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

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ABSTRACT

Purpose: In India, 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 the male building construction workers associated with MMH tasks.

Materials and methods: Mean (SD) of 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 Ovako Working Posture Analysis System (OWAS) and Rapid Entire Body Assessment (REBA) method, body part discomfort was assessed by Nordic questionnaire and perceived exertion was evaluated by Borg's 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 to that of the upper extremity intensive workers ($p<0.05$). This study showed that most of the working postures were hazardous. Magnitude of risk for MSD was much higher as per REBA compared to OWAS. Most of the workers suffered from pain in head, neck, shoulder, lower back and arm region. As per the Borg scale 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, rescheduled work rest cycle are essential to reduce physiological and perceived work load.

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

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INTRODUCTION

Industrialization and urbanization have resulted in rapid growth of the unorganised sector. This in turn has led to the flourishing of construction industry. About 340 million people are occupationally involved in unorganized sector in India and about half of them are employed in 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 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. 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 prolonged duration, environmental stress, lack of usage of personal protective equipment are cumulatively affecting the health status of the workers. Angular deviation of joint angles from neutral posture, continuous and speedy work pattern, and heavy load carriage can exert cardiovascular load on the workers and it enhances with increased environmental temperature and humidity [11,12]. There has been scarcity of work on 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 on determination of work load of the 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. cumulative effect of static and dynamic muscle load on workers. This study aimed to assess the cardiac strain and postural stress of the 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 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 Institutional Ethical Committee (Human) and Declaration of Helsinki.

Selection of subjects

35 male construction workers associated with manual material handling were randomly selected 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 control group. Plastering, carpenting, painting jobs was considered as 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. The 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

Height and weight of the workers were collected by using Martin's anthropometric rod (Seiber and Heigner, Switzerland) and weighing machine (Libra) respectively. Body Mass Index (BMI) was calculated from height and weight data [13]. Table 1 shows characteristics of 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 experimental and 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 during performing their jobs. (Photo 1).

Table 1. Participant characteristics associated with manual material handling tasks and upper extremity intensive works. 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 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

Perceived exertions of the workers were assessed by Borg's Rated Perceived Exertion (RPE) scale [16].

Body Part Discomfort

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

Wet Bulb Globe Temperature index

Heat stress was assessed by 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 control group [19].

RESULTS

Table 2 shows Resting Heart Rate (RHR) and 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 to 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 the 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 significant difference between the two groups ($p<0.05$).

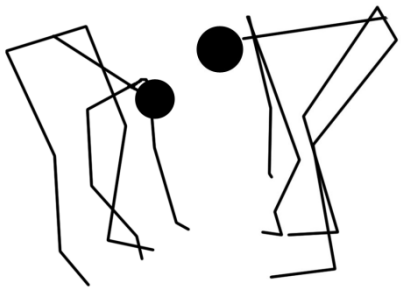
Table 3 shows percentage of workers (n=35) perceiving different magnitude of exertion. It was observed that the exertion was 'heavy' for 68.57% of workers followed by 'very hard' (17.14%) and 'somewhat hard' (14.29%). WBGT (indoor) and WBGT (outdoor) were 21.7°C and 26.8 °C respectively.

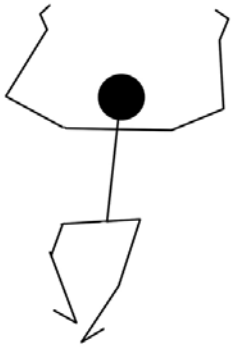
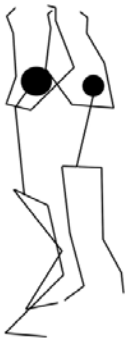
Table 3. Percentage of workers perceiving different magnitude of exertion

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

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

Figure 1. Analysis of working postures of the 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 percentage of workers (n=35) suffering from pain. 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.

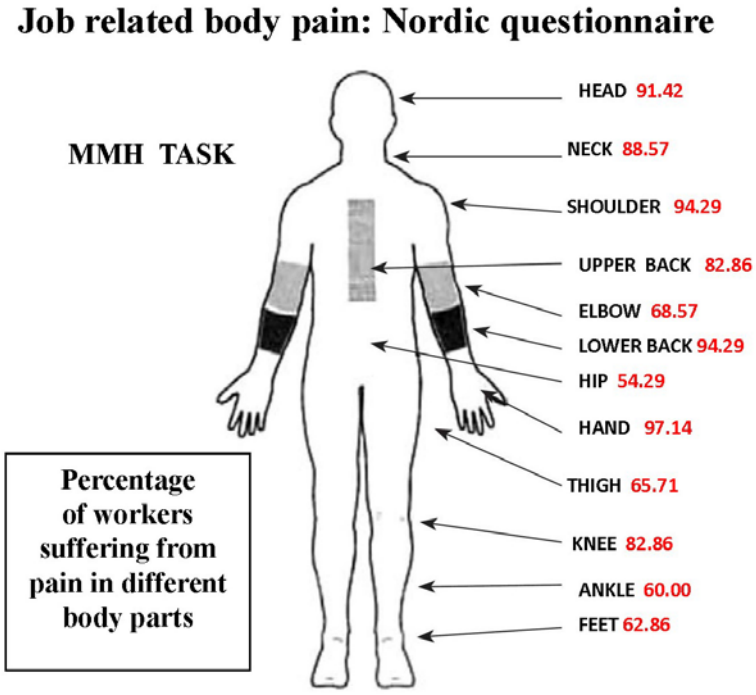


Figure 2. Percentage of workers suffering from pain in different body parts of the workers (adapted from Nordic questionnaire) [17]

DISCUSSION

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 have been done in this study. MMH tasks require loading, lifting, carrying and lowering the object. Similar study has been conducted in Brick kiln sector where lifting, lowering, carrying, pushing, pulling, stretching, bending, reaching etc were highly prevalent. Prevalence of Work related MSDs were due to prolonged stresses and strain occurred by these various hazardous activities [20]. Previous study showed that poor safety aspects with higher physiological work load in building construction sector leading to an unsafe and hazardous industry in India [21]. Studies showed strong correlation

between awkward posture and MSDs [22-24]. Physiological workload was considered as 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 the recommended limit for industry and indicate the heavy nature of the job [27,28]. Significant difference between the peak HR of workers associated with MMH and upper extremity intensive worker indicates that MMH tasks are more strenuous than the static repetitive work.

Similar study has been conducted to assess the cardiac costs of male brick kiln workers of two different age groups [11] and it was observed that mean (SD) of 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 heavy load with awkward posture, workers suffer from discomfort and pain in upper part of the body such as head, neck, shoulder, arms and also in the lower back region. It was found from another study that pain in back, shoulder, wrist, sprain injuries, severe fatigue were associated with MMH tasks [29]. Biomechanical evaluation in another study revealed that compressive force at L5/S1 was beyond the threshold level [30]. Postural alterations like bending forward or standing and load bearing activities may resulting in backache, low back pain and neck pain and so on [31]. Posture analysis revealed that the workers were susceptible to risk of MSD and implementation of 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 the workers engaged in heavy load carriage required immediate ergonomic interventions [20, 32].In this study different methods of load carriage have been observed. OWAS score is dependent of posture of the back, position of both the hands and amount of load carriage. OWAS and REBA score showed difference in the severity of risk for MSD. Work load category was also assessed on the basis of rate of perceived exertion. As per Borg's RPE the most of the workers perceived the work as 'hard and heavy' task. Previous study indicated that physiological and psychological well being of workers was affected by manual heavy load carriage [33]. Outdoor WBGT suggested that the workers had to work in stressful environmental condition. Several studies concluded that for WBGT index, value more than 25°C is stressful [34-36].

This study needs to be repeated on large number of subjects considering the variability of different types of MMH tasks done by the construction workers. Based on the results of large number of subjects, proper job rotation and evaluation of ergonomic intervention 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 object, awkward posture and high cardiac strain. Load limit optimization, ergonomic lifting technique, alteration of fatigue allowances, proper work rest cycle with short rest periods are essential to reduce the risk of MSD, occupational injury, physiological work load and ensure safety, wellbeing of the workers associated with MMH tasks.

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Conflicts of interest

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

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