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International Journal of Current Research
Vol. 8, Issue, 10, pp.40639-40643, October, 2016

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

Evaluation of cardiac strain among workers associated with upper extremity intensive jobs at construction sites of West Bengal, India

Prasenjit Saha, Bibaswan Basu, Koumi Dutta and Devashish Sen

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

ARTICLE INFO

Article History:
Received 23rd July, 2016
Received in revised form
08th August, 2016
Accepted 14th September, 2016
Published online 30th October, 2016

Key words:
Construction industry,
Upper Extremity Intensive jobs,
Monotask, Cardiac strain,
Physiological work load.

ABSTRACT

The construction work represents a major unorganized sector and involves large number of manual labour. Predominantly upper extremity intensive tasks at construction sites are repetitively performed monotask which are more hazardous than multitask. This study aimed to evaluate task specific cardiac strain among workers associated with painting, stone cutting, manual piling, carpenting, plastering, plumbing which involve upper extremity intensive activity. Working Heart Rate (WHR), recovery rate pattern and Working Oral Temperature (WOT) were measured to determine the heaviness of the job. Net Cardiac Costs (NCC), Percent of Heart Rate Reserve (% HRR) were also considered to assess the work load. Thermal stress was evaluated by using Wet Bulb Globe Temperature (WBGT) index. The mean values of WHR for all the tasks were higher than the optimum value. The mean values of WHR, NCC and %HRR were highest in painting followed by carpenting and manual piling. The recovery was unsatisfactory for all the tasks. Appreciable rise in WOT was observed in all the tasks especially in painting, stone cutting and manual piling. Mean WBGT was higher than the recommended range. Job rotation, proper work rest cycle may help the worker to reduce cardiac strain and improve the quality of life.

Citation: Prasenjit Saha, Bibaswan Basu, Koumi Dutta and Devashish Sen, 2016. "Evaluation of cardiac strain among workers associated with upper extremity intensive jobs at construction sites of West Bengal, India", *International Journal of Current Research*, 8, (10), 40639-40643.

INTRODUCTION

Industrialization and urbanization have led to rapid flourish in Construction Industry. Various technological transformation and introduction of automated tools and mechanized work process has significantly reduced manual labour to a great extent. In India, about 340 million workers are occupationally engaged in unorganized sector and about half of them involved in construction industry (NCEUS, 2006; Das, 2007; Ramesh, 2009; Cross National Policy Exchange: Asia Social Protection Papers, 2009; Rajasekhar *et al*., 2009). In India it is the second largest economic activity after agriculture (A report by G20 training strategy, International labor office GENEVA. 2010). Involvement of large population of manual labour, adverse working environment, lack of job security, socioeconomic constraints in the construction industry (Tiwary and Gangopadhyay, 2011; Abdelhamid and Everett, 2002; Bouchard and Trudeau, 2008; Biswas *et al*., 2012) have made this sector an epicenter of investigation.

***Corresponding author: Devashish Sen,**
Ergonomics, Work Physiology, Occupational Health Management Laboratory, Department of Life Sciences, Presidency University, Kolkata, India.

Moreover the jobs in construction industry are highly physically demanding and musculo skeletal pain is highly prevalent among the workers (Boschman *et al*., 2012). Several work physiological studies have been conducted by various researchers who observed higher rates of disability, decrease in muscle strength and lowered physical function in jobs with high degree of physical demands (Russo *et al*., 2006; Cassou *et al*., 1992; Li and Wen, 2000). In construction sectors manual labours are engaged in wide range of occupation which include both dynamic manual material handling and static repetitive upper extremity intensive monotask. Cardiac strain and prevalence of MSD have been extensively evaluated, but a task specific work stress and physiological strain assessment among workers engaged in upper extremity intensive jobs in this sector are of significant importance. Studies showed that performance of mono task may be more hazardous than carry out multitask throughout the day (Drinkaus *et al*., 2005). Cardiac strain in case of upper extremity intensive tasks increases at same absolute intensity as leg intensive tasks of similar workload (Astrand *et al*., 1968). Brouha found in large scale field studies that measuring Heart Rate reactions is the most direct and simple method available for evaluating job stress. Pulse rate recording reflects quiet accurately the cardiovascular reactions during wide variety of muscular activity and at the same time measuring blood pressure and cardiac output are quiet impractical (Brouha, 1960). Numerous studies revealed that heart rate palpation does not significantly differ from monitored post exercise heart rate Couldry *et al*., 1982; DeVan *et al*., 2005; Kosiek *et al*., 1998; Pollock *et al*., 1972 and Sharpe, 1996). The recovery pulse rate pattern gives information about the amount of physiological stress and physical aptitude for a specific task (Johnson *et al*., 1942). In tropical country like India, workers are not only exposed to work stress but also subjected to environmental heat load which is a prime contributory factor to increase their job stress (Ramphal, 2000). The objective of this study was to assess physiological strain of the upper extremity intensive workers with relation to specific task and working postures.

MATERIALS AND METHODS

Construction workers participated in this study either signed or gave their left thumb impression on consent letter. Data collection was performed strictly abiding by 'Institutional Ethical Committee (human)' guidelines and conforms to the recommendation from Declaration of Helsinki (1983).

Study Design

70 male construction workers engaged in Distal Upper Extremity intensive tasks with a minimum five years of experience were selected from three different construction sites of Kolkata, West Bengal, India. The study was conducted on workers (age group 25-40years) involved in following six upper extremity intensive tasks:

Painting (n=10)
Stone cutting (n=11)
Manual piling (n=11)
Carpenting (n=11)
Plaster work (n=15)
Plumbing (n=12)

Workers were examined during April-May (summer). All the subjects volunteered for the study consumed food between 7-7.30 AM and started their work from 10AM for those days. All the resting physiological parameters were measured at the beginning of morning shift which was followed by 2-2.30 hours rest period after food intake. To standardize the experiment, the upper extremity intensive construction workers of all the six occupations performed their routine tasks for one hour and number of recordings was taken both during work and just immediately after the cessation of work cycle.

Physical Parameters

Height and weight of the workers were measured using Martin's anthropometer (Seiber and Heigner, Switzerland) and weighing machine (Libra, India) respectively. Body Mass Index (BMI) was obtained from height and weight data.

Resting Physiological Parameters

Heart rate and Oral Temperature were taken the principal physiological parameters measured at the beginning of morning shift. Resting Heart Rate was measured in seated posture by placing the stethoscope at the apex of the heart and the time taken for 30 minutes was recorded with stopwatch. Oral Temperature was measured by placing digital thermometer sublingually for three minutes. The subjects did not consume anything orally (hot or cold) two hours before the activity. Maximum Heart Rate (MHR) was obtained as the difference between 220 and age of the subjects in years. Heart Rate Reserve (HRR) was calculated as the difference between MHR and RHR.

Working Physiological Investigation

Working Heart Rate (WHR) was measured by placing the stethoscope at the apex of the heart by 10 beats methods. Heart rate reactions at work by this method is widely accepted and used by different Indians. Time required for 10 beats was measured with a stop watch which was finally expressed as beats/minute (Sensarma, 1975). Number of recordings was taken both during work and just immediately after the cessation of work cycle.

Working Oral Temparature

Oral Temperature was measured by placing digital thermometer sublingually for three minutes with minimum interference in the subjects' freedom of motion and work methods.

Recovery Heart Rate (RHR)

Recovery Heart Rate was measured in sitting posture at comfortable area by the standardized procedure (Brouha, 1960). These Recovery Heart Rates are called Recovery 1 (R1), Recovery 2 (R2), Recovery 3 3 (R3). R1, R2, R3 were measured by counting heart beats during the final 30 seconds of first, second and third minute after cessation of work ie., 30sec-1min, 1.30-2min, 2.30-3min. Apart from the above parameters, Net Cardiac Cost (NCC), Percent Heart Rate Reserve (% HRR) and Limit for Continuous Work (LCW) were considered as indicator of cardiac strain. NCC was evaluated as the difference between WHR and RHR. To depict the relative intensity of workload (relative cardiac cost), %HRR was taken into account. This is calculated as NCC/HRR*100 (American Heart Association, 1972., Trites *et al*., 1993). LCW was obtained by adding 30 beats with the worker's RHR (Costa *et al*., 1989).

Wet Bulb Globe Temparature Index: Heat stress was assessed using Wet Bulb Globe Temperature (WBGT) index (Yaglou and Minard, 1957).

Statistics: Statistical analysis was done in MS Excel 2010. Mean, Standard Deviation (SD) and percentage of different parameters were calculated.

RESULTS

Table 1 shows the physical characteristics and physiological data of the workers involved in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n=11), plaster work (n=15), plumbing (n=12). Table 2 shows mean and Standard Deviation (SD) of Working Heart Rate (WHR), Net Cardiac Costs (NCC), Percent Heart Rate Reserve (%HRR) and Recovery Heart Rate (R1, R2, R3) of workers engaged in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n-11), plaster work (n=15) and plumbing (n=12). According to a study (Brouha, 1953) the cumulative effect of the task and environmental stress should not create enough strain to cause heart rate to increase 110 beats/minute. This value was given as the optimum value for industrial workers for 8 hours jobs.

Table 1. Physical characteristic and physiological data 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)	Resting Heart Rate (beats/min)	Heart Rate Maximum (beats/min)	Heart Rate Reserve (beats/min)
	Mean (SD)	Mean (SD)	Mean (SD)	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)	70.6 (2.84)	187.2 (5.57)	116.6 (5.60)
Stone Cutting	31(4.69)	163.4 (5.77)	59.4 (6.16)	22.2 (1.72)	72.5 (5.47)	189 (4.69)	116.5 (8.63)
Manual Piling	32.3 (5.66)	161.1(9.72)	61.9(7.73)	24.3 (5.35)	73.3(2.57)	187.7(5.66)	114.5(6.25)
Carpenting	33(4.58)	161.8(3.40)	60.2(5.12)	23(2.58)	71.6(2.50)	187(4.58)	115.5(3.35)
Plaster work	32.9(5.58)	164.3(4.65)	57.6(10.77)	21.3(3.47)	72.4(4.42)	187.1(5.58)	114.7(8.17)
Plumbing	30 (5.16)	163.5 (4.58)	61 (4.85)	22.9 (1.85)	72.7 (4.13)	190 (5.16)	117.3 (6.63)

Table 2. Mean and Standard Deviation (SD) of Working Heart Rate (WHR), Net Cardiac Costs (NCC), Percent Heart Rate Reserve (%HRR) and Recovery Heart Rate (R1, R2, R3) of workers 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	n	WHR (beats/min)	NCC (beats)	% HRR (%)	Recovery Heart Rate (beats/min)		
					R1	R2	R3
Painting	10	127.6 (5.86)	57.0 (5.61)	49.1 (5.92)	114.6 (2.50)	107.4 (2.98)	93.2 (2.53)
Stone Cutting	11	113.8 (9.86)	41.4 (12.65)	35.2 (9.78)	104.9 (5.39)	97.5 (4.01)	93.3 (4.03)
Manual Piling	11	125.2 (8.03)	51.9 (9.15)	45.3 (6.89)	113.5 (5.59)	106 (4.65)	101.2 (3.87)
Carpenting	11	123.9 (10.88)	52.3 (11.76)	45.5 (11.26)	111.1 (3.51)	103.1 (3.02)	95.8 (3.16)
Plaster work	15	112.6 (6.39)	40.2 (8.00)	35.0 (6.79)	102.3 (3.10)	98.1 (2.88)	93.3 (2.84)
Plumbing	12	112.5 (10.23)	39.8 (9.87)	34.8 (9.40)	100.2 3.63	95.8 (3.74)	90.6 (3.04)

Table 3. Percentage of workers exceeding recommendation range of Limit for Continuous Work (LCW), Working Heart Rate (WHR), Percent Heart Rate Reserve (%HRR)

Task	n	>LCW Granjean (1988) WHO-(1969)	WHR >110 WHO, Saha *et al.* 1969	% HRR Lablache- Combier 1984	
				>35%	> 50%
Painting	10	100%	100%	100%	40%
Stone Cutting	11	72.73%	63.64%	63.64%	---------
Manual Piling	11	100%	100%	100%	9.09%
Carpenting	11	100%	100%	100%	18.18%
Plaster work	15	86.87%	80%	60%	--------
Plumber	12	66.67%	50%	50%	-------

Table 4. Mean and Standard Deviation (SD) of Resting Oral Temperature (ROT) and Working Oral Temperature (WOT) of workers 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	Resting Oral Temperature	Working Oral Temperature
Painting	97.1 (0.16)	98.3 (0.30)
Stone Cutting	96.8 (0.29)	97.9 (0.33)
Manual Piling	97.4 (0.32)	98.5 (0.41)
Carpenting	97.2 (0.19)	98.2 (0.19)
Plaster work	97.4 (0.37)	98.3 (0.32)
Plumbing	97.2 (0.19)	98.2 (0.19)

In this study the mean values of WHR for all tasks were higher than the optimum value. The mean value of WHR was highest in painting job followed by manual pilling and carpenting. RHR can be used as a tool for the assessment of physiological work load. The mean of three minutes recovery response (R, R2, R3) are summated in Table 2. According to a study (Brouha, 1960) the Recovery Heart Rate in third minute (R3) should be below 90 beats/minutes. According to this recovery pattern criterion, in all the tasks, the recovery was unsatisfactory as R3 were higher than 90 beats/minutes. Table 3 shows percentage of workers exceeding recommendation range of Limit for Continuous Work (LCW), Working Heart Rate (WHR), Percent Heart Rate Reserve (%HRR). This table depicts that 100% of the workers involved in painting, manual piling, carpenting exceeded the recommended limit for continuous work (Grandjean, 1988) and (WHO, 1969). On the basis of Working Heart Rate as proposed by WHO Saha *et al* and % HRR as recommended by Lablache- Combier 1984 similar trends were observed. Table 4 shows mean and Standard Deviation (SD) of Resting Oral Temperature (ROT) and Working Oral Temperature (WOT) of workers engaged in painting (n=10), stone cutting (n=11), manual pilling (n=11), carpenting (n-11), plaster work (n=15) and plumbing (n=12). In this study it has been observed that there was an appreciable rise in Oral Temperature during work in all the tasks especially for painting, stone cutting and manual piling; average rise varying from 0.9° to 1.1° F. WBGT of 25°-25.9° C has been recommended for 'heavy and continuous' task with 75% work and 25% in each hour (ACGIH, 2000). From this study it appeared that the mean WBGT (32.5° C) was higher the recommended range and imposed thermal load on the workers.

DISCUSSION

Assessment of physiological strain of the workers engaged in Upper Extremity Intensive tasks with reference to thermal load have been done in this study. Christensen (1953) classified the heaviness grades of muscular tasks on the basis of various parameters like Working Heart Rate, Energy Expenditure, sweat rate etc ranging from light to unduly heavy. Several other studies have showed that high level of risks for MSD and physical workload are associated with Manual Material Handling, repetitive movements and awkward static posture (Intaranont and Vanwonterghem, 1993). Excessive physiological workload and heat stress have been recognized contributory factors which could lead to sudden unexplained death syndrome (Gogh, 1990). The physiological strain as evaluated from physiological responses viz., Working Heart Rate, Oral Temperature and Recovery Heart Rate pattern was heavy and severe in most tasks. Upper Extremity Intensive workers are exposed to prolong awkward static posture, repetitive monotonous activity and perennially susceptible to pain, fatigue and injury (Tiwary and Gangopadhyay, 2011; Abdelhamid and Everett, 2002). Being a labour-intensive sector, the building construction industry thrives on the massive physiological strain of the workers (Tiwary and Gangopadhyay, 2011). Adverse health effects including increased heart rate and oxygen consumption have been observed to be associated with various awkward postures ((Intaranont and Vanwonterghem, 1993). Evaluation of physiological work load in Upper Extremity Intensive workers revealed that the tasks require immediate ergonomic interventions and extensive modifications. Special focus should be given on ergonomic tool design, job rotation and scheduled rest pauses to reduce physiological strain associated with Upper Extremity Intensive monotasks.

Acknowledgement

We would like to acknowledge all the construction workers who volunteered as subjects in the study.

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