Ergonomic evaluation of physiological stress of building construction workers associated with manual material handling tasks

Saha P, Basu B, Devashish Sen D.*

Ergonomics, Work Physiology, Occupational Health Management Laboratory, Department of Life Sciences, Presidency University, Kolkata, India

A- Conception and study design; **B -** Collection of data; **C -** Data analysis; **D -** Writing the paper;
E- Review article; **F** - Approval of the final version of the article

ABSTRACT

Purpose: In India, the cost of manpower is very low; hence Manual Material Handling (MMH) is the cheapest solution. This study aimed to quantify the cardiac strain and postural stress of male building construction workers associated with MMH tasks.

Materials and methods: Mean (SD) age (years) and job experience (years) of the workers were 31.0(4.65) and 8.8 (3.23), respectively (n=35). Working peak heart rate was recorded by polar heart rate monitor, posture analysis was done by the Ovako Working Posture Analysis System (OWAS) and the Rapid Entire Body Assessment (REBA) method, body part discomfort was assessed by the Nordic questionnaire, and perceived exertion was evaluated by the Borg scale. Two-tailed unpaired Student's t test was performed between peak heart rate of workers associated with MMH tasks and upper extremity intensive tasks (n=31).

Results: Results revealed that mean peak heart rate of the workers was significantly different (higher) compared with that of the upper extremity intensive workers ($p<0.05$). This study showed that most of the working postures were hazardous. The magnitude of risk for musculoskeletal disorders (MSD) was much higher as per REBA compared with OWAS. Most of the workers suffered from pain in the head, neck, shoulder, lower back, and arm region. As per the Borg scale, the rate of perceived exertion was 'hard and heavy' among most of the workers (68.57%).

Conclusions: Postural stress and cardiac strain beyond the safe limit indicates the heavy nature of the job. Load limit optimization, ergonomic lifting technique, and rescheduled work-rest cycle are essential to reducing physiological and perceived work load.

Key words: Construction industry, Manual Material Handling, posture, peak heart rate.

DOI: 10.5604/01.3001.0010.2413

***Corresponding author:**
Devashish Sen
Professor and Head, Department of Life Sciences, Presidency University, Kolkata,
e-mail: dsen.dbs@presiuniv.ac.in, Tel.: 9831478105

Received: 30.01.2017
Accepted: 03.03.2017
Progress in Health Sciences
Vol. 7(1) 2017 pp 54-62

INTRODUCTION

Industrialization and urbanization have resulted in rapid growth of the unorganized sector. This in turn has led to the flourishing of the construction industry. About 340 million people are occupationally involved in the unorganized sector in India and about half of them are employed in the construction industry [1-4]. Building construction is the core pillar of industrialization and urbanization. It needs to be mentioned in this context that such acceleration in the construction industry is not only witnessed in India, but the entire world has seen a rapid growth in this sector.

In India, it is the second largest economic activity after agriculture [5], and includes both skilled and unskilled workers. The workers are exposed to high physically demanding jobs and musculoskeletal disorders (MSDs), cardiac strain; decreased muscle strength and reduced physical functions are prevalent among the workers of this sector [6-9]. Manual Material Handling (MMH) tasks are frequently carried out in the construction sector along with upper extremity intensive tasks. Heavy load carriage is highly predominant among MMH workers and their job is heavy in nature. Frequent lifting, carrying, lowering are associated with MMH tasks.

The incidence of MSDs, increased heart rate, and oxygen consumption has been found to be associated with various awkward postures [6,10]. Heavy load carriage, awkward postures for a prolonged duration, environmental stress, lack of usage of personal protective equipment are cumulatively affecting the health status of workers. Angular deviation of joint angles from neutral posture, continuous and speedy work pattern, and heavy load carriage can exert the cardiovascular load on the workers, and it enhances with increased environmental temperature and humidity [11,12].

There has been a scarcity of work on the determination of physiological and subjective work load of Indian male building construction workers, including brick carriers. Studies on comparative evaluation of cardiac strain between workers associated with MMH tasks and upper extremity intensive static repetitive tasks are of significant importance. Special attention should be given to the determination of work load of MMH workers, because they are exposed to both static and dynamic muscle load. This assessment of work load of MMH operations and interactions of various stressors associated with MMH is essential in order to recommend remedial measures.

In spite of extensive studies, there are lacunae in (i.) physiological and subjective workload determination of Indian male building construction workers associated with MMH, (ii.) comparative evaluation of cardiac strain between MMH workers and upper extremity intensive workers, (iii.) the cumulative effect of static and dynamic muscle load on workers. This study aimed to assess the cardiac strain and postural stress of male construction workers associated with MMH. The potential benefit lies in implementing ergonomic guidelines for construction workers associated with MMH to ensure a sustainable change in quality of life with reduction in occupational hazards and to improve health, safety, and efficiency of workers under the existing construction work environment in India.

MATERIALS AND METHODS

Ethical Clearance

Consents were obtained from the construction workers who participated in this study. Data were collected following the guidelines of the Institutional Ethical Committee (Human) and the Declaration of Helsinki.

Selection of subjects

35 male construction workers associated with manual material handling were randomly selected, aged between 25-39 years, having experience of more than 5 years. 31 male workers engaged in distal upper extremity intensive repetitive jobs were randomly chosen as the control group. Plastering, carpentry, and painting jobs were considered upper extremity intensive tasks. Building construction workers were taken from two different construction sites of Kolkata, West Bengal, India.

Study design

Workers associated with MMH tasks were asked to perform their daily activity for 30 minutes. After this duration, their peak heart rate was obtained. Workers engaged in upper extremity intensive static repetitive work were also asked to perform their job for the same duration without rest, and after that their peak heart rates were also collected.

Participant characteristics

Workers' heights and weights were collected using Martin's anthropometric rod (Seiber and Heigner, Switzerland) and a weighing scale (Libra), respectively. Body Mass Index (BMI) was calculated from height and weight data [13].

Table 1 shows the characteristics of the participants associated with manual material handling tasks (experimental group) and upper extremity intensive workers (control group). There was no significant difference between the age, height, weight, BMI of the experimental and th control group ($p>0.05$).

Measurement of Working Heart Rate

Electronic polar heart rate monitor (Polar Electro, Finland) was used to measure the peak heart rate of the workers while performing their jobs. (Photo 1).

Table 1. Participant characteristics associated with manual material handling tasks and upper extremity intensive work. EG= Experimental Group, CG= Control Group. There is no significant difference between the two groups (p>0.05)

Parameters	**Workers associated with MMH tasks (EG)** (n=35)	**Upper extremity intensive workers (CG)** (n=31)
	Mean (SD)	Mean (SD)
Age (years)	31.0 (4.65)	32.8 (4.49)
Height (cm)	161.4 (6.83)	162.1 (3.96)
Weight (Kg)	57.5 (3.77)	58.4 (5.85)
Body Mass Index (kg/m^2)	22.1 (2.14)	22.3 (2.41)

Photo. 1. Load carriage (taken from actual field site)

Posture analysis

Videography and photography methods were used to prepare a stick diagram of the frequently adopted posture. Scores of postures were obtained by Rapid Entire Body Assessment (REBA) and Ovako Working Posture Analysis System (OWAS) with the help of Ergofellow 2.0 software [14,15].

Rate of Perceived Exertion

The workers' perceived exertions were assessed using Borg's Rated Perceived Exertion (RPE) scale [16].

Body Part Discomfort

Feeling of discomfort or pain in different parts of the body was recorded using the Nordic questionnaire [17].

Wet Bulb Globe Temperature index

Heat stress was assessed with the Wet Bulb Globe Temperature (WBGT) index [18].

Statistics

Descriptive statistics (Mean, Standard Deviation) were performed by using MS Excel 2010. Student's t test (unpaired two-tailed) was done to find out the significant difference between the mean of working heart rate of the experimental and the control group [19].

RESULTS

Table 2 shows the Resting Heart Rate (RHR) and the Peak Heart Rate of the workers associated with MMH and upper extremity intensive workers. Two-tailed unpaired t-test revealed that the mean peak heart rate of workers (147.0 beats/min) associated with MMH was significantly different (higher) compared with that (122.9 beats/min) of upper extremity intensive workers ($p<0.05$). No significant difference in RHR was observed between the two groups ($p>0.05$).

Table 2. Resting heart rate (beats/min) and peak heart rate (beats/min) of workers associated with MMH tasks and upper extremity intensive tasks

Parameters	**Workers associated with MMH tasks (EG)** (n=35)	**Upper extremity intensive workers (CG)** (n=31)
	Mean (SD)	Mean (SD)
Resting Heart Rate (beats/min)*	73.1 (3.49)	74.3 (2.00)
Peak Heart Rate (beats/min) **	147.0 (11.44)	122.9 (11.40)

*= there is no significant difference between the two groups ($p>0.05$); **= there is a significant difference between the two groups ($p<0.05$).

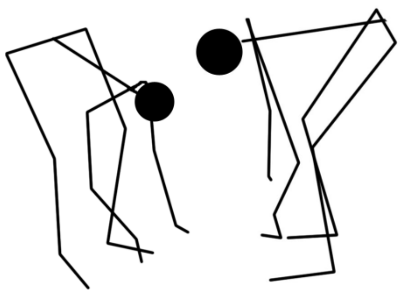
Table 3 shows percentage of workers (n=35) perceiving different magnitudes of exertion. It was observed that the exertion was 'heavy' for 68.57% of workers, followed by 'very hard' (17.14%), and 'somewhat hard' (14.29%). WBGT (indoor) and WBGT (outdoor) were 21.7°C and 26.8 °C, respectively.

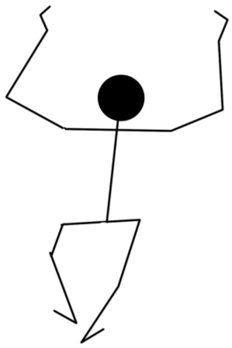
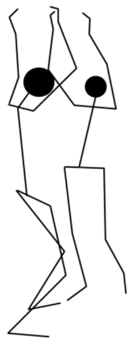
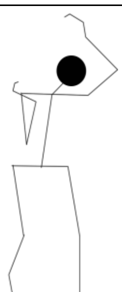
Figure 1 shows different postures adopted during lifting, carrying, and lowering. The magnitude of risk of MSD was greater as per REBA than OWAS method.

Table 3. Percentage of workers perceiving different magnitudes of exertion

Task	**Somewhat Hard (%)**	**Hard (%)**	**Very Hard (%)**
Manual Material Handling	14.29	68.57	17.14

Figure 1. Analysis of working postures of workers associated with manual material handling tasks

Activity	**Posture**	**OWAS Remarks**	**REBA Remarks**
Lifting		Corrective action should be done as soon as possible	Very high risk, implement change

Lifting		Corrective action should be done as soon as possible	Very high risk, implement change
Carrying		Corrective actions required in near future	High risk, investigate and implement change
Lifting		Corrective actions for improvement required immediately	Very high risk, implement change
Lifting		Corrective actions for improvement required immediately	Very high risk, implement change
Carrying		Corrective actions for improvement required immediately	Very high risk, investigate and implement change

Carrying		Corrective actions required in near future	High risk, investigate and implement change
Lowering		Corrective action should be done as soon as possible	Very high risk

Figure 2 shows the percentage of workers (n=35) suffering from pain. An upper body part, such as head (91.42%), neck (88.57%), shoulder (94.29%), upper back (82.86%), hand (97.14%), and lower segment, e.g., lower back (94.29%) and knee (82.86%), were mostly affected by pain and discomfort.

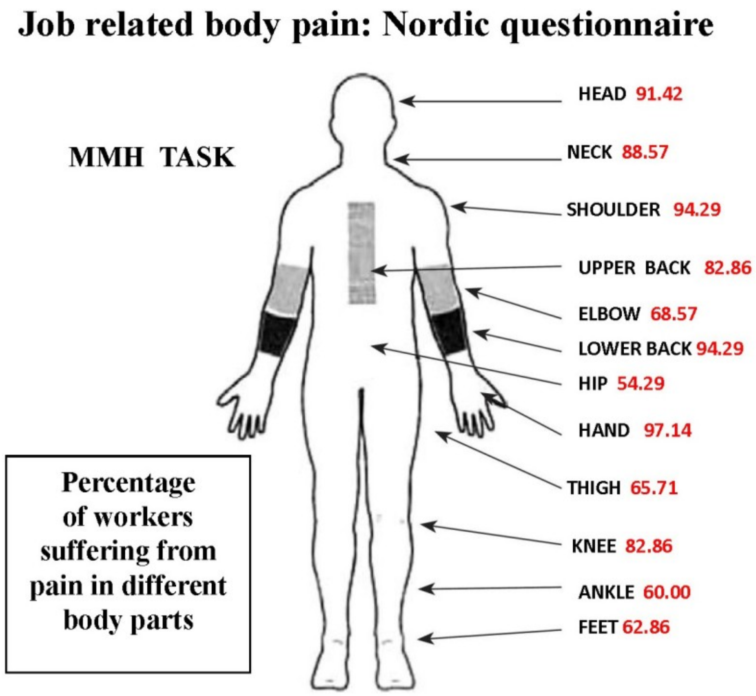


Figure 2. Percentage of workers suffering from pain in different body parts (adapted from the Nordic questionnaire) [17]

DISCUSSION

The building construction industry is an occupationally hazardous sector. There are several ergonomic risk factors associated with manual load carriage and upper extremity intensive repetitive jobs. Evaluation and quantification of physiological stress associated with MMH were done in this study. MMH tasks require loading, lifting, carrying, and lowering the object. A similar study was conducted in the Brick kiln sector, where lifting, lowering, carrying, pushing, pulling, stretching, bending, reaching, etc. were highly prevalent. The prevalence of work-related MSDs were due to prolonged stresses and strain resulting from these various hazardous activities [20]. A previous study showed that poor safety aspects with higher physiological work load in the building construction sector have been leading to an unsafe and hazardous industry in India [21]. Studies showed a strong correlation between awkward posture and MSDs [22-24]. Physiological workload was considered a key contributory risk factor for MSDs and poor working ability [25,26].

This study revealed that peak heart rates of the workers associated with MMH task was much higher than the recommended limit for the industry and indicate the heavy nature of the job [27,28]. A significant difference between the peak HR of workers associated with MMH and upper extremity intensive workers indicates that MMH tasks are more strenuous than static repetitive work.

A similar study was conducted to assess the cardiac costs of male brick kiln workers of two different age groups [11], and it was observed that mean (SD) Maximum Heart Rate (HR max) of the younger group (18-39 years) was 142.55 (5.63) beats/min at higher WBGT. But this study showed that mean peak heart rate of the MMH workers was 147.0 (11.44) beats/min at lower WBGT. Due to frequent lifting and carrying of heavy loads with awkward postures, workers suffer from discomfort and pain in the upper part of the body, such as the head, neck, shoulder, and arms, and in the lower back region.

Another study found that pain in the back, shoulder, wrist, sprain injuries, and severe fatigue were associated with MMH tasks [29]. Biomechanical evaluation in another study revealed that the compressive force at L5/S1 was beyond the threshold level [30]. Postural alterations like bending forward or standing and load bearing activities may result in backache, low back pain, neck pain and so on [31].

Posture analysis revealed that the workers were susceptible to risk of MSD and implementing change was highly required. Posture analysis by using RULA, REBA, and OWAS have shown similar results in other studies, which concluded that the postures adopted by workers engaged in heavy load carriage required immediate ergonomic interventions [20, 32].

In this study, we observed different methods of load carriage. The OWAS score is dependent on the posture of the back, position of both hands, and the load carriage amount. The OWAS and the REBA scores showed differences in the severity of risk for MSD.

The work load category was also assessed on the basis of rate of perceived exertion. As per Borg's RPE, most of the workers perceived the work as a 'hard and heavy' task. A previous study indicated that the physiological and psychological wellbeing of workers was affected by manual heavy load carriage [33]. Outdoor WBGT suggested that the workers had to work in stressful environmental conditions. Several studies concluded that for the WBGT index, a value of more than 25°C is stressful [34-36].

This study needs to be repeated on a large number of subjects considering the variability of different types of MMH tasks done by the construction workers. Based on the results of a large number of subjects, proper job rotation and evaluation of ergonomic interventions need to be done.

CONCLUSIONS

Excessive physiological work load can lead to various occupational health hazards, including MSD, discomfort, fatigue, and disability. This work load results from heavy load carriage, frequent lifting of heavy objects, awkward posture, and high cardiac strain. Load limit optimization, ergonomic lifting techniques, alteration of fatigue allowances, and a proper work-rest cycle with short rest periods are essential to reducing the risk of MSD, occupational injury, physiological work load and to ensure the safety and wellbeing of the workers associated with MMH tasks.

Acknowledgement

We would like to acknowledge all the workers who volunteered for this study. Polar heart monitors were purchased with the Presidency University FRPDF fund.

Conflicts of interest

In this study entitled "Ergonomic evaluation of physiological stress of building construction workers associated with Manual Material Handling (MMH) tasks", there are no conflicts of interest among the authors.

Funding

We would like to thank the Presidency University for funding this work (FRPDF scheme).

REFERENCES

1. NCEUS. Report on Social Security for Unorganised Workers. National Commission for Enterprises in the Unorganised Sector, Government of India, New Delhi. 2006.
2. Das S. Workers in unorganised sector lack security. Down to Earth. 2007.
3. Ramesh PB. Rethinking Social Protection for India's Working Poor in the Unorganised Sector. Cross National Policy Exchange: Asia Social Protection Papers. 2009;1–18.
4. Rajasekhar D, Suchitra JY, Madheswaran S, Karanath GK. At times when limbs may fail: Social Security for Unorganised workers in Karnataka. Karmayoga. 2009; 1-32.
5. A skilled workforce for strong, sustainable & balanced growth. A report by G20 training strategy, International labour office GENEVA. November 2010
6. Boschman JS, van der Molen HF, Sluiter JK and Frings Dresen MHW. Musculo-skeletal disorders among construction workers: a one-year follow-up study. BMC Musculoskelet Disord. 2012 Oct;13:196.
7. Russo A, Onder G, Cesari M, Zamboni MV, Barillaro C, Capoluongo CE, Pahor M, Bernabei R, Landi F, Ferrucci L. Lifetime occupation and physical function: a prospective cohort study on persons aged 80 years and older living in a community. Occup Environ Med. 2006 Jul;63(7):438–42.
8. Cassou B, Derriennic F, Iwatsubo Y, Amphoux M. Physical disability after retirement and occupational risk factors during working life: a cross sectional epidemiological study in the Paris area. J Epidemiol Community Health. 1992 Feb;46 (5):506–11.
9. Li CW, Wu SC, Wen SW. Longest held occupation in a lifetime and risk of disability in activities of daily living. Occup Environ Med. 2000 Aug;57(8):550–4.
10. Intaranont, K. Vanwonterghem, K. Study of the exposure limits in constraining climatic conditions for strenuous tasks: An ergonomic approach. Unpublished manuscript, European Commission (DGXII RTD), Brussels, Belgium.1993.
11. Maity SG and Sahu S. Assessment of Cardiac Cost of Two Age Groups of Brick Carriers During Summer in Different Unorganized Brick making Sector in West Bengal, India. Int J Curr Res Aca Rev. 2016 Jan;4(1):65-76.
12. Azer NZ, McNall PE, Leung HC. Effects of Heat Stress on Performance. Ergonomics 1972;15(6):681-91.
13. Keys A, Fidanza F, Karvonen MJ, Kimura N, Taylor HL. Indices of relative weight and obesity. J Chronic Dis. 1972 Jul; 25(6):329-43.
14. Hignett S, McAtamney L. Rapid entire body assessment (REBA). Appl Ergon. 2000 Apr;31(2):201-5.
15. Hsien Tzu- Lee, Han Chia-Shan. Analysis of Working Postures at a Construction Site Using the OWAS Method. Int J Occup Saf Ergon. 2013;19(2):245–50.
16. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14(5):377–81.
17. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, Jørgensen K. Standardized Nordic Questionnaire for the analysis of musculoskeletal symptoms. Appl Ergon. 1987 Sep;18(3):233–37.
18. Yaglou CP, Minard D. Control of heat casualties at military training centres. AMA Arch Industrial Health. 1957 Oct; 16(4):302–16.
19. Das D, Das A. Statistics in Biology and Psychology. 4th ed. Academic publishers, India, p. 109, Das A. Statistics in Biology and Psychology. 4th ed. Academic publishers, India, 2005; p. 109.
20. Qutubuddin SM, Hebbal SS, Kumar ACS . Ergonomic Evaluation of Tasks Performed by Workers in Manual Brick Kilns in Karnataka, India. GJRE. 2013;13(4):35-42.
21. Maiti R. Workload assessment in building construction related activities in India. Appl Ergon. 2008 Nov;39(6):754–65.
22. Anita AR, Yazdani A, Hayati KS, Adon MY. Association between awkward posture and musculoskeletal disorders (MSD) among assembly line workers in an automotive industry. Malays J Med Health Sci. 2014 Jan;10(1):23-8.
23. Gerbaudo L, Violante B. Relationship between musculoskeletal disorders and work-related awkward postures among a group of health care workers in a hospital. Med Lav. 2008 Jan-Feb; 99(1):29-39.
24. DeLooze MP, Toussaint HM, Ensink J, Mangnus C, van der Beek AJ. The validity of visual observation to assess posture in a laboratory-simulated, manual material handling task. Ergonomics. 1994 Aug; 37(8):1335-43.
25. Da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: A systematic review of recent longitudinal studies. Am J Ind Med. 2010 Mar;53(3): 285–323.

26. Van den Berg TIJ, Elders LAM, de Zwart BCH, Burdorf A. The effects of work-related and individual factors on the Work Ability Index: A systematic review. Occup. Environ. Med. 2009 Apr;66(4):211–20.
27. Brouha, L. Physiology in Industry, Pergamon Press, Oxford, UK. 1967.
28. Astrand PO, Rodhal K. Textbook of Work Physiology, McGraw-Hill Publication, New York. 1986.
29. Ray PK, Parida R, Saha E. Status Survey of Occupational Risk Factors of Manual Material HandlingTasks at a Construction Site in India. Procedia Manufacturing. p. 6579-6586. 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015.
30. Parida R, Sarkar S, Ray PK. Improving occupational health of Indian construction workers: A biomechanical evaluation approach. In book: Smart Technologies for Smart Nations- Part of the series Managing the Asian Century, Edition: 2016, Chapter: Part III, Publisher: Springer Singapore, Editors: Purnendu Mandal, John Vong, pp.195-216.
31. Tiwary G, Gangopadhyay PK. A review on the occupational health and social security of unorganized workers in the construction industry. Indian J Occup Environ Med 2011 Mar;15(1):18-24.
32. Bhattacharya R& Biswas G. Assessment of Working Postures and Associated Health Status of Construction Workers. Sci & Cult. 2011 Jan-Feb;77(1–2):52–7.
33. Majumder J, Begepally BS, Shah P, Kotadiya S, Yadav S, Naha N. Comparison of workers' perceptions toward work climate and health symptoms between ceramic and iron foundry workers. Indian J Occup Environ Med. 2016 Mar;20(1):48-53.
34. Dey NC, Samanta A, Saha R. Assessment of cardiac strain amongst underground coal carriers – A case study in India. Int J Ind Ergonomics. 2007 Jun;37(6):489-95.
35. WHO. Health Factors in working under conditions of heat stress, WHO Technical Report Series, Geneva, 1969; p. 412.
36. American Conference of Governmental Industrial Hygienists (ACGIH), Threshold limit values for chemical substances and physical agents and biological exposure indices, American Conference of Governmental Industrial Hygienists, Cincinnati, 1992-1993.