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Ergonomic Evaluation of Postural Strain and Musculoskeletal Disorders among Workers Associated with Upper Extremity Intensive Jobs at Construction Sites of West Bengal, India

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KEYWORDS

Construction industry, upper extremity intensive jobs, monotask, postural strain, rapid entire body assessment, strain index, musculoskeletal disorders.

A B S T R A C T

Work related musculoskeletal disorder is a major cause of injury and absenteeism among construction workers. Predominantly upper extremity intensive works are repetitively performed monotask. Hazards associated with monotask are higher than multitask performance. This study aimed to evaluate task specific postural strain associated with painting, stone cutting, manual piling, carpenting, plastering, plumbing which involve awkward static posture and upper extremity intensive activity. Videography of each task was performed and subsequent posture analysis with Rapid Entire Body Assessment (REBA) and Moore and Garg was done using Ergofellow 2.0 Software. Questionnaire was employed to identify the pain map. Borg scale was used to evaluate task specific perceived exertion among workers. Thermal stress was measured by Wet Bulb Globe Temperature (WBGT) index. REBA and Moore and Garg scores were much above safe standards and required immediate implementation. Painters were identified to have highest REBA and Moore and Garg score. Incidence of pain was observed in back, shoulder, upper and lower limb. Painting was perceived to involve heavy exertion while other jobs were categorized to be ‘somewhat hard’. Ergonomic interventions are required to modify tool design, work place orientation. Properly scheduled work rest cycle and job rotation may mitigate the work stress.

Introduction

In India, building construction is one of the fastest growing industries with an annual growth of 10% (Baruah, 2008). Construction industry is the second largest unorganized sector in the country, second only to agriculture (A report by G20 training strartegy, International labor office GENEVA. 2010). In India, about 40 million workers are involved in construction related jobs (Kulkarni, 2007). Construction industry encompasses a wide range of skilled and unskilled labor including load carrier, stonecutter, carpenter, plumber, mason, painter, piler and electrician. The major challenge in this industry is attaining preset levels of productivity in adverse environmental condition of sultry tropical climate (Gyi *et al*., 1998). Immense work pressure, awkward postures, prolong duration of work-hour have resulted in high prevalence of Musculo Skeletal Disorder (MSD) among these workers (Gangopadhyay *et al*., 2005; Gangopadhyay *et al*., 2008., Punett *et al*., 1991). Cardiac strain and postural stress of workers at construction site have been widely evaluated, but a work specific assessment and subsequent comparative analysis among workers performing predominantly Distal Upper Extremity (DUE) intensive works at construction sites are of significant importance. According to a study conducted in the year 2000, by Bureau of Labour Statistics (BLS) 68,323 injuries occurred as a result of repetitive work. Among these injuries approximately 75% affected the upper extremities (United States Department of Labor, BLS 2003). Upper extremity intensive work increases cardiac strain at the same absolute intensity as lower extremity intensive work of the similar work load (Astrand *et al*., 1968). DUE intensive works generally involves skillful use of hand tool, forceful manual exertions, repetitions and the worker assumes a particular awkward posture for extensive part of the work cycle. Summated effect of prolonged duration of exertion, high work speed and frequency may result inpremature onset of fatigue, decline of cognitive ability reflecting in degraded quality of performance at the same time detrimentally affecting productivity levels. Fatigue may also culminate in increased distractions leading to error, unsafe behavior and accident proneness (Abdelhamid and Everett, 1999; Abdelhamid and Everett, 2002). It has already been evaluated that performance of single task may lead to more hazard than multiple varied tasks through the entire day. Assessment of postural strainis necessary in order to identify the potential risk factors associated with the tasks prior to devise remedies to ameliorate the condition.

The aim of the study was to assess the risk associated with monotask distal upper extremity intensive work among males working at construction sites of West Bengal, India. Postural strain generated in distal upper extremity intensive work, due to repetitive and awkward working postures, speed of work, hand-wrist position, prolong duration of exertion. These workers are also exposed to different unfavorable environmental conditions. An attempt to make a task specific comparative analysis of postural strain perceived exertion and pain of workers have been done.

Materials and Methods

Ethical Clearance

Participants either signed or gave their left thumb impression on consent letter either reading or listening to it prior to data collection. The process of data collection was performed strictly abiding by 'Institutional Ethical Committee (human)' guidelines and conforms to the recommendation from Declaration of Helsinki (1983).

Subject selection

70 male workers performing distal upper extremity intensive tasks from three

different construction site of Kolkata, West Bengal were chosen to participate. The subjects were engaged in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n-11), plaster work (n=15) and plumbing (n=12). Age group of the participants were within the range of 25-40 years, since most workers involved in construction activities belong to this age group, and workers with an experience of minimum 5 years were considered for the study.It was confirmed none of the subjects had any history of injury or cardiopulmonary ailment that can interfere with their daily performance.

Study Design

The study was conducted at different construction sites of West Bengal. The following six distal upper extremity intensive construction jobs were identified to evaluate the body postures, pain and perceived exertion:

i. Painting
ii. Stone-cutting
iii. Manual Pilling
iv. Carpenting
v. Plaster work
vi. Plumbing

Physical and physiological parameters

Height and weight of the workers at construction site were measured using Martins Anthropometer (Seiber & Heigner, Switzerland) and weighing machine (Libra, India) respectively. BMI was calculated from height and weight data.

Assessment of work posture

Evaluation of task specific different working postures and digital photography were performed. The different working postures of the workers performing DUE tasks were assessed by using Moore and Garg (Strain Index) (Moore and Garg, 1995) and Rapid Entire Body Assessment (REBA) (Hignett and McAtamney, 2000). Stick diagrams were drawn from frozen frame video recordings and most assumed posture was selected. Ergo Fellow 2.0 software was employed to compute the strain index and REBA.

Moore and Garg (Strain Index)

Moore and Garg or Strain Index (SI) is majorly employed to evaluate the risks associated with a monotask repetitive activities of the upper arm on the basis of six variables like intensity of exertion, duration of exertion, efforts per minute, speed of work, hand wrist posture, duration of task. The contributions of scores from six different aspects are multiplied to yield a cumulative index of physical and physiological stress.

Rapid Entire Body Assessment (REBA)

Rapid Entire Body Assessment (REBA) is posture analysis tool used to evaluate required or selected body posture, forceful exertions, type of movement or action, repetition, and coupling. A score will be assigned for each of the following body regions: neck, shoulders, trunk, back, wrists, forearms, elbows legs and knees. The biomechanical analysis of assumed posture was considered in order to generate the cumulative REBA score, score that represent the level of MSD risk.

Perception of Pain

Perception of pain in different body parts of the workers were noted, using a 10 point subjective scale (Corlett, 1995). Feeling of pain during, after work and during sleep was recorded.

Rate of Perceived Exertion (RPE)

Subjective perception of exertion of the task and its effect on the whole was evaluated by using the RPE Borg Scale, to identify the perceived work load category (Borg, 1982).

Mean (up to one decimal) and SD of perceived values were calculated. Finally, rounding method was employed to convert the value to nearest whole number in order to develop the pain map and job category.

Working Environment

Thermal load was evaluated using Wet Bulb Globe Temperature (WBGT) index (Yaglouand Minard, 1957). The Dry Bulb, Wet Bulb and Globe temperature were recorded on the days of data collection and the heat stress was evaluated.

Statistical analysis was done in MS Excel 2010 by computing descriptive statistics ie., mean, Standard Deviation (SD) of age, height, weight, BMI, scores of SI and REBA. Percentage of workers experienced discomfort was also calculated. Mean and SD of perceived values were obtained. Finally rounding method was employed to convert the value to nearest whole number in order to develop pain map and job category.

Results and Discussion

Table 1 shows the physical characteristics (height, weight, BMI) of subjects (n=70) engaged in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n-11), plaster work (n=15) and plumbing (n=12).

Table.2 shows mean (SD) of REBA and Moore and Garg (Strain Index) score. Posture analysis revealed that REBA and Moore and Garg score of all the upper extremity intensive tasks like painting, stone cutting, manual piling, carpenting, plaster work, plumbing were much higher than the safe limits. Table 2a shows scores of REBA corresponding to risk of musculoskeletal disorders (MSDs).

Table 3 shows mean of perceived pain among workers engaged in painting, stonecutting, manual piling, carpenting, plaster work, plumber. This study showed that 100% of the subjects (n=70) performed upper extremity intensive tasks experienced and suffered from occupation related pain in different parts of the body. A task specific pain map was obtained according to average perception of pain. Table 4 shows the scores corresponding to different perceptions of pain.

Figure 1 shows the analysis of working postures of workers engaged incarpenting, manual pilling, plaster work, plumbing, stone cutting and painting. An analysis of working postures revealed that all the postures were hazardous, highly risky and implementation of change was required.

Figure 2 shows the mean perceived exertion of painter, plumber, carpenter, stone cutter, manual piler, plaster worker according to Borg's rated perceived exertion (RPE) scale. This study revealed that the average rate of perceived exertion of was 'hard and heavy' for painter (16) and 'somewhat hard' for plumber (14), carpenter (14), stone cutter (13), manual piler (13), and plaster worker (13).

Table 5 shows most workers performing different upper extremity intensive task experienced discomfort during sleep and after work.

The workers had to work in adverse condition. The average value of outdoor and indoor WBGT was 31.3° C and 33.7°C respectively.

The subjects were standardized in terms of socioeconomic condition and nutritional status. All the tasks chosen were performed at construction site in hot and humid tropical climate with similar heat stress except during the months of winter. Heat stress enhances fatigue thereby increases chances of error and accident.

Table.1 Physical characteristics of workers (n=70) engaged in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n-11), plaster work (n=15) and plumbing (n=12)

Task	Age (years)	Height (cm)	Weight (Kg)	Body Mass Index (kg/m^2)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Painting	32.8 (5.57)	159.9 (2.30)	60.9 (5.11)	23.8 (2.05)
Stone Cutting	31 (4.69)	163.4 (5.77)	59.4 (6.16)	22.2 (1.72)
Manual Piling	32.3 (5.66)	161.1 (9.72)	61.9 (7.73)	24.3 (5.35)
Carpenting	33 (4.58)	161.8 (3.40)	60.2 (5.12)	23 (2.58)
Plaster work	32.9 (5.58)	164.3 (4.65)	57.6 (10.77)	21.3 (3.47)
Plumbing	30 (5.16)	163.5 (4.58)	61 (4.85)	22.9 (1.85)

Table.2 Mean (SD) of Rapid Entire Body Assessment (REBA) and Moore and GARG (Strain Index) score

Task	Number of subjects (n)	Rapid Entire Body Assessment (REBA) Score	Moore and Garg (Strain Index) (>7 Hazardous)
		Mean (SD)	Mean (SD)
Painting	10	10.7 (0.82)	78.3 (18.33)
Stone Cutting	11	10.4 (0.50)	4.6 (1.57)
Manual Piling	11	9 (1.26)	29.5 (6.27)
Carpenting	11	9.6 (1.57)	45.3 (15.03)
Plaster work	15	10.7 (1.10)	15.3 (8.02)
Plumbing	12	10.4 (0.50)	50.1(8.85)

Table.2a Scores of Rapid Entire Body Assessment (REBA) corresponding to risk of Musculo Skeletal Disorders (MSDs) - Ergofellow Software

Score	Risk
1	Negligible risk
2 or 3	Low risk, change may be needed
4to 7	Medium risk, further investigation, change soon
8 to 10	High risk, investigation and implement change
11 or more	Very high risk, implement change

Table.3 Mean of perceived pain among workers engaged in painting, stonecutting, manual piling, carpenting, plaster work, plumbing

Task	n	Neck	Shoulder		Upper arm		Lower arm		Upper Back	Mid Back	Lower Back	buttocks	Thighs		Legs	
			L	R	L	R	L	R					L	R	L	R
Painting	10	6	5	6	6	6	6	7	6	5	8	4	4	4	6	6
Stone Cutting	11	3	3	4	5	5	6	6	6	6	8	4	4	4	6	6
Manual Piling	11	5	3	3	3	6	3	7	5	5	7	3	4	4	5	5
Carpenting	11	6	6	6	6	6	6	7	6	5	8	4	5	5	6	6
Plaster work	15	5	5	5	5	5	6	6	6	6	8	3	4	4	6	6
Plumbing	12	6	6	6	6	6	6	7	6	5	7	2	3	4	6	6

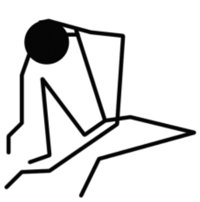
Table.4 Scores corresponding to different perceptions of pain (Corlett, 1995).

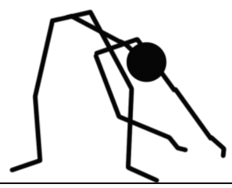
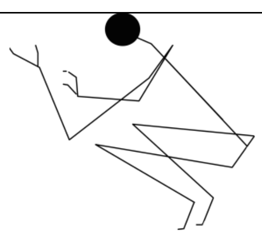
	Score		Score
No pain	0	Moderate pain	6
Discomfort ness	1	Severe pain	7
Very mild pain	2	Very much severe pain	8
Mild pain	3	Very Very much severe pain	9
Numbness	4	Intolerable	10
Average pain	5		

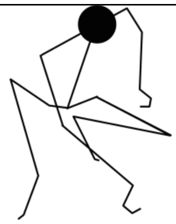
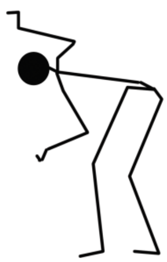
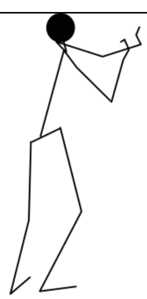
Table.5 Feeling of discomfort during, after work and during sleep

Tasks	Number of subjects (n)	Subjects affected	During work	After work	During sleep
Painting	10	10 (100%)	2 (20%)	5 (50%)	7 (70%)
Stone Cutting	11	11 (100%)	2 (18.18%)	4 (36.36%)	6 (54.55%)
Manual Piling	11	11 (100%)	1 (9.09%)	5 (45.45%)	5 (45.45%)
Carpenting	11	11 (100%)	2 (18.18%)	5 (45.45%)	6 (54.55%)
Plaster work	15	15 (100%)	3 (20%)	5 (33.33)	7 (46.67%)
Plumbing	12	12 (100%)	2 (16.67%)	3 (25%)	7 (58.33)

Fig.1 Analysis of working postures of workers engaged in carpenting, manual pilling, plaster work, plumbing, stone cutting and painting

Activity	Posture	Description of posture	Duration (as per SI scale)	Frequency (as per SI scale)	Duration of exertion as per percentage of work cycle (based on SI scale)	Remarks
Carpenting		Forward back bending, Both arms below the shoulder level and bending of both the knees	4-8 hours	15-19times/min	>80 of cycle	Hazardous and very high risk, investigate, implement change
Carpenting		Forward back bending, both arms below the shoulder level and bending of both the knees	4-8 hours	15-19times/min	>80 of cycle	Hazardous and very high risk, investigate, implement change
Carpenting		Squatting posture, forward back bending, both arms below the shoulder level and bending of both	4-8 hours	>20times/min	>80 of cycle	Hazardous and very high risk, investigate, implement change

		the knees				
Carpenting		Forward back bending, right arm above the shoulder level, left arm below the shoulder level and bending of both the knees	4-8 hours	>20 times/min	>80 of cycle	Hazardous and very high risk, investigate, implement change
Manual pilling		Side bending of back, both arms below the shoulder level and bending of both the knees	4-8 hours	15-19times/min	50-79% of cycle	Hazardous and very high risk, investigate, implement change
Manual pilling		Squatting posture, forward back bending, both arms below the shoulder level and bending of both the knees	2-4 hours	>20 times/min	50-79% of cycle	Hazardous and very high risk, investigate, implement change
Plaster work		Forward back bending, both arms below the shoulder level and bending of both the knees	4-8 hours	>20 times/min	50-79% of cycle	Hazardous and very high risk, investigate, implement change
Plaster work		Squatting posture, forward back bending, both arms below the shoulder level and bending of both the knees	4-8 hours	15-19times/min	<10% of cycle	Hazardous and ery high risk, investigate, implement change

Plaster work		Squatting posture, forward back bending, both arms below the shoulder level and bending of both the knees	4-8 hours	15-19times/min	50-79% of cycle	Hazardous and very high risk, investigate, implement change
Plaster work		Forward back bending, Both arms below the shoulder level and bending of both the knees	4-8 hours	9-14 times/min	30-49% of cycle	Hazardous and very high risk, investigate, implement change
Plaster work		Forward back bending, Right arm below the shoulder level , left lower arm above the shoulder level and bending of both the knees	4-8 hours	15-19times/min	30-49% of cycle	Hazardous and very high risk, investigate, implement change
Plumbing		Forward back bending, Left arm above the shoulder level and bending of both the knees	4-8 hours	>20 times/min	>80 of cycle	Hazardous and very high risk, investigate, implement change
Stone cutting		Squatting posture, forward back bending, both arms below the shoulder level and bending of both the knees	4-8 hours	<4 times/min	10-29% of cycle	Uncertain and very high risk, investigate, implement change
		Squatting posture, side	4-8 hours	>20 times/min	50-79% of cycle	Hazardous and high risk,

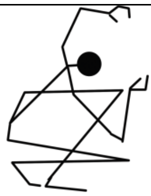
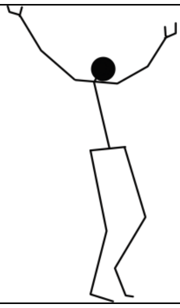
Painting		bending of back, right arm and left lower arm above the shoulder level and bending of both the knees				investigate, implement change
Painting		Backward back bending, both arms above the shoulder level and bending of both the knees	4-8 hours	>20 times/min	50-79% of cycle	Hazardous and very high risk, investigate, implement change

Fig.2

Figure 2: Mean perceived exertion of painter, plumber, carpenter, stone cutter, manual piler, plaster worker according to Borg's rated perceived exertion (RPE) scale

It was found that the repetitive monotask posture assumed by the workers for prolonged period of time performed at a high speed was hazardous and required implementation of revision. According to the Moore and Garg or Strain Index of the task, painting was identified to be most strenuous job. All other tasks like stone cutting, carpenting, plastering, manual piling, plumbing that were considered, transcended the safe limit (had strain index score higher than 7) significantly. Rapid Entire Body Assessment for the posture assumed while performing the selected tasks were done. The cumulative score based on forceful exertion, position of each body part, repetition, and coupling was obtained. It revealed that all of the postures required further investigation and ergonomic intervention. Postures associated with painting and plastering was identified to be most alarmingly hazardous. The risks for developing work related musculoskeletal disorder were aggravated due to combined effect of awkward posture assumed while task performance and the strain associated with the task.

The workers performed a particular task and the pain experienced by them were recorded. A task specific pain map was prepared. Pain was mostly observed to affect the back region especially lower back probably due to heavy spinal loading over an extensive period. Pain was also observed in the neck, shoulder, upper arm, and lower limbs due to their awkward alignment while performing the task. Prevalence of pain was also high at the wrist region of lower arm, probably due to high rate of monotask repetition.

The identification of work load category was done on the basis of the recorded perceived exertion. While most tasks were identified to be ‘somewhat hard’, but painting was identified to be ‘hard and heavy’ complying with the both REBA and strain index score.

Physical work load was evaluated by analyzing angular deviation of body segment from neutral posture, repetitive hand wrist movement; recurring and forceful exertion; increased muscle load over duration. The evaluated distal upper extremity intensive tasks require extensive modification and ergonomic intervention. The tool design, organization of work station and the job design also require changes to reduce the potential risks associated with these jobs by eliminating hazardous postures. Alteration in work rest cycles, rescheduling task specific working hours per day, or frequent short breaks may improve performance and probably productivity. Job rotation for the workers performing monotask may also be helpful. Most of the workers at the construction site are subjected to heat stress and sweat extensively. Frequent fluid replenishment may be an important implementation to mitigate the immense water loss and delay the onset of fatigue. As cumulative effect of the aforementioned remedial measures, pain and injury related absenteeism may be reduced; safety of the workplaces, productivity and quality of life can be increased.

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