This study presents performance and exhaust emission characteristics of VCR engine fueled with Babassu oil methyl ester and compared with diesel fuel.

2 Methodology

2.1 Variable Compression Ratio (VCR) Engine Test Procedure

A single cylinder four Stroke VCR Engine (Fig. 1) was used for the present work. The engine develops 3.5 KW at a rated speed of 1,500 rpm. The loading was provided by an eddy current dynamometer coupled with the engine shaft. In addition, a magnetic rpm sensor was attached at the end of the dynamometer for rpm measurement. Two separate tanks were used for diesel and biodiesel (BOME) blends. Airflow rate was measured using a mass airflow sensor while fuel consumption rate was measured by 20 cc burette and stop watch with level sensors. The performance parameters (BP, BTE, SFC, and EGT) were measured. The gaseous emissions were measured from an exhaust surge tank. The CO, HC, and NOx were measured with the help of an AVL Di-gas emission analyzer (Fig. 2) [3–9]. The specification of VCR Engine is presented in Table 1.

Fig. 1 VCR engine

Fig. 2 AVL Di-gas emission analyzer

Table 1 Specifications of the engine

Engine type	4 stroke VCR engine
No. of cylinders	Single cylinder
Capacity	661 cm^3
Bore	87.5 mm
Stroke	110 mm
Compression ratio	14:1–20:1
Power	3.5 kW at 1500 RPM
Dynamometer	Eddy current type water cooled
Software	"Engine soft LV" engine performance analysis

3 Results

3.1 Performance Characteristics

Experimentation had carried out in VCR engine, three different blends had been tested with three compression ratios (14:1, 16:1, and 18:1) at constant engine speed and load was varied in an increment of 2 kg with maximum load being 10 kg. The performance parameters such as BP, BTE, SFC, and EGT, were calculated using engine software.

3.1.1 Brake Thermal Efficiency (BTE)

From Fig. 3, it is envisaged that brake thermal efficiency showed linear trend with loads. This is because of less loss of heat and high power obtained at increasing loads. BB30 has higher BTHE in all the experiments. Relatively lower value of BTHE than diesel fuel is attributed because of higher viscosity and poor spray characteristics of blended fuel [10]. For compression ratio 14, highest BTHE obtained at full load (100%) was 23.57% for BB30. For compression ratio 16, highest BTHE obtained was 25.46% for BB 30 and for compression ratio 18, highest BTHE obtained was 28% at full load (100%). At CR 18, BTHE is improved as compared to CR16 and CR14 due to better combustion of blended fuel.

3.1.2 Brake Power (BP)

From the following graphs (Fig. 4), it was concluded that BP followed linear trend with increasing engine load. There is not much significant difference in the power obtained using biodiesel blended fuel [11]. This is because of greater density and viscosity of biodiesel which compensates for lower calorific value of biodiesel

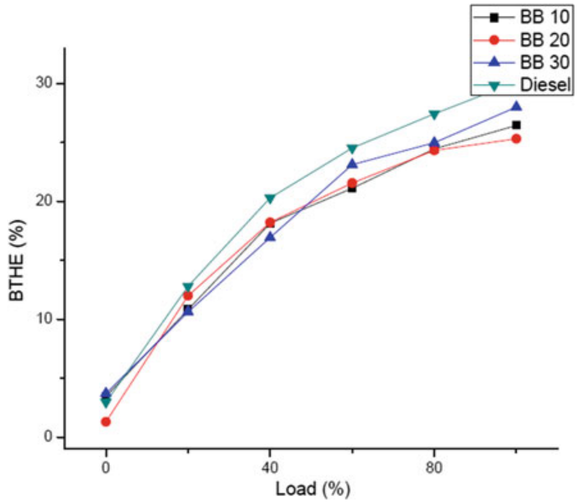

Fig. 3 BTE versus load for BOME at CR 18

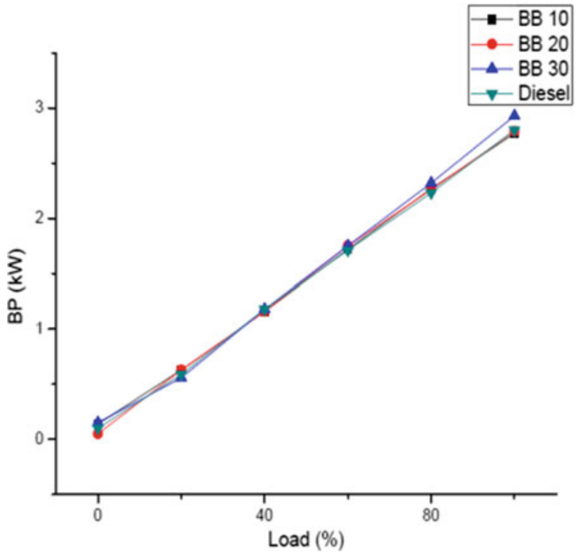

Fig. 4 BP versus load for BOME at CR 18

thereby increasing air–fuel mixing which leads to proper combustion process. Another reason for almost near BP trends for biodiesel and diesel is high BSFC for the biodiesel. At CR18, BB30 showed higher BP at full load. This might be because of better combustion and higher cylinder temperature which supports combustion.

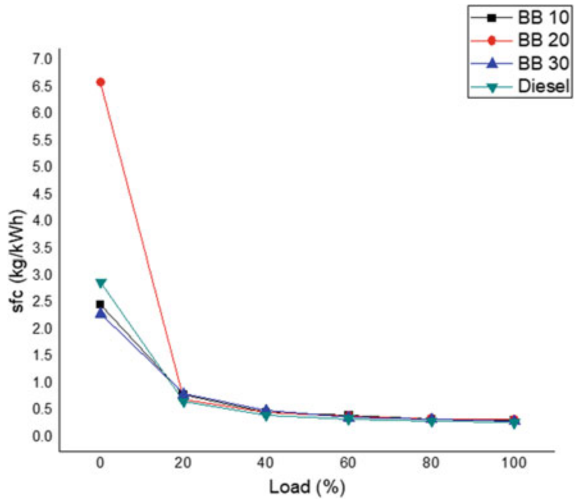

Fig. 5 SFC versus load for BOME at CR 18

3.1.3 Specific Fuel Consumption (SFC)

From the following graphs (Fig. 5), it has been found that as the engine load increases, SFC decreases. This is because of an increase in brake power with fuel consumption. Another reason is improved combustion process due to high in-cylinder temperature which occurs on increasing engine load which further improves mixing and enhances atomization process for better combustion [12]. For BB10 and BB20, there is an increase in SFC at lower loads. Such trend is attributed due to relatively high density of BOME than diesel fuel. Thus resulting in a high discharge of fuel. For BB30 decreasing trend was obtained. This is because of better combustion and more oxygen available at high blends.

3.1.4 Exhaust Gas Temperature (EGT)

From the acquired graphs (Fig. 6), it is elucidated that fumes gas temperature ascends at higher loads at all pressure proportions. Exhaust gas temperature of blended fuel BB10, BB20, and BB30 is more than petrodiesel. Maximum EGT is for BB30. This trend is followed because of the extra oxygen content available in the blended fuel and the presence of high boiling point components which support combustion [13]. At compression ratio 18 and 14 same trend was noticed. Blended fuel exhibits highest EGT as compared to diesel fuel with BB30 showing maximum EGT for each of the compression ratio at full load condition.

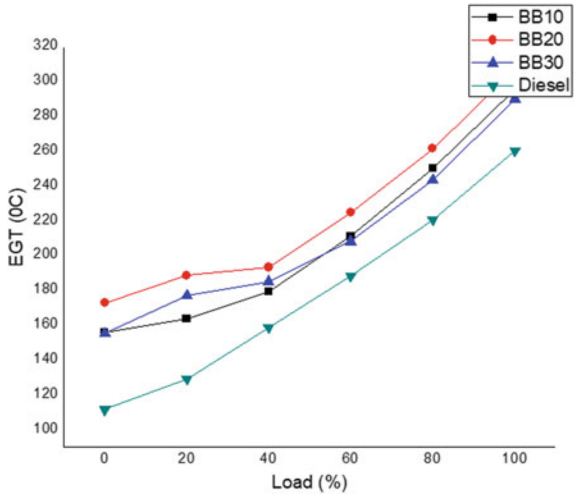

Fig. 6 EGT versus load for BOME at CR 18

3.2 Emission Characteristics

Emissions from VCR engines contribute to environmental pollution considerably, particularly on fossil fuels. One of the advantages of renewable fuels such as biodiesel over its fossil fuel counterpart is its lower emissions. The subsequent section describes the emission characteristics of BOME and its blends with diesel. Emissions were noted down using exhaust analyzer by inserting sensing probe into the exhaust of engine and noting down values on digital screen of the instrument.

3.2.1 Carbon Monoxide Emissions (CO)

As the load is increased engine cylinder temperature rises up causing a reduction in CO emissions. At full load, CO emission tends to rise (Fig. 7). This is because of the production of smoke on excess fuel delivery preventing oxidation of CO to CO_2 [14]. For all the compression ratios, it has been investigated that blended fuel trims down the level of CO emissions when compared to petrodiesel.

3.2.2 Hydrocarbons (HC)

From Fig. 8, it is observed that HC emissions are lowered in comparison to high-speed diesel fuel. It was suggested that saturation in the compounds present in blended fuel

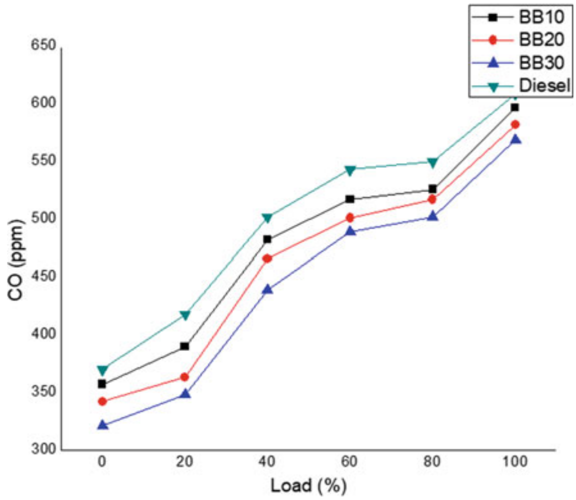

Fig. 7 CO versus load for BOME at CR 18

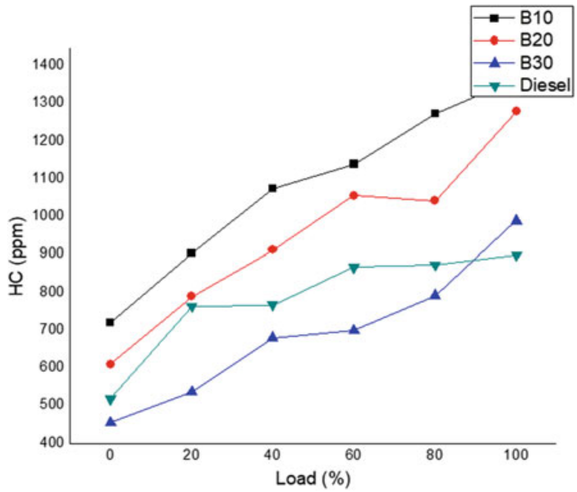

Fig. 8 HC versus load for BOME at CR 18

and stable combustion and faster rate of evaporation. Another explanation behind this pattern is propelled infusion timing combined with high cetane number. But with load, it is reported that at higher loads, HC emission leveled up. This is because of high rate of fumigation and oxygen is less available to support combustion at higher engine loads [15]. Hence increasing trend for HC with respect to load was observed.

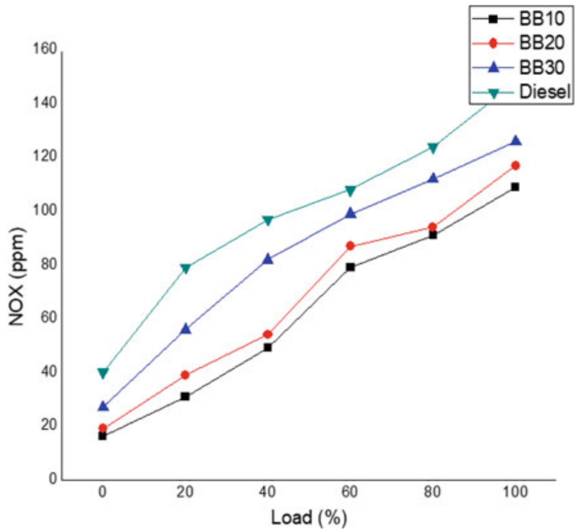

Fig. 9 NO_x versus load for BOME at CR 18

3.2.3 Nitrogen Oxides (NO_x)

Firstly, NO_x emissions are directly proportional to load varied. With increasing loading, NO_x emissions increases (Fig. 9). This is because at higher engine loads, combustion chamber temperature shots up and NO_x emissions are directly temperature-dependent. Another perception that has been made is that NO_x discharges are lower when contrasted with diesel. This is a result of high cetane number which causes a decrease in start defer resulting in downfall of NOx emissions. Another explanation for reduced NO_x emissions is saturation in fatty compounds [16].

4 Conclusion

In the present work, an exhaustive engine trial was carried to evaluate the performance and emission characteristics of different BOME-diesel blends. The following conclusions drawn as follows.

Performance characteristics: BB30 has higher BTE in all fuel blends. For CR = 18, BTE was obtained 28% at full load. The BP follows linear trend with increasing engine load, no significant results achieved at all fuel blends. For BB10 (BOME 10) and BB 20 (BOME 20), there is a drastic increment of SFC at lower blends. This is due to high density of BOME. For BB30 (BOME 30), it reveals decreasing trend of SFC was observed. This is because of better combustion and more oxygen available at high blends. The maximum EGT had obtained at BOME 10, BOME 20, and BOME 30 for CR 16. Maximum EGT obtained at BOME 30 for all fuel blends at full load condition.

Emission Characteristics: For all CR's, reduction of CO emission had been achieved. For CR's 14 and 16, HC emission reduces and slightly increases at CR = 18. For all CR's, NOx emission reduction had been observed. From experimental investigation, it may be concluded that babassu oil methyl ester is a potential alternative to diesel fuel without any engine modification.

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References

1. S. Subhani, S. Kommana, Optimization of compression ratio for computerized VCR CI engine fueled with peanut oil blended with diesel and additive. IJRTE **8**(1S3), 156–161 (2019)
2. E.J.M. Paiva, M.L.C.P. Silva, Evaluation of biodiesel production from Babassu oil and ethanol applying alkaline transesterification under ultrasonic technology. Bioenergy Technol. 303–310 (2011)
3. M. Saraswat, N.R. Chauhan, Environmental Impact of Butanol and Algae oil addition in Gasoline at different compression ratio. J. Sci. Ind. Res. **78**, 382–385 (2019)
4. R. Sabarish, D. Mohankumar, Performance and emission characteristics of diesel engine with biodiesel blend at various compression ratio. Int. J. Pure Appl. Math. **118**(18), 957–965 (2018)
5. M. Saraswat, N.R. Chauhan, Performance evaluation of Algae oil-Gasoline blends in variable compression ratio SI engine. J. Sci. Ind. Res. **77**, 723–727 (2018)
6. S. Navya Sree, A.V. Krishna Chaitanya, Performance and emission characteristics of variable compression ratio diesel engine fueled with waste plastic oil and dimethyl carbonate. IJCIET **8**(7), 332–339 (2017)
7. A.V. Krishna Chaitanya, Experimental investigation on variable compression ratio diesel engine fueled with Mahua oil and diesel blends. Int. J. Chem. Sci. **15**(3), 1–12 (2017)
8. S.V.U. Rao, T.V.H. Rao, Effect of variable compression ratio on performance and emission characteristics of IC Engine. IJETT **37**(6), 317–326
9. S.S. Ragit, S.K. Mohapatra, K. Kundu, Performance and emission evaluation of a diesel engine fueled with methyl ester of neem oil and filtered neem oil. J. Sci. Ind. Res. **69**, 62–66 (2010)
10. S. Jindal, B.P. Nandwana, N.S. Rathore, V. Vashistha, Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester. Appl. Therm. Eng. **30**, 442–448 (2010)
11. M. Lapuerta, Effect of the alcohol type used in the production of waste cooking oil biodiesel on diesel performance and emissions. Fuel **87**, 3161–3169 (2008)
12. J. Singh Pranil, K. Jagjit, S. Anirudh, Preparation, characterization, engine performance and emission characteristics of coconut oil based hybrid fuels. Renew Energy **35**, 2065e70 (2010)
13. S. Puhan, N. Vedaraman, G. Sankaranarayanan, B.V.B. Ram, Performance and emission study of Mahua oil (Madhuca indica oil) ethyl ester in a 4-stroke natural aspirated direct injection diesel engine. Renew Energy **30**(8), 1269–1278 (2005)
14. M.P. Dorado, E. Ballesteros, J.M. Arnal, J. Gomez, F.J. Lopez, Exhaust emissions from a diesel engine fueled with transesterified waste olive oil. Fuel **82**(11), 1311–1315 (2003)

15. A. Monyem, J.H. Van Gerpen, M. Canakci, The effect of timing and oxidation on emissions from biodiesel-fueled engines. Trans. ASAE **44**(1), 35–42 (2001)
16. S. Kalligeros, F. Zannikos, S. Stournas, E. Lois, G. Anastopoulos, C. Teas, F. Sakellaropoulos, An investigation of using biodiesel/marine diesel blends on the performance of a stationary diesel engine. Biomass Bioenergy **24**(2), 141–149 (2003)

Chapter 29
Validation of Safety Factors for Work Environment in Small-Scale Manufacturing Industry—Punjab

Satnam Singh and Lakhwinder Pal Singh

1 Introduction

The ILO also makes sure that workers are protected against misshapes due to workplace and also it shows the priorities regarding action to improve working conditions and work organization risks [1]. A lot of improvement is required to industries and required research to improve occupational safety [2]. Different changes, emphasizing, national development in policy, and methods regarding occupational safety done in Australia during last 15 years and a phase is followed for introducing modern legislation and new institution also created different research programs started on occupational safety [3]. Small industries have very little attention about the occupational safety in Canada that arises some serious problems. The main reason for these misshapes are little attention of manager about worker safety and overworked [4]. Jeong studied that larger companies have a lower accidental rate than smaller in Korea and all major accidents occurred in the first year of employment [5]. The accidents and injuries are controlled by proper safety guidelines. The necessary and key hazards and environmental conditions at workplace and work safety and ultimately propose a method that can use to assess safety risks and evaluate significant environmental aspects [6]. Now, many seminars and conferences are held in India, for example, "Fifth India-EU seminar on employment and social policy occupational safety and health" [7].

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2 Literature Review

In occupational safety, organizational and management issue plays a major role and more attention is required regarding safety training and management supports to improve safety climate [8]. Azadeh checks the performance optimization of industry by considering the safety, health ergonomics, and environment as main factors [9]. Shikdar discussed the different parameters that affects the worker's safety like demography of company, productivity issue; ergonomic issue, environmental factors, and management issue [10]. Workplace has a good effect on safety climate. Economic conditions and employee's work behavior are also the main parameters of occupational safety [11]. Lu and Tsai suggested that job safety has higher importance than management safety practices and training regarding safety and logistic regression analysis used to find out the different safety climate proportions [12]. Hayes et al. found the main five factors in their study by using factor analysis. This study also shows that there is a strong link between co-worker and supervisor safety practices with employee's compliance with safety behavior [13].

Cheng considers the improper protective equipment, work hazard awareness as a major factor in occupational safety and suggests training as a necessary part for workers [14].

Workers have a positive attitude towards safety management and procedure followed at the workplace but it is negative towards management commitment regarding safety [15]. The main causes of occupational safety were inadequate safety rules, procedure, production pressure, and breakage of rules. In addition, length of employment, effective safety education, and training also recommended for worker safety [16]. The main content of occupational safety is work environment, safe procedure, individual responsibility, and communication between worker and management [17].

Polluted enterprises expose the environment and worker to hazardous substances that cause different health problem. There is a need for awareness regarding interlinks between workers, environmental conditions, and occupational health and safety [18]. Ramli suggested that all pollution factors like air, water, and land pollutions are taken into account in occupational safety [19]. Few factors like heat, noise, and protective clothing are also a part of occupational safety and also first Aid box as an important parameter in his study [20, 21]. The basic welfare parameters like drinking water, washroom, and restroom also play a vital role in case of employee safety.

Mittal and Miller in their study discuss that training is very important for controlling workplace injuries and misshapes; increase the productivity with improving the skills of workers [1–33]. Das shows in his study that linear relationship between quality performance and safety disconnect, logically quality might be affected with safety perceptions and the worker with metal misgiving about safety effect the product quality [27].

Jung discussed in his study that three types of training sessions are running simultaneously in Korea such as international workshops on participatory approaches, national training on work improvement in small enterprises, and training on small construction sites. Firefighting arrangement may also be consided as an important factor of work-related safety. The major and minor variables are also provided in detail in Factory Act 1948 of India [28].

3 Methodology

The literature review provides the 42 factors for occupational safety in this study. The validation of these factors is checked by using content validity index (CVI) method [29–31]. Although by documentary content validity may seem expensive in terms of time and shows the greater attention when a valid assessment is to be developed [30]. In this method, a panel of experts were asked to give rating to various factors according to their relevance on a four-point Likert scale such as 1 = not relevant, 2 = somewhat relevant, 3 = quite relevant, and 4 = highly relevant. In conclusion, a factor was rated quite or highly relevant by four of the five experts that would have F-CVI = 0.80. Hence, F-CVI was measured for each factor and S-CVI for full scale [32].

$$F\text{-}CVI = \frac{Number\ of\ experts\ giving\ rating\ 3\ or\ 4}{Total\ number\ of\ \exp erts}$$

$$S\text{-}CVI = \frac{Mean\ F - CVI\ \geq\ 0.78}{Number\ of\ factors\ having\ F\text{-}CVI\ \geq\ 0.78}$$

The method used to calculate the average of all F-CVI of individual factor denoted as $S\text{-}CVI_{ave}$. Similarly, $S\text{-}CVI_{ua}$ that is known as "universal agreement" among experts also determines.

$$S\text{-}CVIave = \frac{sum\ of\ F\text{-}CVI}{number\ of\ items}$$

and

$$S\text{-}CVIua = \frac{total\ items\ of\ full\ agreements}{number\ of\ items}$$

To counter the limitations of CVI, F-CVI is computed for chance agreement by calculating modified kappa statics [33]. In this, we have to measure the probability of chance agreement (Pc).

$$\mathrm{Pc} = \frac{\mathrm{N!}}{\mathrm{A!(N - A)!}} \times 0.5\mathrm{N}$$

where N denotes number of experts and number of experts give a rating 3 or 4 is denoted by A. Hence, modified Kappa (K) is calculated as

$$K = \frac{(F - CVI) - Pc}{1 - Pc}$$

4 Result

Six experts were participated in content validity for analyzing the content validity index. These all experts were male and have good work experience of about 10–20 years in the industry. They agreed to give their opinion on the worker's safety because they experienced in their career that safety of employees is one of the major part to run industry without any misshapen. They rated content validity questionnaire, and 37 out of 42 factors (88%) showed excellent (F-CVI) factor content validity index and three factors showed good F-CVI, however two factors showed poor rating.

In nutshell, 40 factors from 42 have a content validity index (F-CVI > 0.78) greater than 0.78 and modified kappa (K^*) > 0.74. Two factors that got poor rating had a value of F-CVI such as factor number 6(0.66) and factor number 39 (0.33). $S\text{-}CVI_{UA}$ and $S\text{-}CVI_{AVE}$ of the whole data were calculated as 0.88 and 0.96, respectively.

The second part of the calculation is to check the normality of data provided by the experts. SPSS was used to check the value of Skewness and Kurtosis that showed the result as 0.943 and 0.586, respectively, as shown in Table 1 .

Secondly, the histogram curve shows the result of aggregate of experts' opinion as in Fig. 1. Hence, from these two parts it proves that the rating provided by experts is having normality.

5 Discussion

The purpose of this case study was to find out the validity of major factors for worker safety in Punjab. Therefore, we can control the accident rate at workplace by concentrating on these valid factors. Experts judged most of the factors relevant. The results of F-CVI and K^* were linear to each other. The factors that have a value of F-CVI less than 0.78 also do not get good K^* values and vice-versa. Hence, the conclusions of both methods provide strength to current evidence [33]. The result of $S\text{-}CVI_{AVE}$ having a value of 0.96, similarly value of $S\text{-}CVI_{UA}$ is 0.88, both of these values are acceptable as recommended by Polit et al. [33]. The two factors of the questionnaire (factor 6: Proper records of accidents and injury and factor 39: rest room for workers) got less relevancy by experts. These two factors were also cross-checked with the help of modified Kappa method but result was same, so these

Table 1 Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Aggregate	66	158	163	160	1.78	3.20	0.94	0.84	0.58	1.74
Valid N										

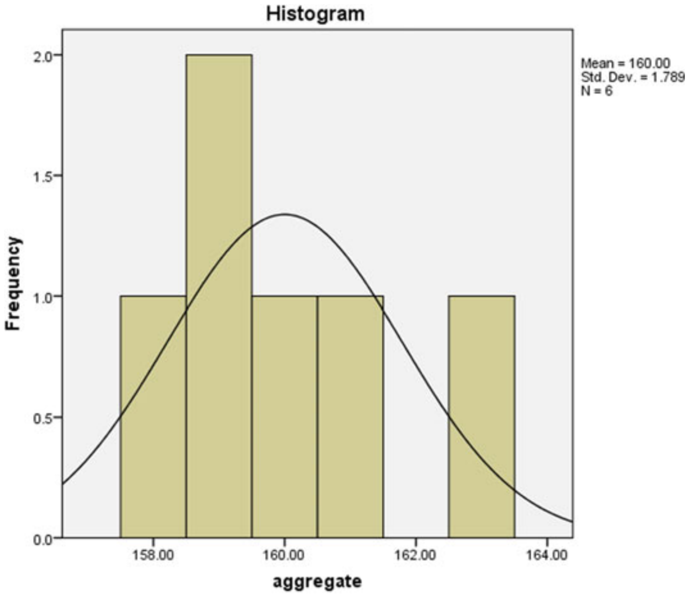

Fig. 1 Histogram curve

factors have less effect on worker's safety. Hence, we can neglect both factors in further study.

One of the most important key points of this study is statistically verification of data with SPSS. The rating given by experts shows a normality curve of histogram in SPSS as depicted in Fig. 1. The value of Skewness and kurtosis again provide the strength to the study [34].

This study has few limitations that only six experts were part of this study but in actual they were enough according to content validity index method. Therefore, we can also take the review from the safety officers, labor officers, and others, so they will help to identify more easily and recommend some other factors that will help to improve the accident curve in India.

6 Conclusion

Present research examines the key factors of occupational safety of workers related to manufacturing industry of Punjab. This study consists of 42 factors related to occupational safety of workers. Established factors are validated with content validity index (CVI). To assure the credibility and validity of factors and scale, only the factors having content validity F-CVI > 0.78 and scale content validity S-CVI > 0.90 are considered, with expert opinion. It is concluded that 37 factors have excellent rating,

Table 2 Values of CVI and modified kappa

S.N	Factors	No. in agreement	F-CVI	P_c	K^*
1	Safety committee in the factory	5	0.83	0.09	0.81
2	Regular communication between worker and occupier	6	1	0	1
3	Following of proper factory acts and policies	6	1	0	1
4	Feedback related to workplace safety from worker	6	1	0	1
5	Safe working condition provided by management	6	1	0	1
6	Proper records of accidental or injury	4	0.66	0.23	0.55
7	Importance of Fencing of machinery	6	1	0	1
8	Regular inspection of machinery during motion	6	1	0	1
9	Employment of experienced persons on dangerous machines	6	1	0	1
10	Satisfaction of worker on job	6	1	0	1
11	Limit of load lifted by worker	6	1	0	1
12	Training related to safety of workers	6	1	0	1
13	Proper schedule of training	6	1	0	1
14	Skills of resource person for worker training	6	1	0	1
15	Effect of training on worker's safety	5	0.83	0.093	0.81
16	Provision of personal protective equipment	6	1	0	1
17	Quality of personal protective equipment	6	1	0	1
18	Impact of personal protective equipment on injury rate	6	1	0	1
19	Safe workplace layout in factory	6	1	0	1
20	Proper Lifting machines, chains, ropes and lifting tackles	6	1	0	1
21	Proper space between two machines	6	1	0	1
22	Arrangement of suitable devices for cutting off power in emergencies	6	1	0	1

(continued)

Table 2 (continued)

S.N	Factors	No. in agreement	F-CVI	P_c	K^*
23	Importance of safe electric installations	6	1	0	1
24	Importance of proper notice and caution sign	6	1	0	1
25	Regular maintenance of building	6	1	0	1
26	Importance of firefighting system in factories	6	1	0	1
27	Preventive measure in danger of fire	6	1	0	1
28	Importance of fire exits	6	1	0	1
29	Importance of fire alarm	6	1	0	1
30	Cleanliness in factory	6	1	0	1
31	Proper disposal of wastes and effluents	6	1	0	1
32	Proper Ventilation	6	1	0	1
33	Controlling of Dust and fume	6	1	0	1
34	Proper Lighting arrangement	6	1	0	1
35	Proper drinking water	6	1	0	1
36	Proper Latrines and urinals	6	1	0	1
37	Proper temperature	6	1	0	1
38	Proper canteen or lunch room	6	1	0	1
39	Rest room for workers	2	0.33	−1.40	−2.64
40	Presence of first aid box	6	1	0	1
41	Periodical check-up of worker	5	0.83	0.09	0.81
42	Medical insurance of workers	6	1	0	1

whereas three have good and two are having poor rating. The $S\text{-}CVI_{AVE}$ and $S\text{-}CVI_{UA}$ have values of 0.96 and 0.88, respectively.

The result is also verified by using SPSS. The histogram curve shows the normality on expert rating. In addition, Skewness and Kurtosis have value of 0.943 and 0.586, respectively. These valid factors have high importance and it helps to improve the occupational safety in small-scale manufacturing industries. The major parameters which may help to improve worker safety in Punjab are role of management, job safety, workplace layout, training of workers, personal protective equipment, firefighting arrangement, and welfares.

References

1. S. Niu, Ergonomics and occupational safety and health: an ILO perspective. Appl. Ergon. **41**, 744–753 (2018)
2. R.V. Agnihotram, R. Article, An overview of occupational health research in India. Indian J. Occup. Environ. Med.;**9**, 10–14 (2005)
3. E.A. Emmett, Occupational health and safety in national development-the case of Australia. Scand. J. Work Environ. Health **23**, 325–333 (1997)
4. D. Champoux, J.-P. Brun, Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research. Saf. Sci. **41**, 301–318 (2018)
5. B Y. Jeong, Characteristics of occupational accidents in the manufacturing industry of South Korea. Int. J. Ind. Ergon. **20**, 301–306 (2007)
6. I.H.M. Fauzey, F. Nateghi, F. Mohammadi, F. Ismail, Emergent, "Occupational Safety & Health and Environmental Issues of Demolition Work: Towards Public Environment." Proc. Soc. Behav. Sci. **168**, 41–51 (2017)
7. Fifth India-EU, Seminar on Employment and Social Policy, *Occupational Safety and Health*, New Delhi – September 19–20 (2017)
8. Q. Ma, J. Yuan, Exploratory study on safety climate in Chinese manufacturing enterprises. Saf. Sci. **47**, 1043–1046 (2009)
9. A. Azadeh, M. Sheikhalishahi, An efficient taguchi approach for the performance optimization of health, safety, environment and ergonomics in generation companies. Saf. Health Work **6**, 77–84 (2016)
10. A.A. Shikdar, N.M. Sawaqed, Worker productivity, and occupational health and safety issues in selected industries. Comput. Ind. Eng. **45**, 563–72 (2013)
11. J.M. Beus, M.E. Bergman, S.C. Payne, The influence of organizational tenure on safety climate strength: a first look. Accid. Anal. Prev. **42**, 1431–1437 (2010)
12. C.S. Lu, C.L. Tsai, The effects of safety climate on vessel accidents in the container shipping context. Accid. Anal. Prev. **40**, 594–601 (2018)
13. B.E. Hayes, J. Perander, T. Smecko, J. Trask, Measuring Perceptions of Workplace Safety: Development and Validation of the Work Safety Scale. J. Saf. Res. **29**, 145–161 (2013)
14. C.W. Cheng, T.C. Wu, An investigation and analysis of major accidents involving foreign workers in Taiwan's manufacture and construction industries. Saf. Sci. **57**, 223–235 (2010)
15. E.H. Sukadarin, N.S. Suhaimi, N. Abdull, Preliminary study of the safety culture in a manufacturing industry. Int. J. Humanit. Soc. Sci. **2**, 176–183 (2016)
16. J.B. Baek, S. Bae, B.H. Ham, K.P. Singh, Safety climate practice in Korean manufacturing industry. J. Hazard Mater. **159**, 49–52 (2018)
17. H. Nordlof, B. Wiitavaara, U. Winblad, K. Wijk, R. Westerling, Safety culture and reasons for risk-taking at a large steel-manufacturing company: investigating the worker perspective. Saf. Sci. **73**, 126–135 (2015)
18. Mukul. Polluting Industries, Environment and Workers' Health: a case for intervention. Econ. Polit. Weekly **32**, 37–44 (1997)
19. N.A. Ramli, S. Munisamy, Eco-efficiency in greenhouse emissions among manufacturing industries: a range adjusted measure. Econ. Model **47**, 219–227 (2015)
20. F.O. Sari, Effects of employee trainings on the occupational safety and health in accommodation sector. Proc. Soc. Behav. Sci. **1**, 1865–1870 (2009)
21. M.H. Noweir, M.M. Alidrisi, I.A. Al-Darrab, M.A. Zytoon, Occupational safety and health performance of the manufacturing sector in Jeddah Industrial Estate, Saudi Arabia: A 20-years follow-up study. Saf. Sci. **53**, 11–24 (2013)
22. P. Miller, C. Haslam, Why employers spend money on employee health: Interviews with occupational health and safety professionals from British Industry. Saf. Sci. **47**, 163–169 (2009)
23. F. Act, Statistics on Status of compliance with statutory provisions based on data collected, by *DGFASLI* Chapter 8 (2017)

24. S. Unnikrishnan, R. Iqbal, A. Singh, I.M. Nimkar, Safety management practices in small and medium enterprises in India. Saf. Health Work **6**, 46–55 (2015)
25. X. He, L. Song, Basic characteristics of work safety in China. Proc. Eng **26**, 1–9 (2009)
26. T.R. Cunningham, R. Sinclair, Application of a model for delivering occupational safety and health to smaller businesses: case studies from the US. Saf. Sci. **71**, 213–225 (2015)
27. A. Das, M. Pagell, M. Behm, A. Veltri, Toward a theory of the linkages between safety and quality. J. Oper. Manag. **26**, 521–535 (2018)
28. Factory act 1948, India.
29. E. Devriendt, K. Van den Heede, J. Coussement, E. Dejaeger, K. Surmont, D. Heylen, Content validity and internal consistency of the Dutch translation of the Safety Attitudes Questionnaire: an observational study. Int. J. Nurs. Stud. **49**, 327–337 (2012)
30. F. Yaghmale, Content validity and its estimation. J. Med. Educ. **3**, 25–27 (2003)
31. A. Ghahramani, H.R. Khalkhali, Development and validation of a safety climate scale for manufacturing industry. Saf. Health Work **6**, 97–103 (2015)
32. M.R. Lynn, Determination and quantification of content validity. Nurs. Res. **35**, 382–386 (1986)
33. D.F. Polit, C.T. Beck, The content validity index: are you sure you know what's being reported? Critique and recommendations. Res. Nurs. Health **29**, 489–497 (2006)
34. A. Mital, A. Pennathur, R.L. Huston, D. Thompson, M. Pittman, G. Markle, The need for worker training in advanced manufacturing technology (AMT) environments: a white paper. Int. J. Ind. Ergon. **24**,173–184 (1999)

Chapter 30
Effect of Process Parameters on Water Absorption Behaviour of Biodegradable Green Composites

Guravtar Singh, Lakhwinder Pal Singh, and Pramod Kumar

1 Introduction

The growing concern for environmental issues due to climate change because of which sea levels are rising, global average temperatures are increasing and diminishing and recycling of petrochemical resources have increased due to which awareness of renewable biodegradable green composites products for sustainable development [1]. Polymer composites have many advantages, but the lack of adequate degradation of these materials remains a major obstacle [2]. Scientists have developed new categories of sustainable material in recent years, and natural fibre "organic" composites have shown significant interest in the community due to their recyclability and biodegradation features that are useful in applications to replace state-of-the-art synthetic fibres (e.g. glass fibres) [3]. Agricultural waste can be used to build for industrial use fibre-reinforced polymer composites and has a branding appeal. The characteristics of natural fibres rely heavily on the plant's nature, the location in which it is grown, the plant's age and the technique of extraction used [4]. Bio-composite material is widely used and bamboo can be seen as an option in industries such as decor, automotive and other related products [5]. Starch-based plastics, poly(lactic acid) (PLA) and polyhydroxyalkanoate (PHA) will be the main products in terms of overall volumes [6]. The lower weight also enhances fuel efficiency and lowers emissions, particularly in automotive applications, during the product's use cycle. Natural fibre biodegradability results in energy and carbon credits [5].

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2 Literature Review

Ahmed et al. [5] developed hand-lay-up isenthalpic polyester composites made of woven jute and glass and examined the mechanical characteristics impact of hybridization. The performance of the composite was measured using efficiency curves. The results indicated that the structural characteristics such as tensile strength and impact strength were significantly improved with the inclusion of glass fibre, in addition to the composite's water absorption behaviour, with the introduction of glass fibre [7]. Birat et al. [8] experimentally investigated the mechanical properties of laminated three-ply and five-ply jute/glass hybrids composite and compared to the theoretical values. Hand layup method was used for fabrication of composites. It was observed that the deflection resistance of the theoretical values of the composite material particularly for layers 3 (70%) was much higher than that of layers 5-Taped (2%). The water absorption behaviour was also enhanced with hybridization. Melkamu et al. [9] investigated the mechanical and water absorption behaviour of sisal fibre and polyester matrix composites. Specimens were treated with alkaline solution of sodium hydroxide. The values of volume fraction were maintained at 10, 20 and 30%. The results revealed that alkaline treatment improved the tensile, compressive and impact strength of the composite with the added benefit of low water absorption. Meenakshi et al. [10] fabricated flax, sisal and glass fibre-reinforced epoxy hybrid composites and examined the effect of surface modification of these fibres various mechanical properties and thermal, hydrothermal and water absorption behaviours. It was observed that alkaline-treated sisal and flax fibres enhanced the mechanical properties significantly. Moreover, the surface morphology results revealed that there was good interfacial bonding between various layers. Vivek et al. [11] investigated the mechanical properties of hybrid natural of hybrid natural fibres sisal, flax, banana and kenaf. Bagasse ash (BGA) was filled in bio-composite to enhance mechanical and thermal properties. The vacuum bag-assisted resin transfer method was used for fabrication of composites. Mechanical testing and thermogravimetric analysis were conducted to determine mechanical properties and thermal stability of composites. The results revealed that incorporation of 3 wt% of BGA enhanced the mechanical properties significantly. Shih et al. [12] manufactured green composites using melt-mixing methods to reuse fibre from disposable chopsticks and PLA matrix. Mechanical tests showed that the composites tensile strength improved considerably with the fibre content, reaching 115 MPa when reinforced with 40 nylon fibres, about three times higher than pristine PLA. Lee et al. [13] concluded that the piling layer of denim fabrics increased the tensile strength of PLA/denim fabric composites. The three-layer denim-reinforced composite showed the best results among all samples with 75.76 MPa and 4.65 GPa, respectively, tensile strength and tensile unit (Table 1).

Table 1 Levels of the variables used in the experiment

Levels	Variables		
	A:MT	B:CP	C:CT
1	165	255	35
2	190	305	65
3	215	355	95

3 Methodology

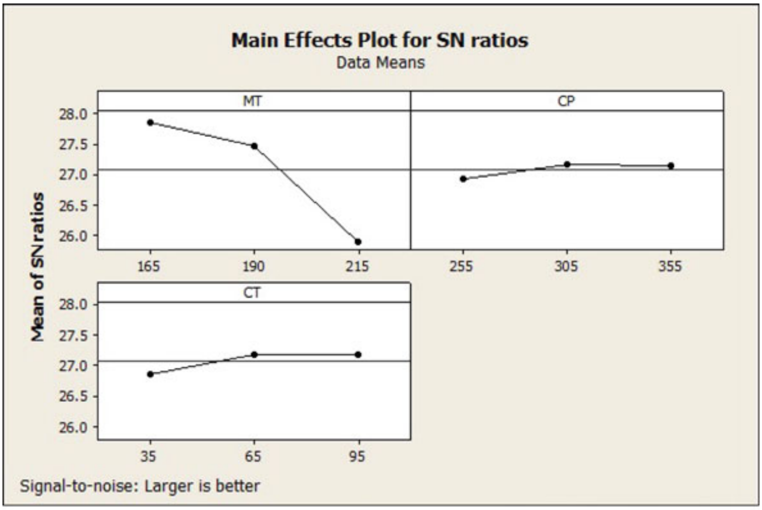
In present research work, an effort has been made to study the water absorption ability of the hybrid poly-lactic-acid composites prepared by using sisal and jute fibres using compression moulding press. The input process parameters such as compression pressure, moulding temperature and volume fraction have been studied using Taguchi method. The Taguchi approach gives information on the full range of research scenarios covering different applications. There are possible three categories for quality characteristics (1) Smaller is better, (2) nominal is better and (3) Larger is better. The goal of the current research is to study the effect of different parameters on hybrid composite water absorption behaviour. Therefore, greater quality characteristics are chosen. Which is given as Fig. 1 shows that parameter values at levels A1, B2 and C3 are the best choice in terms of impact intensity and water absorption values at levels A1, B3 and C2 are the best choice in terms of optimum levels. L9 array is used in this experimentation as shown in Tables 2 and 3.

From the ANOVA it was found that for the percentage of water absorption melting temperature is the most significant factor as compared to other factors such as compression pressure and compression time. As shown in Table 5.

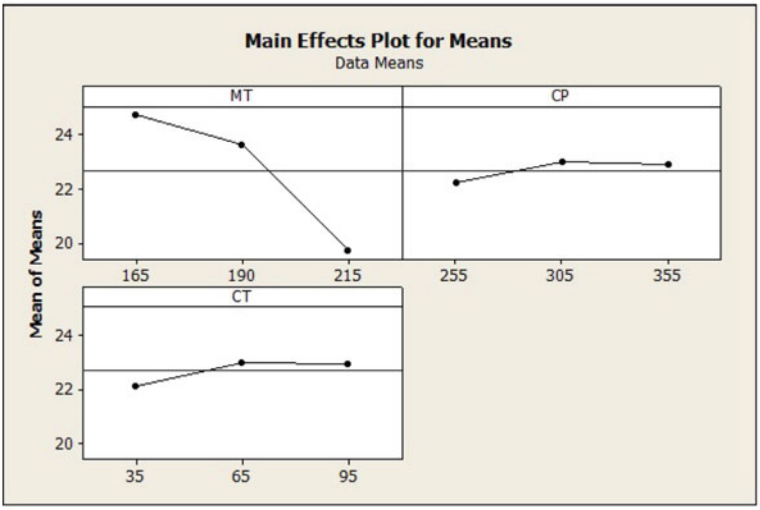
4 Discussion

It can be seen that all three variables play an important role in the manufacture of sisal and jute hybrid composites, but it is observed that the die's heating temperature determines the peak values. The melting of PLA starts at 165 °C at this temperature when a pressure of 250 KN is applied and curing is carried at 30 °C temperature the PLA starts flowing between the materials but some voids are left in the material Because proper adhesion does not take place and bonding between the matrix and material is not proper. As the temperature is increased to 195 °C, pressure of 305 KN is applied with curing at 65 °C. The flow of matrix material is in all directions due to which good bonding takes place which influences the tensile and flexural properties of the material.

So it would be reasonable to think that all the parameters governing the manufacture of composites are affected by the tensile strength and flexural strength in the manufacture of Jute and sisal hybrid composites. From



(a)



(b)

Fig. 1 Mean (**a**) and S/N plot (**b**) for water absorption

S/N ratio it was observed that the water absorption will be maximum when melting temperature, compression pressure and curing temperature having values 165 °C, 305 KN and 65 °C, respectively. Table 4 shows response table for water absorption percentage from it can be determined that melting temperature is most significant parameter and compression pressure is least significant (Table 5).

Table 2 The l_9 orthogonal array

Exp no	MT	CP	CT
1	165	255	35
2	165	305	65
3	165	355	95
4	190	255	65
5	190	305	95
6	190	355	35
7	215	255	95
8	215	305	35
9	215	355	65

Table 3 Results of the L_9 orthogonal array experimental design for water absorption percentage

Exp no	MT	CP	CT	Water absorption %	S/N (dB)
1	165	255	35	23.37	27.3732
2	165	305	65	26.05	28.3173
3	165	355	95	24.76	27.8738
4	190	255	65	23.04	27.2496
5	190	305	95	23.84	27.5461
6	190	355	35	23.94	27.5825
7	215	255	95	20.24	26.1228
8	215	305	35	19.05	25.5979
9	215	355	65	19.91	25.98

Table 4 Response table for means

Level MT CP CT
1 24.73 22.22 22.12
2 23.61 22.98 23.00
3 19.73 22.87 22.94
Delta 5.00 0.77 0.88
Rank 1 3 2

5 Conclusion

The impact of various process parameters on water absorption behaviour of generated hybrid sisal and jute composites have been investigated using the Taguchi technique. Three essential parameters have been studied, namely the temperature of heating, pressure and temperature of curing were studied. It has been observed that the

Table 5 Analysis of variance for water absorption

Analysis of variance for water absorption, using adjusted SS for tests
Source DF Seq SS Adj SS Adj MS F P
MT 2 6.4077 6.4077 3.2038 19.31 0.049
CP 2 0.1100 0.1100 0.0550 0.33 0.751
CT 2 0.2184 0.2184 0.1092 0.66 0.603
Error 2 0.3318 0.3318 0.1659
Total 8 7.0678
S = 0.407315 R-Sq = 95.31% R-Sq(adj) = 81.22%

following parameters melting temperature, compression pressure and curing temperature having values 165 °C, 305 KN and 65 °C, respectively, have most significant effects on water absorption.

References

1. P.K. Bajpai, I. Singh, J. Madaan, Development and characterization of PLA-based green composites: a review. J. Thermoplast. Compos. Mater. **27**(1), 52–81 (2014)
2. G.S. Mann, L.P. Singh, P. Kumar, S. Singh, Green composites: a review of processing technologies and recent applications. J. Thermoplast. Compos. Mater. 0892705718816354 (2018)
3. A. Belaadi, A. Bezazi, M. Maache, F. Scarpa, Fatigue in sisal fiber reinforced polyester composites: hysteresis and energy dissipation. Proc. Eng. **74**, 325–328 (2014)
4. K.N. Bharath, S. Basavarajappa, Applications of biocomposite materials based on natural fibers from renewable resources: a review. Sci. Eng. Compos. Mater. **23**(2), 123–133 (2016)
5. M.R. Nurul Fazita, K. Jayaraman, D. Bhattacharyya, M.K. Mohamad Haafiz, C.K. Saurabh, M.H. Hussin, Green composites made of bamboo fabric and poly (lactic) acid for packaging applications—a review. Materials **9**(6), 435 (2016)
6. O. Faruk, A.K. Bledzki, H.P. Fink, M. Sain, Progress report on natural fiber reinforced composites. Macromol. Mater. Eng. **299**(1), 9–26 (2014)
7. E. Venkata Subba Reddy, A. Varada Rajulu, K. Hemachandra Reddy, G. Ramachandra Reddy, Chemical resistance and tensile properties of glass and bamboo fibers reinforced polyester hybrid composites J. Reinf. Plast. Compos. **29**(14), 2119–2123 (2010)
8. K.C. Birat, S. Panthapulakkal, A. Kronka, J.A.M. Agnelli, J. Tjong, M. Sain, Hybrid biocomposites with enhanced thermal and mechanical properties for structural applications. J. Appl. Polym. Sci. **132**(34) (2015).
9. A. Melkamu, M.B. Kahsay, A.G. Tesfay, Mechanical and water-absorption properties of sisal fiber (Agave sisalana)-reinforced polyester composite. J. Nat. Fibers **16**(6), 877–885 (2019)
10. C.M. Meenakshi, A. Krishnamoorthy, Study on the effect of surface modification on the mechanical and thermal behaviour of flax, sisal and glass fiber-reinforced epoxy hybrid composites. J. Renew. Mater. **7**(2), 153–169 (2019)
11. S. Vivek, K. Kanthavel, Effect of bagasse ash filled epoxy composites reinforced with hybrid plant fibres for mechanical and thermal properties. Compos. B Eng. **160**, 170–176 (2019)
12. Y.F. Shih, C.C. Huang, P.W. Chen, Biodegradable green composites reinforced by the fiber recycling from disposable chopsticks. Mater. Sci. Eng. A **527**(6), 1516–1521 (2010)
13. J.T. Lee, M.W. Kim, Y.S. Song, T.J. Kang, J.R. Youn, Mechanical properties of denim fabric reinforced poly (lactic acid). Fibers Polym. **11**(1), 60–66 (2010)

Chapter 31
Effect of Brightness on Visual Fatigue During Video Viewing

Prerita Kalra and Vinod Karar

1 Introduction

Excessive strain on the eyes can cause visual fatigue. Our eyes get tired if desktop computers, mobiles or tablets are viewed for long durations. This is referred to as computer vision syndrome (CVS) or digital eyestrain by the ophthalmologists.

Symptoms of visual fatigue can be classified as Internal Symptom Factors (ISF) and External Symptom Factors (ESF) [1]. ESF include tearing, irritation, burning and dryness in the front and lower part of the eye. ESF can be attributed to holding the eyelid open, up gaze, glare, small font and flickering. ISF include strain, aching eye and head ache behind the eyes. ISF can be attributed to close viewing distance and mixed astigmatism conditions.

Global statistics show that the percentage of mobile, desktop and tablet users in India in 2019 stands at 76.5%, 23.08% and 0.42% respectively. This shows that a sizeable population of digital display devices in India uses computer desktops. Visual fatigue during desktop usage is affected by the viewing distance, viewing angle, screen brightness and ambient light, screen and content resolution and the blue light emissions.

With the increase in the average number of videos watched per day, visual fatigue due to prolonged video viewing has become a serious cause of concern. Focusing and trying to interpret the video's visual data on a digital screen tires the eye muscles, leading to visual fatigue. As per the details given by Omnicore [2], YouTube has 265

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million active users in India. The video based content and subsequent video viewing is set to grow in the coming years.

The primary strategy for managing digital eyestrain is its prevention. This involves educating the users in order to ensure an ergonomic work environment [3].

The current work investigates the visual fatigue induced during video viewing on a desktop at different levels of screen brightness, under typical illumination conditions.

This research paper is organized along the following lines—Sect. 2 describes the factors affecting visual fatigue, Sect. 3 describes the methods, the results and discussions are given in Sect. 4 and the conclusion is given in Sect. 5.

2 Factors Affecting Visual Fatigue

A. Viewing Distance

The viewing distance from the monitor considerably affects the visual fatigue caused due to it [4]. A very close viewing distance increases the convergence and accommodation demands on the user's eyes and significantly increases near point stress [5]. The monitor should ideally be kept at a distance of 20–30 inches from the face in order to avoid excessive strain on the eyes.

B. Viewing Angle

The angle between the eye level and the line joining the canthus to the center of the screen is known as the viewing angle [6]. The monitor's position with respect to the eye level directly affects visual fatigue. Placing the monitor above the eye level causes the eyes to dry, leading to visual discomfort [7, 8]. The center of the screen should ideally lie 15–20° below the eye level.

C. Brightness

Our eyes can only bear a certain level of light. The cornea and lens of the eye would also deteriorate if exposed to a consistent source of light. Thus, it is understandable that the brightness of the screen with respect to the ambient light would affect the amount of visual fatigue induced. It is expected that both low and high brightness settings are tiring for the eyes.

D. Resolution

The monitor's screen resolution should be in accordance with the screen size. A large screen should have higher resolution. Selecting a monitor with a good resolution helps reduce visual fatigue. A suitably large screen with a screen resolution that exceeds the discriminating ability of the eye is least likely to cause digital strain [9]. A video with the same resolution as that of the screen helps provide a viewing experience with minimal visual strain.

E. Blue Light

The lens and cornea of the adult human eye are adept in preventing the UV rays from reaching the light sensitive retina at the back of the eye. Most of the visible blue light, however, is able to pass through the lens and cornea reaching the retina. This short wavelength, high-energy blue light is scattered easily compared to other wavelengths of the visible light spectrum and is thus not as easily focused. The contrast is thus reduced because of this unfocused visual noise, leading to digital eyestrain. Using a sepia background in place of white background, filters out the blue light, considerably reducing the eyestrain [10].

3 Methods

A. Participants

Twenty-two participants between the age of 19 and 28 (mean age = 22.5) were taken as the subjects. The participants had normal or corrected to normal visual acuity. Their consent was taken before the experiment. The participants, however, did not have any prior idea about the expected outcomes of the experiment.

B. Workstation and Surroundings

The study was conducted in a computer lab which was completely lit by means of overhead LED luminaries. The illumination of the lab was maintained at 250 lx.

18.5-inch LED backlit monitors, with typical brightness of 200 cd/m^2, were used for the purpose of the study. The position and height of the chairs was kept such that the viewing distance and viewing angle were maintained at recommended values. The viewing distance was 24 inches and the center of the monitor was 15 degrees below the eye level.

C. Experiment Design

The experiment was carried out over a period of three days. The participants were made to watch YouTube videos for 2 hours duration on each of the three days. Each of the video was played at the resolution in which it was originally recorded. The brightness of the monitor was kept different on each of the three days for the purpose of the study. The brightness scale was set to values of 10, 55 and 100 for this experiment. These settings have been designated as low, medium (med.), and high, respectively, in subsequent sections. Visual fatigue of the participants was evaluated before and after each video was streamed on their monitors. The visual fatigue was measured using a modified version of the questionnaire developed by Ames et al. [11]. The questionnaire consisted of ten symptoms associated with Asthenopia, the level of which was to be marked on a scale graded from 0 to 6. The value 0 denoted the absence of that symptom and 6 was used to denote its highest severity. The questionnaire is given in Table 1.

Table 1 Asthenopia questionnaire

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

D. Statistical Analysis

The statistical analysis was carried out using IBM® SPSS Version 23 software. One-Way ANOVA was used to statistically check whether the visual fatigue induced in the participants at different brightness levels was significantly different or not. The mean difference was taken to be significant at the 0.05 level.

Post hoc tests were conducted using the Tukey test.

4 Results and Discussions

A. Descriptives

The descriptive statistics—mean, standard deviation and 95% confidence intervals for the measured dependent variable i.e. Asthenopia Score for each of the three brightness levels is given in Table 2.

Table 2 Descriptives of Asthenopia score

	N	Mean	Std. Deviation	Std.Error	95% confidence interval for mean	
					Lower bound	Upper bound
High	22	7.9091	1.79706	0.38314	7.1123	8.7059
Low	22	10.5455	2.92326	0.62324	9.2494	11.8416
Med	22	5.0455	2.75123	0.58656	3.8256	6.2653
Total	66	7.8333	3.37221	0.41509	7.0043	8.6623

Table 3 ANOVA analysis of Asthenopia score

	Sum of squares	df	Mean square	F	Sig
Between groups	332.939	2	166.470	25.817	0.000
Within groups	406.227	63	6.448		
Total	739.167	65			

B. ANOVA Analysis

The One-Way ANOVA analysis gave a significance value lower than 0.05 ($F(2,63) = 25.817$, $p < 0.05$), thus proving that there was a statistically significant difference in the Asthenopia Score measured at the three different brightness levels. The results of the ANOVA analysis are given in Table 3.

C. Post Hoc *Tests*

The One-Way ANOVA analysis proved that there were statistically significant differences in the Asthenopia Scores recorded at different brightness levels. The multiple comparisons table, given in Table 4, was obtained using the Tukey post hoc test on the One-Way ANOVA. It can be inferred from the multiple comparisons table that there is a statistically significant difference between the Asthenopia Score recorded at high and low brightness levels ($p = 0.003$), the Asthenopia Score recorded at high and medium brightness levels ($p = 0.001$) as well as between the Asthenopia Score recorded at low and medium brightness levels ($p < 0.001$).

D. Means Plot

The means plot in Fig. 1 plots the mean Asthenopia Score versus the different levels of brightness—low, medium and high. The mean Asthenopia Score was the least for medium brightness setting and maximum for low brightness setting.

Table 4 Multiple comparisons table of Asthenopia score

(I) Brightness value	(J) Brightness_Value	Mean Difference (I-J)	Std.Error	Sig	95% Confidence interval	
					Lower bound	Upper bound
High	Low	−2.63636[a]	0.76563	0.003	−4.4741	−0.7986
	Med	2.86364[a]	0.76563	0.001	1.0259	4.7014
Low	High	2.63636[a]	0.76563	0.003	0.7986	4.4741
	Med	5.50000[a]	0.76563	0.000	3.6622	7.3378
Med	High	−2.86364[a]	0.76563	0.001	−4.7014	−1.0259
	Low	−5.50000[a]	0.76563	0.000	−7.3378	−3.6622

[a] The mean difference is significant at the 0.05 level

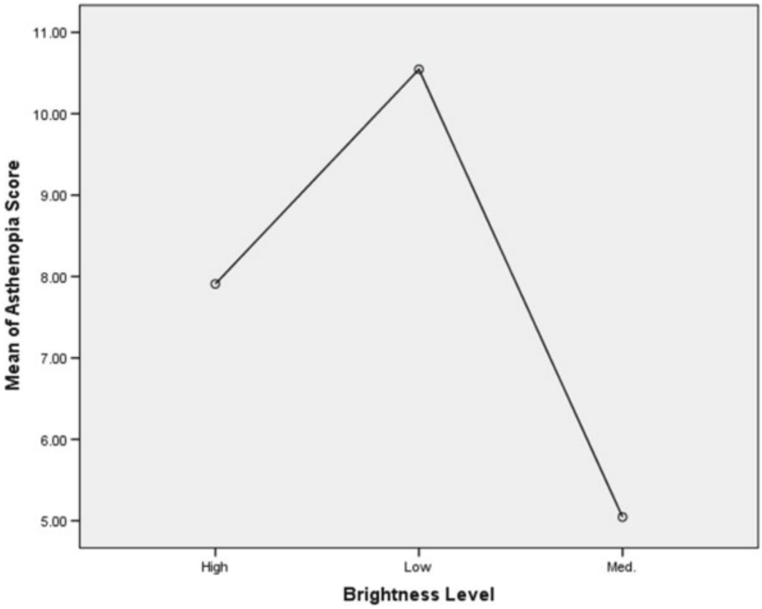

Fig. 1 Means plot between the mean of Asthenopia Score and the brightness levels

5 Conclusion

This study was aimed at investigating the impact of screen brightness on visual fatigue during video viewing tasks under typical illumination conditions. The results showed that the visual fatigue induced in the participants varied significantly with change in brightness levels. In a room illuminated by LED luminaries; keeping the viewing distance, viewing angle and video resolution at recommended values; the mean Asthenopia Score was found to be the least in the case of the monitor being set at a medium brightness level. It can be concluded that medium brightness level induces the least visual fatigue in case of video viewing in a room lit by LED luminaries. Hence, it is recommended that VDT and desktop users, under similar illumination conditions, use the medium brightness settings so as to reduce the incurrence of CVS.

References

1. J.E. Sheedy, J. Hayes, J. Engle, Is all Asthenopia the same? Optom. Vis. Sci. **80**(11), 732–739 (2003)
2. S. Aslam, YouTube by the numbers: stats, demographics & fun facts (2019 Sept. 5), https://www.omnicoreagency.com/youtube-statistics/
3. C. Coles-Brennan, A. Sulley, G. Young, Management of digital eye strain. Clin. Exp. Optom. **102**(1), 18–29 (2019)

4. M.Z. Ramadan, M.H. Alhaag, M.H. Abidi, Effects of viewing displays from different distances on human visual system. Appl. Sci. **7**(11) (2017)
5. J. Long, R. Cheung, S. Duong, R. Paynter, L. Asper, Viewing distance and eyestrain symptoms with prolonged viewing of smartphones. Clin. Exp. Optom. **100**(2), 133–137 (2017)
6. C.M. Sommerich, S.M.B. Joines, Effects of computer monitor viewing angle and related factors on strain, performance, and preference outcomes. Hum. Factors **43**(1), 39–55 (2001)
7. U.O. Bergqvist, B.G Knave, Eye discomfort and work with visual display terminals. Scand. J. Work Environ. Health **20**(1), 27–33 (1994)
8. W. Jaschinski, H. Heuer, H. Kylian, Preferred position of visual displays relative to the eyes: A field study of visual strain and individual differences. Ergonomics **41**(7), 1034–1049 (1998)
9. M.S. Smith, Why 4K monitors are easier on your eyes (2014 Dec. 3), https://www.digitaltrends.com/computing/can-4k-resolution-really-make-you-go-blind/
10. H. Isono, A. Kumar, T. Kamimura, Y. Noguchi, H. Yaguchi, The effect of blue light on visual fatigue when reading on LED-backlit tablet LCDs, in Proceedings of the 20th International Display Workshops (IDW'13), VHFp-9L (2013)
11. S.L. Ames, J.S. Wolffsohn, N.A. McBrien, The development of a symptom questionnaire for assessing virtual reality viewing using a head-mounted display. Optom. Vis. Sci. **82**(3), 168–176 (2005)

Chapter 32
Levels of Physical Activity Among Female Students Staying in Hostel of Mumbai

Chauhan Manjit Kaur, Patel Prachi, and Sarma Noorisha

1 Introduction

Physical activity (PA) is defined as 'any bodily movement produced by skeletal muscles that result in energy expenditure' [1]. It includes activities undertaken while working, playing, carrying out household chores, traveling and engaging in recreational pursuits. Regular physical activity has many human health benefits, [2]. It is a key component of strategies to counteract the current epidemic of obesity, also to prevent and treat their associated diseases [3]. Physical activity patterns are established in childhood, adolescence and young adulthood [4].

A sedentary lifestyle and lack of daily exercise is a worldwide public health problem [5]. More than 80% of the World's adolescent Population is insufficiently physically active, which is one of the leading risk factors for non-communicable diseases (NCDs) such as cardiovascular diseases, cancer and diabetes [6]. One study indicated that in a developing country, cardiovascular morbidity and mortality are high and physical inactivity is common in both genders [7]. Review of studies of young people showed the decline in physical activity is greater in female than male subjects [8]. Similarly adolescent girls were less active than adolescent boys, with 84% vs. 78% not meeting WHO recommendations [6].

Children and youth should accumulate at least 60 min of physical activity on a daily basis and engage in a variety of physical activity of different intensities [9]. Recent recommendations [6] also specified that the adults (age 18–64) should do at

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least 150 min of moderate-intensity physical activity or 75 min of vigorous-intensity physical activity throughout the week.

Buckworth and Dishman [10] emphasized two cognitive variables, perceived benefits and perceived barriers which account for physical activity levels. Perceived benefits can positively, barriers can negatively influence the participation in activity.

With the introduction of technology at personal and educational level, the lifestyle of the adolescent and students is impacted. Inactivity and sedentariness among the adolescents will similarly rise alike other developed nations. In India, young female usually limit their participation in physical activity due to cultural and educational perspective. Furthermore, female students residing in hostels may have added limitation to participate in physical activities, which may increase the risk of diseases and health problems among them. Therefore, the current study was conducted to identify the level of involvement of female hostel students in daily physical activities, sports and leisure activities. It will also assess the barriers and challenges faced by the female students to participate in physical activities.

2 Material and Methods

A cross-sectional survey was conducted on 80 female students [undergraduate (UG; n = 40) and post-graduate (PG; n = 40)] residing in Women's Hostel in Mumbai. The stratified sampling method was used to identify the involvement of female students in various types of physical activities, sports and leisure activities and to understand the reasons for non-involvement in physical activities. Questionnaire was developed and used as an interview schedule to collect more authentic responses.

The questionnaire was divided into two major parts. First part consisted of general demographic information such as name, Age, Locality, Height, Weight, Income and General Health Problems. Body pain was assessed on a 10-point rating scale, where 0 was the least pain and 10 was maximum Pain perceived.

Second part consisted of physical activity (PA) related questions focusing on the type of PA, duration of involvement, perception toward PA and barriers which prevents the involvement in PA. Ranking method was used to examine the barriers which prevented the subjects from doing any kind of PA. The responses were ranked from 1 to 5 where first rank was the most important barrier and fifth rank was the least important barrier.

Height and weight were measured and BMI was computed [BMI = weight (Kg)/ Height (m2)] to classify respondents into different weight-related risk categories.

The subjects were informed about the purpose of the study. Consent from each of the subjects was taken prior to the study. The data was analyzed for descriptive statistics using Excel and SPSS.

3 Result and Discussion

A. General Demography and Background information

The Average Age (years) ± SD (Range) of the respondents was 21.02 ± 1.82 (17–25); Height (cm) was 158.61 ± 8.72 (125–173); Weight (kg) was 52.46 ± 9.34 (37–78) and BMI was 20.81 ± 3.42 (14.8–29.9) (Table 1).

Out of 80 female students residing in women's hostel; 37.5% belonged to Maharashtra and 62.5% were from outside the Maharashtra region. More than 74% of the samples had monthly salary above 30,000 INR, representing their moderate to high socioeconomic status (Table 2).

When compared between the two age groups of female students, there was not much difference between the height and Body pain rating (Scale 0–10), but there was distinct difference for weight and BMI, with older students having more weight (Table 1). Further classification with respect to BMI (Table 2) showed that 26.2% were 'Underweight' and 8.7% were 'Overweight' category and rest 63.7% were 'Normal weight' category. But when compared between the groups, it was again evident that UG group had more subjects being Underweight whereas the PG group had more subjects being Normal weight and Overweight. Thus, showing a transition in weight gain among young female students in just few years. Thus, it further strengthen the need to assess the physical activity among this group, where more of education and age lead to increase in body weight.

When enquired to describe their weight, around 89% of the total sample felt their weight was ranging from slight underweight–normal weight–slight overweight. But when compared between the two groups, around 12.5% of PG Students rated their weight as 'Very Overweight', whereas none of the UG students felt they were 'Very Overweight'. This can be additionally supported with the results where 45% of the PG students were trying to 'Lose weight' as against 37.5% of UG students trying to 'Gain weight' (Table 2).

Table 1 Average age, height, weight and BMI of the female college students staying in the hostel

General information	Total (n = 80)	UG (n = 40)	PG (n = 40)
	$\bar{x}$±SD (Range)	$\bar{x}$±SD (Range)	$\bar{x}$±SD (Range)
Age (years)	21.02 ± 1.82 (17–25)	19.79 ± 1.59 (17–23)	22.22 ± 1.09 (20–25)
Height (cm)	158.61 ± 8.72 (124.9–173.3)	157.74 ± 9.38 (124.9–173.7)	159.48 ± 8.04 (140.2–173.7)
Weight (kg)	52.46 ± 9.34 (37–78)	49.12 ± 7.93 (37–65)	55.81 ± 9.53 (39–78)
BMI Score	20.81 ± 3.42 (14.8–29.9)	19.82 ± 3.31 (14.8–28)	21.8 ± 3.27 (15.9–29.9)
Rating for Body Pain (Scale 0–10)	2.42 ± 2.17 (0–10)	2.33 ± 1.87 (0–10)	2.50 ± 2.45 (0–9)

Table 2 Demographic profile of the female college students staying in hostel

Parameters	Total (n = 80)		UG (n = 40)		PG (n = 40)	
	Sum	%	Sum	%	Sum	%
Hometown in Maharashtra	30	37.5	10	25.0	20	50.0
Hometown Outside Maharashtra	50	62.5	30	75.0	20	50.0
Avg. Monthly Family Income (INR)						
< 30,000	3	16.2	5	12.5	8	20.0
30,000–60,000	26	32.4	13	32.5	13	32.5
60,000–80,000	11	13.7	6	15.0	5	12.5
> 80,000	30	37.5	16	40.0	14	35.0
BMI category						
Underweight	21	26.2	15	37.5	15	15.0
Normal Weight	51	63.7	23	57.5	23	70.0
Overweight	7	8.7	2	5.0	2	12.5
Describe your weight						
Very Underweight	4	5	1	2.5	3	7.5
Slight Underweight	16	20.0	14	35.0	2	5.0
Proper Weight	31	38.8	17	42.5	14	35.0
Slight Overweight	24	30	11	27.5	16	40.0
Very Overweight	5	6.25	0	0.0	5	12.5
What are you trying to do about weight						
Lose weight	27	33.8	9	22.5	18	45.0
Gain weight	19	23.8	15	37.5	4	10.0
Stay the same	17	21.3	9	22.5	8	20.0
Not doing anything	17	21.3	7	17.5	10	25.0
Fitness App/ Tracker used	9	11.3	4	10.0	5	12.5

Fitness trackers and mobile app have become popular and are easily available in the market. But only about 11% female students used any type of fitness apps/trackers to record their daily PA. Thus, representing a tiny requirement by this group for tracking their daily activity level (Table 2).

B. General Health Problems

According to the general health problems among this cohort (Table 3), Headache (38%), Eye Pain (28%) and Body Pain (20%) were commonly reported. But when compared between the groups, the PG groups was found to rate more of pain-related problems as compared to the Young UG group.

For the Physiological Problems, Poor Sleep (28%), Lack of Energy (21%) and Drowsiness (20%) was commonly stated. Yet again, the PG groups were found to rate more Physiological Problems as compared to UG group.

Table 3 General Health Problems of Female Hostel Students

Health problems	Total (n = 80)		UG (n = 40)		PG (n = 40)	
	Sum	%	Sum	%	Sum	%
Pains related problems						
Head Aches	30	37.5	13	32.5	17	42.5
Eye Pain/Problems	22	27.5	9	22.5	13	32.5
Body Aches/ Pain	16	20.0	7	17.5	9	22.5
Muscle Cramp/ Pain	10	12.5	6	15.0	4	10.0
Joint Pain	6	7.5	1	2.5	5	12.5
Physiological problems						
Poor Sleep	22	27.5	7	17.5	15	37.5
Lack of Energy	17	21.3	10	25.0	7	17.5
Drowsiness	16	20.0	7	17.5	9	22.5
Tiredness / Fatigue	12	15.0	5	12.5	7	17.5
Loss of Appetite	12	15.0	5	12.5	7	17.5
Breathlessness	11	13.8	5	12.5	6	15.0
Excessive Eating	10	12.5	2	5.0	8	20.0
Psychological problems						
Anxiety/Stress	34	42.5	11	27.5	23	57.5
Irritability	14	17.5	4	10.0	10	25.0

From the last segment which measure the Psychological Problems, Anxiety/Stress (43%) was highest rated by both the groups followed by Irritability (18%). Once again the older PG group had rated the Psychological Problems significantly more than the Young UG group.

Thus, indicating that as age increases, pain, physiological and psychological-related problems also increases. This may be associated with the Physical Activity levels of the students.

C. Involvement in Physical Activity (Duration and Type)

Duration of involvement in Physical Activity (Table 4).

The results of physical activities performed in last seven days for more than 60 min/day, showed that hardly few (15%) were seen to be physically active for > 5 day/week and 50% respondents participated in physical activities for 1–4 days/week. Overall about 35% of the respondents did not participated in any physical activity. When assessed in between the two groups, PG group was seen to be more Inactive with around 40% not involved in any type of PA on any day of the week (Table 4).

With respect to the duration, almost 61% and 49% students were involved in < 2 h of PA each day on weekdays and weekends. King and Coles [11] had earlier specified that age is inversely associated with physical activity in studies of children and

Table 4 Duration of involvement of female hostel students in various physical activity (PA)

Involvement in PA	Total (n = 80)		UG (n = 40)		PG (n = 40)	
	Sum	%	Sum	%	Sum	%
Performing activities for more than 60 min (Days/week)						
None (0 day/week)	28	35.0	12	30.0	16	40.0
Low (1–2 day/week)	20	25.0	11	27.5	9	22.5
Medium (3–4 day/week)	20	25.0	9	22.5	11	27.5
High (>5 day/week)	12	15.0	8	20.0	4	10.0
Performing activities on a typical Weekday (Duration/day)						
None (0–2 h)	49	61.2	25	62.5	24	60.0
Low (2–4 h)	23	28.7	12	30.0	11	27.5
Medium (4–8 h)	8	10.0	3	7.5	5	12.5
Performing activities on a typical Weekends (Duration/day)						
None (0–2 h)	39	48.7	22	55.0	17	42.5
Low (2–4 h)	18	22.5	9	22.5	9	22.5
Medium (4–6 h)	22	27.5	9	22.5	13	32.5
Often (6- > 8 h)	1	1.2	0	0.0	1	2.5

adolescents. Study by [12] on female Ph.D. scholars showed that many participants (62.5%) met WHO guidelines of at least 150 min of moderate-intensity aerobic physical activity per week; with almost 50% respondents exercising daily.

There is an alarming situation in present study as a huge section of participants from (85%) is not meeting the recommended physical activity requirement [6, 13, 14] of carrying out at least 60 min of daily moderate to vigorous physical activity.

Involvement in Different types of Physical Activities (Table 5).

While evaluating the activities performed by this cohort (Table 5), it was observed that walking was most dominant activity with 73% performing it during leisure time and 29% performing it while commuting. Other commonly performed activities were dancing (30%), doing household chores like mopping, vacuuming, sweeping (27.5%) and Running / Jogging (22.5%). Very importantly, walking was the only activity found to be performed for the topmost period by 58% for about 5–6 days/week.

There was negligible involvement (less than 7.5%) in other physical activity such as Aerobics Exercise, Skipping rope, Tennis/ Badminton, Gymnastic, PE/Sports/games Class, Yoga, Basketball/ Volleyball/Throw ball, Cricket, Bicycling and Weight Lifting. And there was zero involvement was found for Swimming, Martial Arts, Football/Rugby, Hockey, and Skating.

Thus, leading to the conclusion that female students staying in hostel have poor participation in various sports / exercises which requires specific instruments and space; which is not easily found in Mumbai. Therefore, the most commonly performed activity by female hostel students was walking, dancing and household chores (of their hostel room).

Table 5 Involvement in various types of physical activity (PA) in last seven days by the female hostel students

Involvement in various type of PA in last seven days	Total (n = 80)			UG (n = 40)			PG (n = 40)		
	F	Days/week	Time/Week (min)	F	Days/week	Time/Week (min)	F	Days/week	Time/Day(min)
	Sum (%)	x̄±SD	x̄±SD	Sum (%)	x̄±SD	x̄±SD	Sum (%)	x̄±SD	x̄±SD
Leisure time physical activity									
Walking	58 (72.5)	5.6 ± 1.8	60.9 ± 56.1	26 (65.0)	5.5 ± 2.1	47.5 ± 58.8	32 (80.0)	5.6 ± 1.6	71.7 ± 52.2
Dancing	24 (30.0)	2.2 ± 0.9	37.1 ± 27.1	17 (42.5)	2.2 ± 1.0	39.1 ± 29.9	7 (17.5)	2 ± 0.6	32.1 ± 19.9
Running or Jogging	18 (22.5)	4.7 ± 2.2	52.6 ± 73.6	8 (20.0)	5.4 ± 2.1	20 ± 5.7	10 (25.0)	4.2 ± 2.2	75.5 ± 90.2
Aerobics Exercise	6 (7.5)	2.8 ± 2.1	30.8 ± 9.7	3 (7.5)	2.0 ± 0	31.7 ± 15.3	3 (7.5)	3.7 ± 3.1	30 ± 0
Skipping	5 (6.2)	4.4 ± 2.5	16 ± 8.9	4 (10.0)	5 ± 2.44	12.5 ± 5	1 (2.5)	2 ± 0	30 ± 0
Tennis/ Badminton	5 (6.2)	2 ± 1.2	58 ± 38.9	3 (7.5)	2.3 ± 1.5	46.7 ± 23.1	2 (5.0)	1.5 ± 0.7	75 ± 63.6
Sports or Games	4 (5.0)	3.5 ± 2.6	63.8 ± 39.4	3 (7.5)	4.3 ± 2.5	70 ± 45.8	1 (2.5)	1 ± 0	45 ± 0

(continued)

Table 5 (continued)

Involvement in various type of PA in last seven days	Total (n = 80)			UG (n = 40)			PG (n = 40)		
	F	Days/week	Time/Week (min)	F	Days/week	Time/Week (min)	F	Days/week	Time/Day(min)
	Sum (%)	x̄±SD	x̄±SD	Sum (%)	x̄±SD	x̄±SD	Sum (%)	x̄±SD	x̄±SD
Basketball/ Throw ball	4 (5.0)	4.75 ± 1.7	38.8 ± 17.5	3 (7.5)	5.3 ± 1.52	36.7 ± 20.8	1 (2.5)	3 ± 0	45 ± 0
Other physical activity									
Household Chores	22 (27.5)	2.4 ± 1.3	45 ± 52.1	9 (22.5)	2.33 ± 1.2	40.5 ± 54.4	13 (32.5)	2.5 ± 1.3	48.1 ± 52.5
Walking for Transportation	23 (28.8)	2.3 ± 1.3	44 ± 35.8	9 (22.5)	2.9 ± 1.8	35.6 ± 33.2	14 (35)	1.9 ± 0.76	50 ± 37.4

F = Frequency of Involvement in each of the physical activity

Females had much higher rates of participation in walking than males [15]. Rajpoot and Gupta [12] similarly found 41% of the students doing brisk walking, 37.5% go for swimming, 15.6% preferring jogging and 15.6% badminton, with few involved in cycling, yoga, dancing, skipping, etc.

D. Perception of Physical Activity (Table 6)

When investigated about the importance of physical activities in their day-to-day life, majority of respondents (>90%) rated that PA is always important for good health and it always helps to stay fit. This could also be associated with parents perception on PA, as around 74% of parents always encouraged them to participate in PA and 65% parents were themselves physically active. Also 49%–55% female students always enjoyed doing various PA like Sports/ Yoga/ Games.

Major lacuna found was that even after having fondness for physical activity, still the total involvement was less (Table 5). This could be due to the fact that only 36% set goals to do physical activity and from that hardly 26% kept the track

Table 6 Perception of the Female Hostel Students on Physical Activity

Perception and views on PA		Almost Never			Sometimes			Always		
		Total	UG	PG	Total	UG	PG	Total	UG	PG
PA important for health	F	1	1	0	6	4	2	73	35	38
	%	1.3	2.5	0.0	7.5	10.5	5.0	91.3	88.0	95.0
PA helps stay fit	F	1	1	0	4	3	1	75	36	39
	%	1.3	2.5	0.0	5.0	7.5	2.5	93.8	90.0	97.5
Parents encourage to do PA	F	4	3	1	17	8	9	59	29	30
	%	5.0	7.5	2.5	21.3	20.0	22.5	73.8	72.5	75.0
Parents are active	F	6	4	2	22	15	7	52	21	31
	%	7.5	10.0	5.0	27.5	37.5	17.5	65.0	52.5	77.5
Like doing PA/Sports	F	9	6	3	27	11	16	44	23	21
	%	11.3	15.0	7.5	33.8	27.5	40.0	55.0	57.5	52.5
Enjoy Yoga/ Games/PE class	F	12	6	6	29	14	15	39	20	19
	%	15.0	15.0	15.0	36.3	35.0	37.5	48.8	50.0	47.5
Set goals to do PA	F	24	15	9	27	12	15	29	13	16
	%	30.0	37.5	22.5	33.8	30.0	37.5	36.3	32.5	40.0
You Keep track of PA	F	27	13	14	32	19	13	21	8	13
	%	33.8	32.5	35.0	40.0	47.5	32.5	26.3	20.0	32.5
Do PA even when have work	F	46	22	24	21	11	10	13	7	6
	%	57.5	55.0	60.0	26.3	27.5	25.0	16.3	17.5	15.0

* F = Frequency of rating on Physical Activity perception

of physical activity regularly. During exams, submissions or other work, physical activity was neglected with merely 16% always participating in them even after their busy schedule.

While assessing the trend between both the groups, almost similar results was seen.

Social benefits of exercising with friends and physical look improvements were significant motives for engaging in physical activity in college students [16]. Similarly, the majority of the participants in the study by Rajpoot and Gupta [12] reported that the main motivation for exercise was to improve overall health, increase resistance to illness/diseases and for improving the appearance.

A. Barriers for Involvement in Physical Activity (Table 7)

The major barriers stated for non-involvement in physical activities by both the groups were lack of company (61%) which was highest rated followed by lack of energy (51%), lack of time (44%) and lack of self-discipline (43%), lack of facilities/ Space (38%) and lack of skills needed to perform activities (38%).

But when the barriers rated by both the groups were compared, it was found that lack of company (80%), lack of skills needed to perform activities (48%), Lack of enjoyment from exercise/Sports (45%), Lack of good health (43%), Lack of interest in exercise/sports (38%), fear of injury (35%), Discouragement (33%) and Sweating or Perspiration (28%) were rated dominantly more among the UG group.

Whereas for the PG group, Lack of time (88%) was rated highest by majority of the students, followed by Lack of self-discipline (70%), Lack of energy (58%), Lack of facilities/ space (50%) and Lack of equipment (45%).

Thus, displaying that until graduation there is not much responsibility and load of studies. Therefore, this group may be involved in sports/exercise for pleasure purpose as lack of company, skills and enjoyment from PA was given more priority. However, as the female students advance in their post graduate studies, they have a major shortage of time, energy, and self-discipline (Internal barriers) besides lack of facility and equipment's (External barriers) signifying that older groups wanted to be involved in various PA but couldn't make it possible.

Many factors affect the participation in physical activity like demographic variables, knowledge, attitudes and beliefs about physical activity [17]. Some studies also show that perceived internal barriers were as important as perceived external barriers in young people [18].

'Lack of time due to busy lesson schedule', 'My parents give academic success priority over exercise', 'lack of time due to family and social responsibilities' and 'lack of energy' were most cited items for physical activity barriers [19]. They also stated that the total score of the external barriers was significantly higher than the score of the internal barriers, with Lack of time being most important external barrier and Lack of energy being most important internal barrier.

Lack of time was cited as most common barrier by students [18, 20]. Low level of motivation, time limits and inconvenience were the most cited reasons for academic students for not taking part in physical activity [16].

For females, the significant independent predictors of being insufficiently active were lower social support from family and friends, lower enjoyment of activity and

Table 7 Ranking of Barriers for Participation in Physical Activities by the Female Hostel Students

Ranking of barriers for Involvement in PA		Rank 1		Rank 2		Rank 3		Total Barrier (Rank 1 + 2 + 3)		Rating for barrier	Rank
		UG	PG	UG	PG	UG	PG	Total UG	Total PG	Total (UG + PG)	
External barriers											
Lack of Company	Sum	21	4	3	5	8	8	32	17	49	
	%	52.5	10.0	7.5	12.5	20.0	20.0	80.0	42.5	61.3	**1**
Lack of time	Sum	0	25	0	6	0	4	0	35	35	
	%	0.0	62.5	0.0	15.0	0.0	10.0	0.0	87.5	43.8	**3**
Lack of facilities/ space	Sum	5	4	1	2	4	14	10	20	30	
	%	12.5	10.0	2.5	5.0	10.0	35.0	25.0	50.0	37.5	**5**
Lack of equipment	Sum	2	4	0	5	6	9	8	18	26	
	%	5.0	10.0	0.0	12.5	15.0	22.5	20.0	45.0	32.5	7
Discouragement	Sum	2	3	4	0	7	4	13	7	20	
	%	5.0	7.5	10.0	0.0	17.5	10.0	32.5	17.5	25.0	9
Internal barriers											
Lack of energy	Sum	9	11	5	6	4	6	18	23	41	
	%	22.5	27.5	12.5	15.0	10.0	15.0	45.0	57.5	51.3	**2**
Lack of self-discipline	Sum	2	18	0	7	4	3	6	28	34	
	%	5.0	45.0	0.0	17.5	10.0	7.5	15.0	70.0	42.5	**4**
Lack of skills	Sum	8	3	2	0	9	8	19	11	30	
	%	20.0	7.5	5.0	0.0	22.5	20.0	47.5	27.5	37.5	**5**
Lack of knowledge for exercise	Sum	4	1	2	4	6	11	12	16	28	

(continued)

Table 7 (continued)

Ranking of barriers for Involvement in PA		Rank 1		Rank 2		Rank 3		Total Barrier (Rank 1 + 2 + 3)		Rating for barrier	Rank
		UG	PG	UG	PG	UG	PG	Total UG	Total PG	Total (UG + PG)	
	%	10.0	2.5	5.0	10.0	15.0	27.5	30.0	40.0	35.0	6
Lack of enjoyment from exercise	Sum	6	0	10	1	2	3	18	4	22	
	%	15.0	0.0	25.0	2.5	5.0	7.5	45.0	10.0	27.5	8
Lack of good health	Sum	5	1	6	0	6	4	17	5	22	
	%	12.5	2.5	15.0	0.0	15.0	10.0	42.5	12.5	27.5	8
Lack of interest in exercise/ sports	Sum	4	3	3	0	8	1	15	4	19	
	%	10.0	7.5	7.5	0.0	20.0	2.5	37.5	10.0	23.8	10
Fear of injury	Sum	5	0	2	0	7	1	14	1	15	
	%	12.5	0.0	5.0	0.0	17.5	2.5	35.0	2.5	18.8	11
Sweating	Sum	3	0	2	1	6	0	11	1	12	
	%	7.5	0.0	5.0	2.5	15.0	0.0	27.5	2.5	15.0	12

not working [21]. Adolescent girls noted lack of self-efficacy was prime reason for physical inactivity [22], Whereas other study found that ‘I don’t have time’, ‘I’m too tired’ and ‘exercise doesn’t interest me’ were frequently cited barriers among adolescent females [23]. Another study by Rajpoot and Gupta [12] showed that 36% reported not doing any physical activity or exercise due to laziness, lack of time and not interested in doing so.

This is similarly found in present study as well, where Lack of time and Lack of company were among highest cited Barriers. But ‘lack of company’ was most prominently rated by the Female hostel students in the present study, indicating that may be for safety as well as enjoyment purpose, the students in present study prefer to have a company to participate in leisure or sports activity.

Few limitation of our study were as follows: it was carried out only in one university which is located in the capital of the state. Thus further evaluation on other hostels and hostels from other location could have been a better representation. Also involving students from other UG and PG programs, would have given a better perception on barriers to physical activity. Objective data of physical activity was not recorded. Future studies can be performed on male’s hostel students of same age group in order to get an insight into the difference in perception and barriers among the two genders.

4 Conclusion

It can be concluded that the physical activity levels of the female college-going students residing in hostel is very low. There is awareness about the importance of physical activity and they seemed concerned about their rise in weight. Still, their involvement in physical activities, especially in Sports or Exercise was very scanty with 85% not meeting the recommended requirement of 60 min of physical activity daily. Walking was the only dominant activity performed by this group at leisure. However, performing household chore and walk while commuting was the dominant non-leisure activity. This may not be beneficial for overall health and physical fitness.

The non-involvement in daily physical activity, especially sports/ exercise is a major concern. The barriers rated by the group need to be assess in order to increase their participation in physical activity for improving their present and future health problems and fitness. External barrier, i.e., lack of company (rank 1), lack of time (rank 3) and lack of facilities/space (rank 5); Internal barriers, i.e., lack of Energy (rank 2), Self-Discipline (rank 4) and skills (rank 5) needs to be introspected.

Encouraging female students to adopt other moderate-vigorous intense may help to improve health during adulthood. The hostel authorities can provide a well-equipped facility, i.e., Gym/ Activity zone; organize yoga/exercise classes along with periodic competition in hostel. An instructor would be advantageous to guide the students, to improve their skills and also to keep a track on lifestyle/diet. Additional, some incentives can be provided to motivate students for participating daily in physical activity.

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References

1. C.J. Caspersen, P.E. Kenneth, C.M. Gregory, Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. Public Health Rep. **100**(2), 126 (1985)
2. Y. Chen, An economic analysis of decisions on physical activity and energy imbalance: cross-sectional evidence from a panel of middle-aged adults. Graduate Theses and Dissertations. 10732 (2009). http://lib.dr.iastate.edu/etd/10732
3. A Bulk-Binschoten, C.M. Renders, F.J.M Leerdam, R.A.. van,Hirasing, Transitional plan for children with overweight. Method for individual primary and secondary prevention in Youth Health Care, Dutch (2005)
4. J. Buckworth, Exercise adherence in college students: issues and preliminary results. Quest **53**, 335–345 (2001). http://doi.org/10.1080/00336297.2001.10491750
5. W.A. Zatoński, HEM project team, Epidemiological analysis of health situation development in Europe and its causes until 1990. Ann. Agric. Environ. Med. **18**(2), 194–202 (2011)
6. WHO, Physical activity (2018). Accessed from: https://www.who.int/news-room/fact-sheets/detail/physical-activity
7. A. Onat, Risk factors and cardiovascular disease in Turkey. Atherosclerosis **156**, 1–10 (2001)
8. J.F. Sallis, Epidemiology of physical activity and fitness in children and adolescents. Crit. Rev. Food Sci. Nutr. **33**, 405–408 (1993)
9. J.F. Sallis, K. Patrick, Overview of the international consensus conference on physical activity guidelines for adolescents. Pediatr. Exerc. Sci. **6**, 299–301 (1994)
10. J. Buckworth, R.K. Dishman, Determinants of physical activity; research to application, in *Lifestyle Medicine*, ed by J. Rippe, M.A. Malden. (Williston Blackwell Science, 1999), pp. 1016–1027
11. A.J.C. King, B. Coles, *The Health of Canada's Youth: Views and Behaviours of 11–13, and 15-Year-olds from 11 Countries* (Minister of National Health and Welfare, Ottawa, Canada, 1992), p. 29.
12. S.S. Rajpoot, K. Gupta, Study about Physical Activity among Female Research Scholars residing in Hostel's of Banaras Hindu University, Varanasi, India. Res. J. Family Community Consum. Sci. **2**(9), 5–8 (2014)
13. U.S. Department of Health and Human Services, Physical Activity Guidelines for Americans (2008)
14. President's Council on Physical Fitness, The Active Lifestyle Program: Rules. On-line (2017), http://www.presidentschallenge.org/the_challenge/active_lifestyle_rules.aspx. Accessed 20 Sept 2017.
15. E. Leslie, M.J. Fotheringham, N. Owen, A. Bauman, Age-related differences in physical activity levels of young adults. Med. Sci. Sports Exerc. Feb. **33**(2), 255–258 (2001)
16. S.A. Brown, D. Huber, A. Bergman, A perceived benefits and barriers scale for strenuous physical activity in college students. Am. J. Health Promot. **2**, 137–140 (2006)
17. R.K. Dishman, *Advances in exercise adherence* (Human Kinetics, Champaign, IL, 1994)
18. N.C. Gyurcsik, S.R. Bray, D. Brittain, R., Coping with barriers to vigorous physical activity during transition to university. Fam. Community Health **27**(2), 130–142 (2004)
19. A. Daskapan, E.H. Tuzun, L. Eker, Perceived barriers to physical activity in university students. J. Sports Sci. Med. **5**, 615–620 (2006)
20. L. Grubbs, J. Carter, The relationship of perceived benefits and barriers to reported exercise behaviors. Fam. Community Health **25**(2), 76–84 (2002)

21. E. Leslie, N. Owen, J. Salmon, A. Bauman, J.F. Sallis, L.S. Kai, Insufficiently active australian college students: perceived personal, social, and environmental influences. Prev. Med. **28**(1), 20–27 (1999)
22. L.B. Robbins, N.J. Pender, A.S. Kazanis, Barriers to physical activity perceived by adolescent girls. J. Midwifery Women's Health **48**(3), 206–212 (2003)
23. S.Y. Kimm, N.W. Glynn, P. Mcmahon, C.C. Voorhees, R.H. Striegel-Moore, R.S. Daniels, Self-Perceived barriers to activity participation among sedentary adolescent girls. Med. Sci. Sports Exerc. **38**, 534–540 (2006)

Chapter 33
Auditing of Indoor Environmental Parameters from Ergonomics Perspective in a Garment Manufacturing Unit–A Case Study

K. N. Subramanya, K. V. S. Rajeswara Rao, N. S. Shobha, and B. G. Sudarshan

1 Introduction

The Indian Textiles Industry plays a vital role through its contribution to industrial output, employment generation and the export earnings of the country. Abundant availability of raw materials such as cotton, wool, silk, jute and skilled workforce has made India a sourcing hub. Karnataka is one of India's leading industrial states, contributing almost eight percent to the national manufacturing income. The garment industry in Karnataka is the second-largest employment provider. There are 2,638 factories in Bangalore employing over 5,40,670 employees, out of which women form 93 percent of the workforce in the industry. The employees in the garment industry in Karnataka comprise skilled, semi-skilled and un-skilled employees [9].

The workplace design can be a powerful tool for supporting the organization's employee performance. The most important factor for productive work is to maintain a safe, healthy and comfortable working environment [2]. Ergonomics plays a vital role in the system design in providing a better work environment by eliminating aspects of system functioning that are undesirable, uncontrolled or unaccounted for, which includes inefficiency, fatigue, accidents, injuries, user difficulties and low morale and apathy [4]. The physical condition of the workplace in terms of environmental ergonomics, occupational health and work psychology essentially includes Lighting, Temperature and Noise [1]. Based on the review of the literature, it is understood that the work environment in the majority of garment manufacturing

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units is unhealthy and unsafe. This includes non-ergonomically designed workstations, congested work areas, improper ventilation, dust, excessive noise, inappropriate lighting, insufficient safety measures and lack of usage of personal protective equipment. Employees working in such poor environment are prone to occupationally related diseases [8]. The unit considered for study in Bengaluru has a strength of 1,200 employees, out of which 90% were women. It was also observed that women employees were predominantly employed in the sewing section of the manufacturing unit. The unit works on a shift basis, wherein the number of shifts was determined based on the demand. At the time of conducting this study, the unit was working for two shifts.

2 Research Design and Methodology

Based on the earlier research works and the preliminary study in the manufacturing unit, the objectives of the study include: (a) to audit the environmental parameters prevailing in the garment manufacturing unit (b) to identify the factors from ergonomics perspective that influence the worker's health and (c) to recommend remedial measures in the form of ergonomic interventions in the garment manufacturing unit.

The research design and methodology comprised of two phases. The first phase essentially focused on the process study, with an aim of understanding the functioning of various departments involved in the garment manufacturing process. The second phase comprised of auditing the indoor physical environment and eliciting information from the employees to gain more insight into the conditions of working environment.

In order to observe the uniformity ratio of daylight, artificial light and temperature, the activity areas were divided approximately into three sections. They are near the window, center of the half space of the depth and farthest from window. The frequency of observations was recorded depending on the nature of work in terms of Light, Moderate and Heavy. In this context, the workload was categorized as Light, Heavy and Moderate based on the combination of tasks, duration, repetitiveness and effort involved. The categorization is purely based on observations. It was also observed that in sections like sewing, stitching, ironing and inspection the work load was Heavy and hence the readings were taken for every 30 min time duration. And in sections like cutting and packing, though the workload was heavy, the work progress was very slow by nature and hence, the readings were taken for every 2 h' time duration.

The instruments used for the study include lux meter, handheld thermometer and sound level meter to measure illumination, temperature and noise levels, respectively. The average of three observations was taken to ensure reliability of the recorded values. The experimental values were compared with the standard values and accordingly interpreted.

3 Results and Discussion

The findings of the study have been tabulated (Table 1) and summarized using the Box-Plots. This enabled us to understand the shape of the distribution; its central value and variability (Fig. 1) are analyzed and interpreted section-wise. In cutting section, the temperature and illumination were above the acceptance level. The room temperature remained to be high due to poor ventilation and the illumination level varied near the window and center of the half-space of the depth. The working environment has only natural light. In the fusing section, the room temperature remained to be high and the illumination level was found to be high and the workers relied on artificial lighting. The room temperature in the numbering section remained to be high and the illumination level was low and this can be correlated with the observation that the tube lights were not functional. The temperature and the illumination levels were above the acceptance level in the sewing department. The illumination level furthest from the window was high as the workers relied more on artificial lighting in both sewing and stitching sections. In the KB section, the room temperature remained to be high and the illumination level was high near the window as the workers relied on both natural and artificial lighting.

The temperature and illumination levels in finishing area were beyond the acceptance levels. The illumination level was high in the center of the half space of depth and in the furthest from the window regions, as it required bright lighting to examine the finished products. The artificial lighting was utilized for eight hours. In the measurement section, the room temperature was high. The illumination and noise levels were found to be within the recommended level.

The room temperature in ironing bay was relatively high as workers were seen ironing the garments on a steam-pressed tables. The workers were exposed to extreme steam and there was no sufficient ventilation which was evident in the exhaustion of workers as reported by them. The illumination level was high as the workers relied on artificial lighting throughout their working hours. The high room temperature in inspection area can be attributed to the congestion observed. The temperature and the illumination levels in packing section were observed to be above the acceptance level. The room temperature and illumination level were high near center of the half space of the depth and at furthest from the window. It was also observed that the activity area was congested and there was little ventilation (Fig. 1 and Table 2).

Table 1 Observed environmental parameters

Location	Temperature (°C)			Luminescence (lux)			Noise (db)		
	1	2	3	1	2	3	1	2	3
Cutting, fusing and numbering section									
A	*28.5*	*31.0*	*33.0*	915	922	*1,092*	79.4	66.5	83.3
B	*28.0*	*32.5*	*28.5*	730	*1,100*	*1,192*	67.1	88.9	66.2
C	*27.5*	*32.5*	*28.0*	*1,171*	*1,147*	*1,061*	63.8	91.9	63.5
Fusing									
A	*31.5*	*33.5*	*33.5*	*1,422*	*1,605*	*1,447*	70.7	66.0	71.7
B	*29.5*	*33.5*	*35.5*	950	*1,032*	*1,096*	73.4	67.6	73.1
C	*32.5*	*34.5*	*34.5*	936	*1,014*	*1,110*	64.9	70.5	71.8
Numbering									
A	*32.5*	*32.0*	*32.0*	214	596	*1,064*	69.8	87.5	88.8
B	*29.0*	*31.0*	*32.5*	384	435	459	78.9	72.8	67.4
C	*31.5*	*31.5*	*31.5*	755	773	785	62.9	71.7	65.8
Sewing, stitching and KB section									
A	*30.0*	*31.5*	*32.0*	442	618	495	82.5	82.3	83.7
B	*31.0*	*31.5*	*33.5*	445	461	511	88.0	85.9	95.4
C	*34.5*	*35.5*	*31.5*	*1,639*	*1,597*	*1,606*	80.4	80.3	89.4
Stitching									
A	*33.5*	*33.0*	*32.0*	907	904	845	78.1	76.9	82.2
B	*36.5*	*36.0*	*31.0*	414	468	419	81.0	77.8	82.3
C	*35.5*	*31.5*	*32.5*	*1,171*	*1,331*	*1,595*	78.3	84.0	84.3
KB section									
A	*30.5*	*31.5*	*32.0*	*1,296*	*1,240*	*1,258*	76.9	75.5	78.7
B	*31.0*	*33.5*	*33.5*	375	424	397	83.3	88.5	91.6
C	*32.5*	*31.5*	*33.5*	660	686	673	83.9	90.2	91.5
Finishing and measurement section									
A	*29.5*	*30.5*	*30*	541	611	721	84.4	84.3	77
B	*31*	*33.5*	*31.5*	*1,625*	*1,749*	*1,764*	76.3	75.2	74.5
C	*31*	*31*	*29.5*	*1,752*	*1,718*	*1,746*	71.3	70.1	73.8
Measurement section									
A	*30.5*	*31*	*30*	776	796	814	77.3	76.4	76.1
B	*33*	*32.5*	*33*	851	995	1,072	73.9	74.5	74.0
C	*31.5*	*30*	*31.5*	945	970	1,064	73.9	73.5	73.3

(continued)

Table 1 (continued)

Location	Temperature (°C)			Luminescence (lux)			Noise (db)		
	1	2	3	1	2	3	1	2	3
Ironing section									
A	*31.0*	*31.0*	*33.5*	748	*855*	*838*	83.6	84.1	84.1
B	*33.0*	*34.5*	*34.0*	*769*	*762*	*784*	82.1	82.6	81.5
C	*35.0*	*35.0*	*34.0*	*723*	*745*	*761*	81.3	81.7	80.0
Inspection section									
A	*32.5*	*33.0*	*32.0*	1,394	1,143	1,193	71.2	71.8	66.5
B	*30.5*	*31.0*	*33.0*	1,522	1,159	1,123	70.8	71.7	68.7
C	*35.0*	*32.0*	*31.0*	926	1,033	1,027	67.6	72.0	72.2
Packing, tagging and size dividing section									
A	24.5	26.0	26.0	353	345	399	62.1	62.6	62.2
B	*29*	*28*	*27.5*	*967*	*995*	*994*	61.9	64.1	61.2
C	*28*	*27.5*	*29*	*785*	*766*	*795*	64	61.3	62.9
Tagging									
A	25.5	26	24.5	*701*	*791*	*798*	72.6	68.5	82.5
B	*27*	*28*	*27.5*	*763*	*839*	*820*	75	70.4	74.3
C	*27.5*	*29*	*27*	*1,075*	*1,137*	*1,183*	69	65	68.9
Size dividing/ratio checking									
A	*28*	*27.5*	*27*	*639*	*671*	*702*	67.6	67.3	68.4
B	*27.5*	*28*	*28.5*	*1,172*	*1,040*	*1,099*	61.2	62.9	62.4
C	*27.5*	*29*	*28*	*1,034*	*1,047*	*1,076*	68.1	66.8	68.7

Note The readings in italic font style indicate those values that do not fit into the standard range provided by OSHA o3, 5–7].

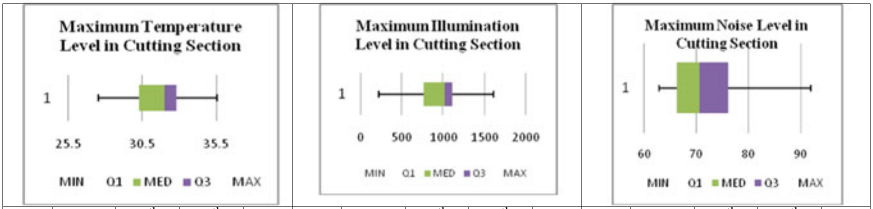
4 Remedial Measures

Based on the environmental audit and observations a comprehensive set of interventions and improvements were suggested to the manufacturing firm. The interventions proposed section-wise are documented below in Table 3.

5 Conclusion

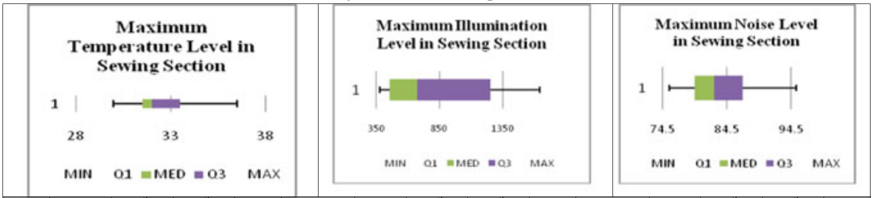
In garment manufacturing units the environmental parameters play a major role in the overall well-being of the organization and the workers. In the Indian context, very few studies have concentrated on the assessment of environmental parameters from ergonomics perspective in garment manufacturing units. This study attempted to

Analysis of Cutting Section



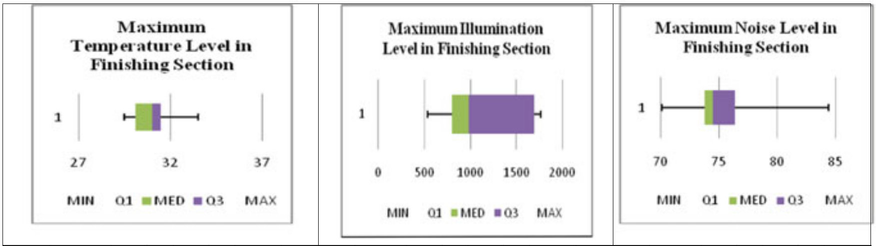
Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value
27.5	30.25	32	32.75	35.5	214	764	1014	1105	1605	62.9	66.35	70.7	76.15	91.9

Analysis of Sewing Section



Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value
30	31.5	32	33.5	36.5	375	453	673	1249	1639	75.5	79.5	82.5	86.95	95.4

Analysis of Finishing Section

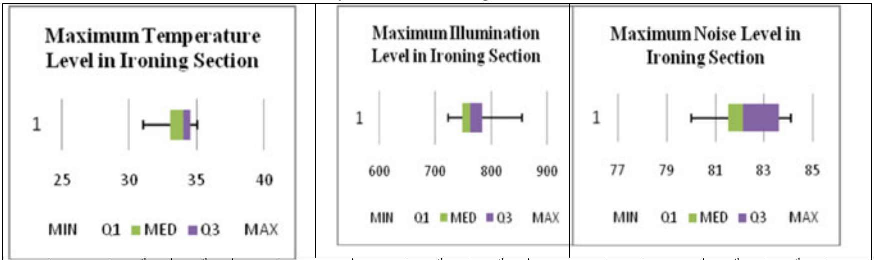


Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value	Min Value	25 percentile	50^{th} percentile	75^{th} percentile	Max Value
29.5	30.12	31	31.5	33.5	541	800.5	982.5	1695	1764	70.1	73.82	74	76.37	84.4

Fig. 1 Box plots in different sections of the garment industry

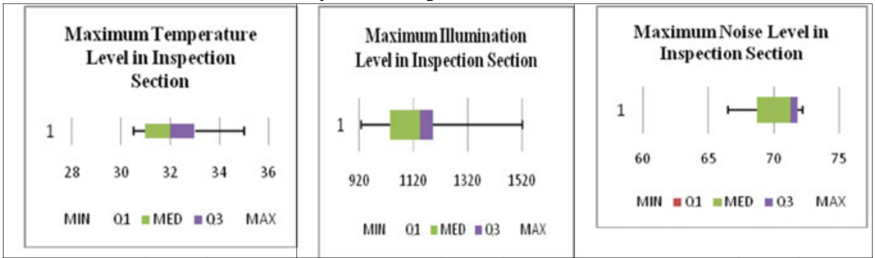
audit the environmental parameters prevailing in the selected garment manufacturing unit in Bengaluru in accordance with the internationally acceptable standards. The environmental parameters such as Temperature, Noise and Luminance were audited in the manufacturing unit. During the course of the study, certain observations were also made by the authors in different sections of the manufacturing unit. The authors proposed interventions from the ergonomics perspective based on the environmental audit, identified gaps/observations and supportive findings.

Analysis of Ironing Section



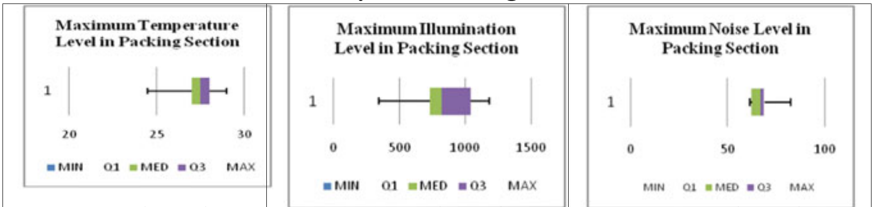
Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value
31	33	34	34.5	35	723	748	762	784	855	80	81.5	82.1	83.6	84.1

Analysis of Inspection Section



Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value
30.5	31	32	33	35	926	1033	1143	1193	1522	66.5	68.7	71.2	71.8	72.2

Analysis of Packing Section



Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value	Min Value	25 percentile	50th percentile	75th percentile	Max Value
24.5	27	27.5	28	29	345	732.5	820	1044	1183	61.2	62.5	66.8	68.8	82.5

Fig. 1 (continued)

The future scope of the work can include a comprehensive ergonomic assessment of the work in terms of work-related musculo-skeletal disorders which are generally the result of an interplay between bad ergonomics in work station design and environmental parameters.

Table 2 Description of box-plot graph

Parameters	Description
MIN	It indicates the minimum value for the given dataset
Q1	Quartile 1 denotes the 25th Percentile
MED	The median denotes the 50th Percentile
Q3	Quartile 3 denotes the 75th Percentile
MAX	It indicates the maximum value for the given dataset
The 25%, 50% and 75% of the data, respectively, is at or below that point	

Table 3 Section-wise interventions

Section of the manufacturing Unit—Cutting section	
Identified gaps/observations	In fusing section, the workers were exposed to extreme heat conditions. The workstations did not have sufficient fans and ventilation for movement of air No seating arrangements were provided. The workers were seen standing for whole working shift
Supportive findings	The workers stated that they suffered from headache, back pain and leg pain at the end of the day**.** Workers also reported that they were a victim of heat burns and suffered from dizziness
Recommendations	Increase in the number of fans is required to overcome the heat conditions and improve air circulation in the work space. Provision for chairs and drinking water should be made mandatory The availability of Personal Protective Equipment and First Aid in the workplace has to be made mandatory
Section of the manufacturing Unit—Sewing Section	
Identified gaps/observations	The fluorescent tubes were placed at a greater height making the illumination level poor especially in farthest from the window position as reported The seating arrangement provided was stool. The workers were standing in bending position There was no sufficient space for the movement of legs
Supportive findings	Musculo-skeletal disorders (MSD) such as back pain, shoulder pain and neck pain were reported by the workers Workers also reported that they suffered from eye strain However, no worker reported of suffering from needle borne infections
Recommendations	Musculo-skeletal disorders (MSD) such as back pain, shoulder pain and neck pain were reported by the workers Workers also reported that they suffered from eye strain However, no worker reported of suffering from needle borne infections

(continued)

Table 3 (continued)

Section of the manufacturing Unit—Ironing section	
Identified gaps/observations	The electric iron boxes provided were technologically old and heavy to lift None of the workers were provided with Aprons and Caps The temperature level was comparatively high in this section About 35% of the fans installed were not in working condition
Supportive findings	The workers reported that they suffered from irritation caused due to sweat It was also reported that this resulted in lack of interest in performing their daily task
Recommendations	Replacing heavy iron boxes based on old technology with new lightweight iron boxes based on steam technology is advisable Regular preventive electrical maintenance will ensure all the installed fans are in working condition
Section of the manufacturing Unit—Inspection section	
Identified Gaps/Observations	The fluorescent tubes were located at a height of about four feet above the worker's height. The workers average height was about five feet two inches. The illumination disposed extreme glare
Supportive findings	Workers reported suffering from eye strain and headache
Recommendations	It is advisable to replace fluorescent tubes with LED tube lights which are energy efficient and of high luminescence
Section of the manufacturing Unit—Packing Section	
Identified Gaps/Observations	The workstation was very congested. Lacks seating arrangements There were no sufficient windows for movement of air The fluorescent tubes were located at a height of about four feet above the workers height. The workers average height was about five feet two inches
Supportive findings	Few of the workers reported that they suffered from varicose veins Majority of the workers reported that they suffered from back pain and leg pain
Recommendations	The seating arrangements have to be provided so that this arrangement can avoid workers standing for the entire shift of eight hours. Fluorescent tubes have to be replaced with LED tube lights which are energy efficient and of high luminescence

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References

1. J. Akbari, H. Dehghan, H. Azmoon, F. Forouharmajd, Relationship between lighting and noise levels and productivity of the occupants in automotive assembly industry. J Environ Public Health (2013)
2. S.U.N.I.T.I. Chandiok, Employee retention in Indian textile industry: a study on Grasim Bhiwani Textile Limited. Asian J Multidimens Res **1**(6), 90–101 (2012)
3. Energy Efficiency Guide for Industry in Asia, Greenhouse Gas Emission Reduction from Industry in Asia, in *United Nations Environment Programme* (2006). ISBN: 92-807-2647-1.
4. J.J. Canas, B.B. Velichkovsky, B.M. Velichkovsky, Human factors and ergonomic, in *IAAP Handbook of Applied Psychology* (2011), pp. 316–337
5. Occupational Health and Safety Act, Section 139 of Regulation 851, Industrial Establishments (1990)
6. OSHA Technical Manual (OTM), Chapter Four: Temperature, Ventilation, Noise and Lighting, *United States Department of Labor*.
7. OSHA's Ergonomic Solutions, *United States Department of Labor* (2012)
8. P. Parimalam, N. Kamalamma, A.K. Ganguli, Ergonomic interventions to improve work environment, *Indian*. J. Occup. Environ. Med. **10**(2), 74–77 (2006)
9. R. Verma, T. Kanti, S. Verma, Role Indian Garment Industry and HRM in Indian Economy. VSRD Int J Business Manag Res **2**(11), 567–569 (2012)

Chapter 34
Assessment of Exposure to Vibration of Two-Wheeler Riders

Anand S. Sharma, S. K. Mandal, G. Suresh, S. Oraon, and D. Kumbhakar

1 Introduction

Published papers related to exposure to WBV are mainly concerned with either heavy-duty industrial vehicles [1–4] or specialized vehicles operating in rough terrain [3, 5, 6]. For all automobile drivers, vehicle vibration is transmitted through the seat of the driver to the buttocks and thereafter to the backbone along vertical axis. The other stresses experienced by the driver are hand and arm vibration through steering and feet vibration through the pedals of either accelerator or clutch or brake. The additional unbalancing character of two-wheeler vehicle adds in amplifying the symptoms by influencing the bioelectric phenomena of the driver. The other common acute health effects from short-term exposure include finger and shoulder symptoms [7], high rate of erectile dysfunction [8], low back pain [9], headache, chest pain, abdominal pain, nausea, fatigue and loss of balance. Adamek [10] study related to bike drivers illustrates that about 83% experience physical impact and about 12% have succumbed to blood circulation problems.

In India, more than 33% people use two-wheelers for travel and commute to work [11]. Depending upon road conditions and types of speed breakers, the riders are frequently exposed to different magnitudes of WBV. The transmitting mediums of vehicle vibration to human body and its magnitude mainly depend upon the type of road, tire specification, structural design of vehicle, suspension systems, engine capacity and weight of the rider. Similarly, the transmitting characteristic to different parts of human body varies with the physique of the rider, age, characteristics, experience, sitting posture and quality of tissue, ligaments and tandem with respect to bone structures [12, 13]. The magnitude of force generated due to vehicle vibration or during resonance when exceeds the internal strength of body parts, the human body is succumbed to injury. The characteristics of detrimental injury aggravate

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Table 1 Comfort environment to the impact of vibration [17]

Measured vibration level of comfort (m/s^2)	Level of comfort
Less than 0.315	Not uncomfortable
0.315–0.63	A little comfortable
0.63–1.0	Fairly comfortable
0.8–1.6	Uncomfortable
1.25–2.5	Very uncomfortable
Greater than 2	Extremely uncomfortable

to fatal with time due to such regular repeated impacts. Dynamic responses to the transmitted vibration may also alter the biochemical and biodynamic metabolism in the driver's nervous system and affects the skeleton system, especially the back bone [14, 15, 16]. The detrimental responses to vibration are generally fatigue, lower back pain, vision problems, interference with or irritation to the lungs, abdomen or bladder and abnormal symptoms in the digestive, genital/urinary and feminine generative systems [9]. As per the ISO standard, the comfortable environment to the impact of vibration is detailed in Table 1.

2 WBV Exposure Evaluation

Considering ISO standard 2631-1 (1997), RMS, CF and VDV should be evaluated in three orthogonal directions to estimate the magnitude of vibration impact on human body [17]. The standard defines a primary contrast approach for figuring out weighted RMS acceleration to evaluate the impact of WBV. Crest factor determines the magnitude of shock experienced by the rider and is determined as the quotient of peak and RMS acceleration [13]. Transient shock is said to be present when the crest factor exceeds nine. In such cases, the exposure to vibration may be underestimated by evaluating the common weighted vibration (A_w). For analysis of such VDV should be determined in addition to RMS. The RMS value, CF and VDV can be evaluated by using the Eqs. 1, 2 and 3, respectively. Since, the health of two-wheeler rider is mostly influenced by the vibration magnitude in vertical direction, i.e., Z-axis, the same has been considered for analysis. To determine the WBV exposure parameters, SvanPC + software has been used to extract the logged data from the precision vibration meter (SV 106A, Svantek).

$$a_w = \left(\frac{1}{T} \int_0^T a_w^2(t) dt \right)^{1/2} \quad (1)$$

where

a_w = frequency-weighted RMS acceleration over a time period, m s^{-2}.

(t) = frequency-weighted RMS acceleration at particular time t, m s^{-2}.
T = duration of measurement (s).

$$CF = \frac{Max[a_w(t)]}{RMS(a_w)} \quad (2)$$

where,

Max [a_w(t)] = Absolute maximum instantaneous peak value of the frequency-weighted acceleration, m s^{-2}.

RMS (a_w) = Frequency-weighted RMS acceleration, m s^{-2}

$$VDV = \sqrt{\int_0^T a_w^4(t)dt} \quad (3)$$

where

VDV = Vibration dose value, m $s^{-1.75}$.

T = duration of measurement, s.

Based on eight-hour everyday exposure, the threshold values or negative health consequences over a lifetime of exposure according to ISO standard are detailed in Table 2.

Table 2 Permissible limits of WBV for 8 h of exposure [9]

	European Union Directive		ISO 2631–1		ISO 2631–5	
	A_w (m/s^2)	VDV (m/$s^{1.75}$)	A_w (m/s^2)	VDV (m/$s^{1.75}$)	S_{ed} (Mpa)	Probability of an adverse health effect
Action limit	0.5	9.1	0.5	9.1	0.5	Moderate
Exposure limit	1.15	21	0.8	14.8	0.8	High

Table 3 Characteristics of riders

Subject	Weight (kg)	Height (cm)	Age (yr)	Body Mass Index (BMI)
R1	88	182	25	26.2
R2	68	165	29	25

Table 4 Specifications of two-wheelers

Specification	Vehicle 1	Vehicle 2	Vehicle 3
Capacity in CC	149.5	499	102
Weight in Kg	144	194	104
Wheel width (inch)	3.15	3.54	3.50
Wheel diameter (inch)	17	19	10
Front suspension	Telescopic with anti-friction	Telescopic 35 mm Fork 130 mm travel	Bottom link with spring-loaded hydraulic damper
Rear suspension	Five-way adjustable, Nitrox shock absorber	Twin gas charged shock absorber with five-step adjustable preload, 80 mm travel	Swing arm with spring-loaded hydraulic damper

3 Methodology

3.1 Participants and Vehicles

The study was conducted for two regular riders driving three unlike two-wheelers at different speeds on bituminous carpeted road for a distance of one kilometer. The speed of the vehicles ranged between 10 and 60 km h^{-1} at 10 km h^{-1} interval, i.e., each driver was monitored at six different speeds in three vehicles. The detailed instruction was explained to both the riders before the test drive. The personal characteristics of both the riders are detailed in Table 3. The details of three unlike two-wheelers (vehicles 1, 2 and 3) of different manufacturers considered for the study are given in Table 4.

3.2 Testing Procedure

Monitoring of data was carried out as per the guidelines stipulated in ISO 2631-1 (1997). Vibration was measured in orthogonal directions, where x-, y- and z-axis measured along anterior–posterior, medial–lateral and vertical directions, respectively. In order to get a representative sample of vibration exposure for three vehicles, short-duration test was conducted for both riders in all three vehicles at different test speeds (10–60 km h^{-1}) for one-kilometer distance.

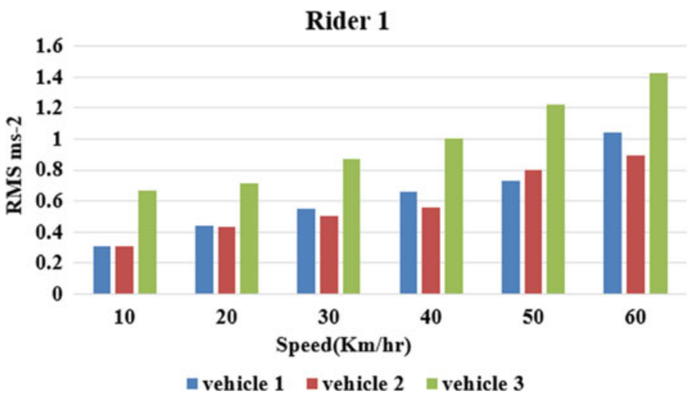
Fig. 1 Human body vibration monitoring system

For each riding task, the tri-axial seat pad accelerometer (SV38, Svantek) was placed between the seat and the rider of two-wheeler. The sensor was connected to the precision vibration meter data logger monitoring, Fig. 1. The model, SV 106A Svantek is a six-channel human vibration meter and analyzer meeting ISO 8041:2005 standard for measurement of human vibration exposure according to ISO standards.

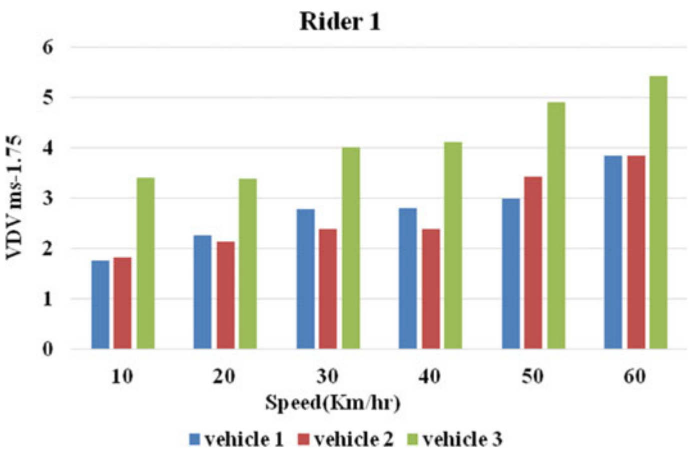
4 Discussion and Analysis

Two riders, R1 and R2, of different body weights were well explained about the study to be conducted and the different speeds to be driven during the study. The riders were also requested to visit the roads before driving the different types of two-wheelers. During driving at different speeds, WBV exposure of the riders in terms of RMS, CF and VDV were collected and are all detailed in Table 5. The data in the most dominant direction, i.e., in the vertical direction was considered for analysis for both the riders. The bar-charts of a_w and VDV_d prepared for each rider at different speeds are shown in Figs. 2 and 3, respectively.

From Table 5, it is observed that magnitude of a_{wd} increases with speed of vehicle and is independent with respect to weight of the rider. However, comparing the magnitudes of a_{wd} with respect to the weight of rider at different speeds, it is observed that for vehicles 1 and 3, it is directly proportional to rider's weight, i.e., for same vehicle and speed, the magnitudes of WBV will be less with decrease in weight of rider. However, for vehicle 2, the magnitude of a_{wd} is increased with decrease in weight of rider. Similarly, for crest factor, Cf_d, the magnitude firstly increases with speed (from 10 to 30 km h^{-1}) for vehicle 1 and thereafter decreases with increase in speed (from 40 to 60 km h^{-1}). Similarly, for vehicle 2, the magnitude firstly increases up to speed of 30 km h^{-1} and thereafter decreases at 40 km h^{-1} and then again increases with increase in speed of vehicle. However, the magnitude of crest factor is always less with decrease in weight of the rider. However, for vehicle 3, though the magnitude of crest factor decreases with decrease in weight of the rider, does not follow any trend, indicating the impact of small diameter of wheel. For same vehicle (vehicles 1 and 2), the magnitude of vibration dose value, VDV, increases



(a) Speed Vs RMS along z-axis



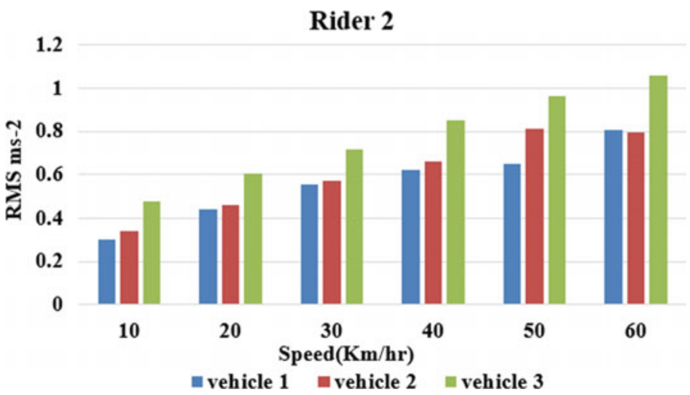
(b) Speed Vs VDV along z-axis

Fig. 2 Impact of vibration exposure for rider 1

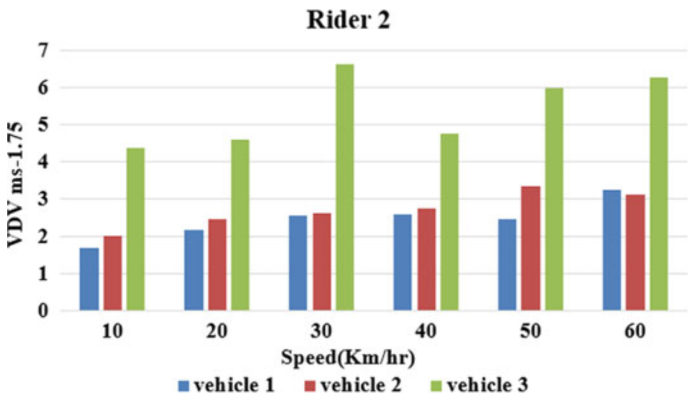
with increase in speed of the vehicle. However, the VDV decreases with decrease in weight of the rider for vehicle 1 and increases for vehicle 2 up to a speed of 50 km h^{-1}, indicating inversely proportional to weight of the rider.

5 Conclusion

The present study illustrates that with increase in speed of two-wheeler, WBV exposure increases, indicating higher exposure magnitude of WBV than the safe limit as recommended on daily exposure limit of frequency-weighted RMS acceleration,



(a): Speed Vs RMS along z-axis



(b) Speed Vs VDV along z-axis

Fig. 3 Impact of vibration exposure for rider 2

A(8) of ISO 2631-1 (1997). The results of the study show that WBV exposure is proportional to the weight of the rider, i.e., the magnitudes increases with increase in weight of the rider. Therefore, Body Mass Index of two-wheeler rider is an important parameter to influence the WBV exposure. From the study, it is found that RMS produced much lower results for WBV exposure in two-wheeler riding than VDV. This observation indicates that a two-wheeler rider encounters many shocks and the magnitude increases with a decrease in wheel diameter. The present study also indicates that the VDV increases with the speed of the vehicle increase for almost the same for all diameters of the wheel.

Table 5 Summary of whole-body vibration exposure of rider 1 (R1) and Rider 2 (R2)

	Vehicle 1						Vehicle 2						Vehicle 3					
Speed (km/hr)	a_{wd} (m/s^2)		Cf_d		VDV_d ($m/s^{1.75}$)		a_{wd} (m/s^2)		Cf_d		VDV_d ($m/s^{1.75}$)		a_{wd} (m/s^2)		Cf_d		VDV_d ($m/s^{1.75}$)	
	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
10	0.312	0.300	6.808	7.161	1.764	1.688	0.310	0.340	5.610	5.152	1.828	2.035	0.668	0.474	6.252	3.591	3.412	4.380
20	0.444	0.444	6.145	5.315	2.254	2.185	0.430	0.457	6.516	6.216	2.133	2.490	0.716	0.605	4.111	3.055	3.377	4.618
30	0.554	0.556	10.28	6.615	2.786	2.588	0.506	0.570	8.100	7.577	2.391	2.645	0.875	0.714	7.244	3.311	4.009	6.637
40	0.659	0.624	5.540	5.794	2.796	2.603	0.562	0.658	5.45	5.018	2.382	2.764	1.007	0.850	4.667	3.596	4.121	4.775
50	0.734	0.648	6.324	5.476	2.992	2.492	0.800	0.814	8.700	6.419	3.420	3.354	1.222	0.964	6.019	4.046	4.903	5.984
60	1.046	0.805	4.753	7.700	3.841	3.255	0.894	0.793	8.327	5.502	3.846	3.115	1.427	1.058	5.768	4.232	5.426	6.302

References

1. L.S. Marin et al., Assessment of whole-body vibration exposure in mining earth-moving equipment and other vehicles used in surface mining. Ann. Work Expo. Heal. **61**(6), 669–680 (2017)
2. C. A. Lewis, P. W. Johnson, Whole-body vibration exposure in metropolitan bus drivers. Occup. Med. (Chic. Ill) **62**(7), 519–524 (2012)
3. A.W. Salmoni, A.P. Cann, E.K. Gillin, T.R. Eger, Case studies in whole-body vibration assessment in the transportation industry-Challenges in the field. Int. J. Ind. Ergon. **38**(9–10), 783–791 (2008)
4. A.P. Vanerkar, N.P. Kulkarni, P.D. Zade, A.S. Kamavisdar, Whole body vibration exposure in heavy earth moving machinery operators of metalliferrous mines. Environ. Monit. Assess. **143**(1–3), 239–245 (2008)
5. A.J. Scarlett, J.S. Price, R.M. Stayner, Whole-body vibration: evaluation of emission and exposure levels arising from agricultural tractors. J. Terramechanics **44**(1), 65–73 (2007)
6. S. Kumar, Vibration in operating heavy haul trucks in overburden mining. Appl. Ergon. **35**(6), 509–520 (2004)
7. S.M. Mirbod, H. Yoshida, M. Jamali, K. Masamura, R. Inaba, H. Iwata, Assessment of hand-arm vibration exposure among traffic police motorcyclists. Int. Arch. Occup. Environ. Health **70**(1), 22–28 (1997)
8. A. Ochiai et al., Do motorcyclists have erectile dysfunction? A preliminary study. Int. J. Impot. Res. **18**(4), 396–399 (2006)
9. R. Rajesh Kumar, M.N. Vinodkumar, A review on WBV and its effects in automobile drivers. IOSR J. Mech. Civ. Eng. **Vdv**, 21–24 (2016)
10. P.J. Adamek, D. Wi, M. Schröter, H. Osnabrück, Human vibration on motorcycles at different driving conditions, 1–20 (2002)
11. C. Economy, ICE 360 o Survey, 2016 ‘ Household Survey on India ’ s Citizen (2016)
12. A. Piette, J. Malchaire, Technical characteristics of overhead cranes influencing the vibration exposure of the operators, **2** (1992)
13. P. Donati et al., Workplace exposure to vibration in Europe: an expert review (2008)
14. B. Hinz, H. Seidel, G. Menzel, R. Blüthner, Effects related to random whole-body vibration and posture on a suspended seat with and without backrest **253**(1) (2002)
15. P.M. Bongers, H.C. Boshuizen, C.T.J. HulshoF, A.P. Koemeester, Long-term sickness absence due to back disorders in crane operators exposed to whole-body vibration. Int. Arch. Occup. Environ. Health **61**(1–2), 59–64 (1988)
16. S. Kitazaki, M.J. Griffin, A modal analysis of whole-body vertical vibration, using a finite element model of the human body. J. Sound Vib. **200**(1), 83–103 (1997)
17. ISO 2631–1, International Standard Iso 2631–1, vol. 1997 (1997)
18. H.C. Chen, W.C. Chen, Y.P. Liu, C.Y. Chen, Y.T. Pan, Whole-body vibration exposure experienced by motorcycle riders - An evaluation according to ISO 2631–1 and ISO 2631–5 standards. Int. J. Ind. Ergon. **39**(5), 708–718 (2009)
19. K.V. Eluri, V.L. Reddy, M. Sivalingam, B. Ps, Analysis of whole body vibration of a two-wheeler rider, in *SAE Technical Papers*, 2019, vol. 2019 (2019), pp. 1–16
20. G.P. Sinha, P.S. Bajaj, Vibration analysis of hero honda vehicle. Int. J. Mech. Prod. Eng. **2**(2), 30–35 (2014)
21. B.S. Shivakumara, V. Sridhar, Study of vibration and its effect on health of the motorcycle rider. Online J. Heal. Allied Sci. **9**(2), 2–5 (2010)

Chapter 35
On-Site Construction Phase Carbon Footprint of Different Multi-Storied Buildings in India

C. H. Suresh Vidyasagar, E. Rajasekar, and P. S. Chani

1 Introduction

There has been a rise in demand that the countries with more than 1% Green House Gas (GHG) emissions should increase their efforts to quickly act in order to reduce its emission. Human activities are the main reason for the release of excessive GHG into the atmosphere, which leads to increasing concentrations of these gases that affect the radiation balance of the Earth [1]. In the name of modernity, every year, millions of new buildings are being constructed all over the world and new building materials are being introduced from time to time. Buildings are the largest consumers of energy and emitters of GHG with more than 40% of the total emissions all over the world [2]. Carbon footprint of a building during the construction stage is considered to be more concentrated and intense within a shorter time as compared to the operational stage which lasts for more than 50 years [3]. Buildings contribute in multiple ways both directly and indirectly to the increase in carbon emission. Direct emissions occur from sources that are owned by the company such as appliances used for the operation, fuel usage for vehicles used for transporting materials to the site and on-site, fuel for heating and cooling, etc., whereas indirect emissions include Embodied Energy (EE) of building materials, emissions by consuming purchased energy, construction activities, etc. For example, cutting of trees to clear the construction site by manpower and cutting of trees for the wood required for buildings is counted as direct emission, and the increase in carbon emission by cutting each tree, which would have otherwise converted some amount of carbon to oxygen, is termed as indirect emission [4]. The manufacturing of the construction materials alone accounts for more than 40% of the total emissions caused by the construction phase [5].

The first step towards reducing GHG emissions is to estimate the total emissions of a certain building and analyze the contributions of various sectors to the total emissions. One of the most reliable methodologies to estimate GHG emissions is the

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Carbon Footprint (CF), which determines the amount of GHG emission produced by a certain process or activity. Wiedmann and Minx [6] defined CF as, "*The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that are directly and indirectly caused by an activity or is accumulated over the life stages of a product*." Although the name consists of only carbon, CF estimates the amounts of other GHG emissions by converting them to carbon equivalents [7].

Till now, because of the larger contribution in the total life cycle of material, only operating energy was considered. However, because of the increased usage of energy-efficient electrical and electronic machines and home appliances, along with more latest and efficient insulation materials, the scope for decreasing operating energy has appreciably improved, and therefore, the present focus has shifted to consider embodied energy associated with the building materials. The share of off-site prefabrication of building components accounts for about 75% of the total embodied energy in buildings, and this percentage is steadily growing as a consequence of the improved application of materials that are high energy-intensive [8]. Therefore, a real-time demand to validate the efficiency of building materials in the context of both embodied and operating energy so as to decrease energy usage.

The use of concrete and steel, both of which account for high GHG emission, makes the construction phase create the most intensive negative impact on the environment [5]. Moreover, the decisions taken during the design and construction stages substantially affect the CF of other stages of the building's life cycle. Therefore, it is necessary to estimate the CF of the building during the design stage so as to apply alternative materials and methods to reduce the overall CF of the building in each phase of its lifetime.

2 A Brief Review of Relevant Literature

The number of scientific reports and research articles on the environmental change due to increased GHG emissions by the construction sector has doubled since the release of a report from the United Nations Climate Panel in 2007 [9]. The amount of scientific reports on the effects of change in climate has rapidly grown since the last report in the year 2007, and the results show a very clear picture of how the increase in carbon footprint deteriorates the environment. However, initially, more efforts were focussed on developing software tools to calculate the carbon footprint [10].

It is found that the operational energy of a building depends on the type of building materials used irrespective of their embodied energies. For example, Kumar et al. [11], calculated the total energy consumption (embodied and operational) of a room with fire clay bricks and the total energy consumption of the same room replacing the fire clay bricks with ash blocks. Interestingly, the results showed that even though the cost of ash blocks is thrice that of fire clay bricks, the use of ash blocks can significantly reduce the heat load and hence reduce the operational energy. Therefore, the CF of materials and the CF of operational energy are interrelated.

In the year 2010, Dixit et al. [8] felt that the present measurements of embodied energy are not clear and the EE of a certain material differs greatly from one database to another, and EE databases become incomparable and face problems of variation. Moreover, a trustworthy and reliable framework, standard, template or protocol is not available which could solve these errors in EE databases. Therefore, new methodologies must be developed as a top priority.

In agreement with Dixit et al. [8], recently Divya et al. [12] stated that since carbon footprinting is connected with finance and was reported to affect the economy, some mandatory legal rules and regulations are compulsory to validate these measurements. Moreover, the calculation of carbon emission must be harnessed as a strong agenda to encourage reductions in carbon emission among various sectors like agriculture, real estate, infrastructure, transportation and should be included as a measuring scale for sustainable development. However, there are several CF calculating tools that are being developed and made available online.

Reddy et al. [13] also felt that present EE calculations of building materials differ greatly because of the method of calculation and assumptions made for energy supply (whether calculated with respect to end-use energy or initial stage energy). Therefore, the calculated EE values of some commonly used building materials in huge amounts in the Indian construction industry vary. Basically, these EE values have been calculated on the basis of actual survey data collected from the industries. The authors also evaluated the application of two basic methods, namely process analysis and input–output method, and reported that the process analysis method is a more suitable method for the calculation of EE in the region of Indian. Furthermore, to analyze the variation in the EE values, a comparison of EE values of materials with respect to two different energy supplies. Their results showed a remarkable variation in the EE values of materials whose production consumes a huge amount of electrical energy with respect to the use of thermal energy.

Mustafa et al. [14] made an attempt to analyze the carbon footprint of residential projects and office buildings so as to determine the major sources and contributions of different infrastructure projects in Malaysia. The authors also proposed materials that are environmentally friendly as an alternative to regular construction materials such as green cement, lightweight concrete, lightweight materials, etc., to achieve the implementation of sustainability.

On the other hand, Luo et al. [15] reported a simpler framework to measure the CO_2 footprint during the initial design stage of the building by performing process-based calculations of carbon footprint for different materials used in office buildings, residential buildings and commercial buildings during preparing the BOQ. The authors concluded that embodied carbon footprint can be remarkably decreased by optimizing the number and amount of materials having high EE in the initial design stage. They also recommended the use of green materials and materials which are environmentally friendly.

Recently, Jamie et al. [5] developed a new tool called "OERCO2 Project" for users without any expertise. The major purpose of this software tool includes analyzing the methods available to calculate the life cycle carbon footprint of European construction projects and materials. By this, a standard European database could be established and made available to common people in this area, hence creating an awareness of the relation between GHG emissions and climate change and spreading the information related to construction projects through an Open Educational Resource (OER).

In spite of the odds and shortcomings in calculating the CF and limiting the carbon emissions, one should not stop but keep on trying to update and modify the existing methods and scenarios. This paper is one such attempt and reports the calculation of CF of four different buildings in India. Some alternative building materials are suggested to reduce the CF and a comparison between the CF of the buildings with and without the substitution of alternative materials is made.

3 Methodology

A. Development of framework

In the present case study, bill of quantities (BOQs) of four different types of buildings, namely, research park, faculty quarters, student's hostel and lecture hall complex buildings, respectively. Each case contains the details such as project name, project budget, the purpose of the project, floor drawings, building type, number of stories, anti-seismic grade, materials used, manpower employed, amount of earthwork done, details of finishing operations, etc.

B. Data source and calculation and details

The following steps were followed for calculating the carbon footprint of the building considered in the present study:

1. Collection of data
2. Analysis of data
3. Defining the boundary conditions
4. Calculation of CF and converting it into appropriate units.

The required data is collected in two stages, namely, details of the embodied energy of building materials (before construction) and details of the energy consumption of construction activities (during construction).

The data regarding on-site activities is gathered from the project manager in the following categories:

(a) Type of project
(b) Value of project
(c) Duration of project
(d) Excavation and foundation details
(e) Bill of quantities

(f) Material supplier's details
(g) Distance and details of materials transportation to the site
(h) On-site transportation, loading and unloading details
(i) Monthly man hours
(j) Monthly fuel, electricity and water consumption details

The corresponding data required for calculating the EE and CF of the building construction materials are collected from respective suppliers of various building materials. The data is acquired from the corresponding suppliers in the following categories:

(a) Product details
(b) Production details
(c) Energy consumption (Direct and Indirect)
(d) Source of raw materials
(e) Distance, mode of transportation raw materials, transportation within the manufacturing unit and details of loading, unloading, and manpower.

In the present study, the overall CF of the multi-storied building (except operational and demolition energy) is calculated by adding CF of building materials, CF of transportation and CF of construction activities. The same can be written in the following equation form:

$$\text{Overall CF} = \text{CF}_{\text{material}} + \text{CFT}_{\text{ransportation}} + \text{CF}_{\text{Activities}} \quad (1)$$

The flow of materials used in the construction and their transportation is shown in Fig. 1.

The collected data from the survey is also used to build a database of construction materials for future calculations. The detailed energy consumption of the building materials from the mining site to the construction site is arranged in the order shown in Fig. 1. The total EE of the materials is then converted to Kg of carbon/m^3.

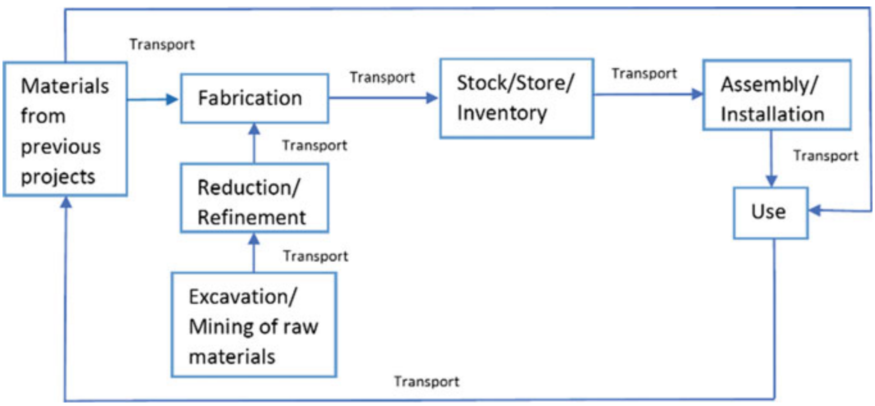

Fig. 1 Material flow diagram

The energy consumption of the construction activities is segregated and sequenced into the following sub-categories:

(1) Site preparation works (cutting of trees, levelling, marking, excavation, piling, etc.)
(2) Concrete works (foundations, slabs, stairs, lifts, walls, etc.)
(3) Brickwork
(4) Metalwork (Steel, aluminium, etc.)
(5) Woodwork
(6) Doors and windows
(7) Mechanical works
(8) Finishing works, etc.

The energy consumption of the above is calculated individually, summed up and converted to Kg of carbon/m^3.

However, the scope of the present study is limited to the above-mentioned categories and the CF of the waste entered on-site, electrical works, safety works, recycled materials, etc., and are not taken into account. Finally, the total carbon footprint is calculated in Tonnes of CO_2 by adding the carbon emission of building materials along with the transportation and the carbon emission of construction activities.

C. The Schedule of Embodied Energy Rates (SEER) model

SEER model basically is a list of embodied energy rates of certain construction work. These rates are obtained by calculating the number of materials used in a particular activity and multiplying them by their embodied energy values (MJ). These EE values are acquired from local, regional and international sources and databases used to retrieve the GHG emission factors for the selected building materials.

A sample of SEER model is shown in Fig. 2.

Initially, the SEER model was created using the BMTPC database, and later, some values were updated from time to time based on some international databases like Inventory of Carbon and Energy (ICE).

The amounts of mortar work, RCC, stone, steel and other materials purchased and used in the construction of these buildings were obtained from the respective BOQs and architectural drawings. Examples include, the Embodied Energy (EE) value for the production of steel was acquired from SEER which was in turn obtained from the ICE database composed by Hammond and Jones, which is within the range of EE of steel produced by various manufacturers at various regions and the EE value for local concrete production was again collected from SEER. The use of regional or local CO_2 emission factors for the major and important building materials is necessary for achieving representative and accurate results. Therefore, regional or local EE factors and CO_2 emission factors of the materials that were updated from time to time in various databases were used in this study.

Concrete Work SEER - IIT Roorkee - BMTPC

Sl.no.	Code No	Description	Unit	Quantity (per cum)	Base value	EEV	Added EEV
4.1.1		1:1:2 (1 cement : 1 coarse sand : 2 graded stone aggregate 20 mm nominal size)	cum	1			
	0295	Stone Aggregate (Single size) : 20 mm nominal size	cum	0.640	538	344.32	
	0297	Stone Aggregate (Single size) : 10 mm nominal size	cum	0.210	538	112.98	
	0982	Coarse sand (zone III)	cum	0.425	0	0	
	0367	Portland Cement (0.425cum)	kg	610.000	6.7	4087	4544.3
4.1.2		1:1½ :3 (1 cement : 1½ coarse sand : 3 graded stone aggregate 20 mm nominal size)	cum	1			
	0295	Stone Aggregate (Single size) : 20 mm nominal size	cum	0.570	538	306.66	
	0297	Stone Aggregate (Single size) : 10 mm nominal size	cum	0.280	538	150.64	
	0982	Coarse sand (zone III)	cum	0.425	0	0	
	0367	Portland Cement (0.2833 cum)	kg	400.000	6.7	2680	3137.3
4.1.3		1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 20 mm nominal size)	cum	1			
	0295	Stone Aggregate (Single size) : 20 mm nominal size	cum	0.670	538	360.46	
	0297	Stone Aggregate (Single size) : 10 mm nominal size	cum	0.220	538	118.36	478.82
	0982	Coarse sand (zone III)	cum	0.445	0	0	
	0367	Portland Cement (0.2225 cum)	kg	320.000	6.7	2144	2622.82
4.1.4		1:2:4 (1 cement : 2 coarse sand : 4 graded stone aggregate 40 mm nominal size)	cum	1			
	0293	Stone Aggregate (Single size) : 40 mm nominal size (0.70 cum - 7.5% for voids i.e. 0.05 = 0.65 cum)	cum	0.520	538	279.76	
	0295	Stone Aggregate (Single size) : 20 mm nominal size	cum	0.220	538	118.36	
	0297	Stone Aggregate (Single size) : 10 mm nominal size	cum	0.110	538	59.18	457.3
	0982	Coarse sand (zone III)	cum	0.445	0	0	
	0367	Portland Cement (0.2225 cum)	kg	320.000	6.7	2144	2601.3

Fig. 2 Sample SEER model

4 Results

A. *Carbon emission of building materials*

Generally, construction projects are very complicated as it involves many different kinds of materials, different activities for different types of buildings. The choice of the materials is also based on the type of building. Therefore, the task of collection of data is complicated and gathering all the information from different perspectives is a difficult and time-consuming process. Also, EE values related to some material or activity may not be readily available. Hence, in the present paper, the calculation of carbon footprint is limited to the materials used, earthwork, manpower, etc. The carbon footprint of these items is calculated individually and summed up to get the total carbon footprint in Tonnes of CO_2 for each building. The building materials are separated as cement, steel, aluminium, stone, bricks, etc. The embodied energies of some major materials according to SEER in Mega Joules are given in Table 1.

B. *Calculation*

According to the SEER values, the embodied energies of the construction activities of the four different buildings described earlier are calculated. The SEER values were updated regularly and the latest values are considered for this study. A sample calculation of different materials based on the SEER database is given below in Fig. 3. A multiplication factor of 0.0786 was applied to the total EE values to convert the total Mega Joules of energy to Tonnes of CO_2.

Table 1 Embodied energies of some materials according to SEER

Items	EE (MJ)
Stone	538
Portland Cement	6.7
Steel	33.6
Aluminium	157
Traditional Brick	7.24
Paint	1590

S.No+A 1:122	DSR-2014	DESCRIPTION	UNIT	QTY		Cement		stone			Brick
II	4.0	CONCRETE WORK									
		PLAIN CEMENT CONCRTE									
11	4	Providing and laying in position cement concrete of specified grade excluding the cost of centering and shuttering - All work up to plinth level :									
	4.1.4	1:2:4 (1 Cement : 2 coarse sand : 4 graded stone aggregate 40 mm nominal size)	cum	1067	2601.30	2144	**2287648**	**457**	**487619**	0	
		DAMP-PROOF COURSE					0		0		
12	4.10	Providing and laying damp-proof course 40mm thick with cement concrete 1:2:4 (1 cement :2 coarse sand : 4 graded stone aggregate 12.5mm nominal size)	Sq.m	147.5	133.74	104.91	**15474.225**	**28.83**	**4252.425**	0	
13		Making plinth protection 50mm thick of cement concrete 1:3:6 (1 cement :3 coarse sand : 6 graded stone aggregate 20mm nominal size) over 75mm bed of dry brick ballast 40mm nominal size well rammed and consolidated and grouted with fine sand including finishing the top smooth	Sq.m	200	139.33	73.7	**14740**	**25.2**	**5040**	**40.3**	**8060**
14		Providing and laying cement concrete in retaining walls, return walls,					0		0		0
	14.1	1:2:4 (1 cement :2 coarse sand : 4 graded stone aggregate 20 mm					0		0		0
		Below Footing & Plinth	cum	251.73	2622.82	2144.00	**539709.12**	**478.80**	120528.3	0.00	0
15		Making plinth protection 50mm thick of cement concrete 1:3:6 (1 cement :3 coarse sand : 6 graded stone aggregate 20mm nominal size) over 75mm bed of dry brick ballast 40mm nominal size well rammed and consolidated and grouted with fine sand including finishing the top smooth	Sq.m	160.79	139.33	73.70	**11850.223**	**25.20**	4051.908	**40.30**	**6479.8**
	15.1	Providing and laying in position **cement concrete** of specified grade excluding the cost of centering and shuttering. (for RCC pipe bedding) by 1:4:8 (1 cement : 4 coarse sand : 8 graded stone agg. 40 mm nominal size)	Cum	30.38	1617.00	1139	**34602.82**	**178.8**	5431.944	0	0
	15.2	12 mm cement **plaster** of mix					0		0		0
	00.1.15	1:4 (1 cement : 4 coarse sand).	Sq.m	12.00	36.6	36.6	439.2	0	0	0	
									0		
							0		0		
					Cement	2904463.6	Stone	626923.6		Bricks	14540
						2904.4636		626.9236			14.54

Fig. 3 Sample calculation of different materials using the SEER database

Based on the above calculations, the embodied energies of the different building construction including the excavation of the area and neatly disposing or dressing them in the prescribed area including manpower are shown below in Table 2.

The various materials along with their corresponding CO_2 emission in Tonnes are given in Table 2.

The pictorial graph of the same mentioned in Table 2 is shown in Fig. 3.

C. *Alternative materials*

Further, based on the calculated actual carbon emission of the present study should be calculated for the floor area of each constructed building in the focus of this study. However, replacing some of the materials used in the present construction such as steel with electric arc furnace recycled steel, traditional bricks with aerated autoclaved

Table 2 shows the calculated Tonnes of CO_2 for various buildings and materials in Tonnes of CO_2

Items	Research Park	Faculty Quarters	Boys Hostel	Lecture Hall Complex	Total
Stone	815.925	208.6158	973.38	523.13	**2521.051**
Cement	4352.684	3292.883	7151.2	3346.789	**18,143.56**
Steel	6584.364	6628.979	5010.3	4370.585	**22,594.23**
Aluminium	454.95	575.868	122	64.327	**1217.145**
Brick	1387.04	439.883	850.028	1148.413	**3825.364**
Paint	59.196	79.665	82.075	40.925	**261.861**
Excavation	115.71	35.6	1.7	25.08	**178.09**
Man power	114	116	107	128	**465**
Others	211.919	62.175	55	54.098	**383.192**
Total	**14,095.79**	**11,439.67**	**14,352.68**	**9701.347**	**49,589.49**

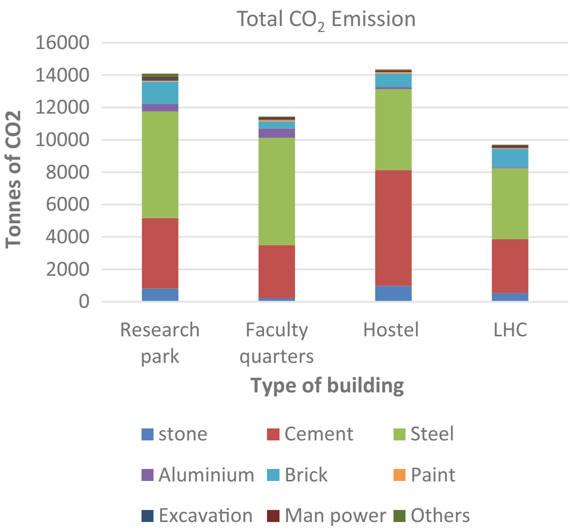

Fig. 4 Graphical representation of the total CO_2 emissions of different buildings

bricks and Portland land cement with Pozzolana cement leads to a decrease of 52.6%, 46%, 42% and 55% decrease in the buildings, respectively, as shown in Fig. 4.

5 Conclusions

Table 2 shows the total CO_2 emission from various buildings such as Research Park (Institutional), Boys Hostel Institutional and Residential), Faculty Housing (Residential) and Lecture Hall Complex (Institutional) which were constructed simultaneously.

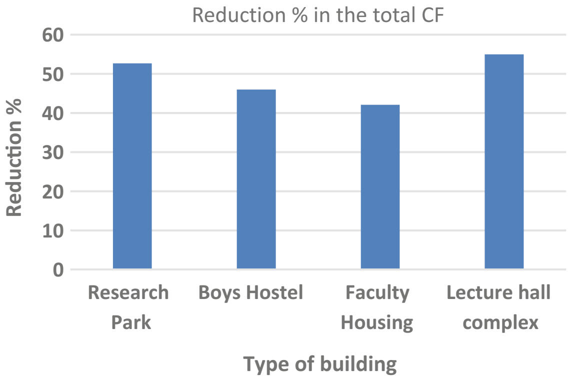

Fig. 5 Percentage of reduction that can be achieved in different types of buildings by replacing them with alternative materials

Based on the present study, the following conclusions can be drawn:

(1) SEER model developed by using hybrid calculations is a tool that is very useful, easier and user-friendly. Though it is not complete in itself, it contains a large amount of data regarding major and important materials and activities (Figs. 2 and 3).
(2) Replacing some of the materials used in the present construction such as steel with electric arc furnace recycled steel, traditional bricks with aerated autoclaved bricks and Portland land cement with Pozzolana cement leads to a decrease of 52.6, 46, 42 and 55% decrease in the buildings.
(3) Effective project management, optimum equipment usage, minimizing the waste generation, use of recycled materials, effective usage of manpower, etc., are some feasible ways to reduce the emission of carbon during the construction stage.
(4) Another effective way of reducing carbon emissions is to identify the supply chain of a certain material and procure materials that are produced or fabricated using alternate and renewable energy sources.

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References

1. S. Plummer, P. Lecomte, M. Doherty, The ESA Climate Change Initiative (CCI): A European contribution to the generation of the Global Climate Observing System. Remote Sens. Environ. **203**, 2–8 (2017)
2. A.P.C. Chan, A. Darko, E.E. Ameyaw, Strategies for promoting green building technologies adoption in the construction industry-An international study. Sustain. **9**(6), 1–18 (2017)
3. L. Xiaodong, Y. Fan, G. Yuanxue, J. McCarthy, Case study of carbon footprint of residential building construction. Mater. Res. Innov. **18**, S472–S476 (2014)

4. M.H. Ramage et al., The wood from the trees: The use of timber in construction. Renew. Sustain. Energy Rev. **68**, 333–359 (2017)
5. J. Solís-Guzmán, C. Rivero-Camacho, D. Alba-Rodríguez, A. Martínez-Rocamora, Carbon footprint estimation tool for residential buildings for non-specialized users: OERCO2 project. Sustain. **10**(5) (2018)
6. T. Wiedmann, J. Minx, A definition of ‘ carbon footprint. Science (80-)., **1**(01), 1–11 (2007)
7. M. Airaksinen, P. Matilainen, A Carbon footprint of an office building. Energies **4**(8), 1197–1210 (2011)
8. M.K. Dixit, J.L. Fernández-Solís, S. Lavy, C.H. Culp, Identification of parameters for embodied energy measurement: A literature review. Energy Build. **42**(8), 1238–1247 (2010)
9. UNITED Report of the Conference of the Parties on its thirteenth session , held in Bali from 3 to 15 December 2007 Part Two : Action taken by the Conference of the Parties at its thirteenth session Decisions adopted by the Conference of the Parties, FCCC/CP/2007/6, (2008), pp. 1–60
10. Z. Ren, V. Chrysostomou, T. Price, The measurement of carbon performance of construction activities: a case study of a hotel construction project in South Wales. Smart Sustain. Built Environ. **1**(2), 153–171 (2012)
11. A. Kumar, D. Buddhi, D.S. Chauhan, Indexing of building materials with embodied, operational energy and environmental sustainability with reference to **2**(1), 11–22 (2012)
12. D. Pandey, M. Agrawal, Carbon footprint : current methods of estimation carbon footprint: current methods of estimation (2011)
13. K.I. Praseeda, B.V.V. Reddy, M. Mani, Embodied energy assessment of building materials in India using process and input-output analysis. Energy Build. **86**, 677–686 (2015)
14. M.M. A. Klufallah, M.F. Nuruddin, M.F. Khamidi, N. Jamaludin, Assessment of carbon emission reduction for buildings projects in malaysia-a comparative analysis. E3S Web Conf. **3** (2014)
15. Z. Luo, Y. Cang, N. Zhang, L. Yang, J. Liu, A quantitative process-based inventory study on material embodied carbon emissions of residential, office, and commercial buildings in China. J. Therm. Sci. **28** (2019)

Correction to: Effect of Brightness on Visual Fatigue During Video Viewing

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Correction to:
Chapter 31 in: L. P. Singh et al. (eds.), *Productivity with Health, Safety, and Environment*, Design Science and Innovation, https://doi.org/10.1007/978-981-16-7361-0_32

In the original version of the book, the following belated corrections have been incorporated:

In chapter 31 "Effect of Brightness on Visual Fatigue During Video Viewing", the affiliation of the authors "Prerita Kalra" and "Vinod Karar" has been changed from "Academy of Scientific & Innovative Research, CSIR-Central Scientific Instruments Organisation, Chandigarh, India" to "CSIR-Central Scientific Instruments Organisation, Chandigarh 160030, India and Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201002, India"

The erratum book and the chapter has been updated with the changes.

The updated original version of this chapter can be found at
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