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Assessment Of Cardiovascular Risk Of Manual Labors Working In Brass Casting Industry, In Raipur District Chhattisgarh.

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Abstract:
***Background**: Work physiology and ergonomics are applied in workplace to preserve the health efficiency, without putting burden on productivity by identifying and controlling workplace stressors. Manual labor is widely used in small-scale unorganized industrial workplace especially in developing countries like India. Hence the workforce employed in these sectors is exposed to daily physical stress. In occupational health practices, work physiological studies are employed for the assessment of energetic load and cardiovascular strain involved in a job. Studies have been conducted on many occupations like confectionery workers, inland fishing task and tea plantation workers. However in context of vast number of manual jobs, many occupations still exist in which the physical stress of the work is yet to be explored. The present study intended to evaluate physiological workload in small scale brass casting works, in accordance the cardiac strain of the workers are assessed in actual situation.*
***Materials and Methods:** The study was conducted on workers involved in brass casting in district Raipur in state of Chhattisgarh. A total of 61 male adult workers with mean age of 37.6±11.5 years and involved in regular employment were recruited for the study. Working heart rate, net cardiac cost, relative cardiac cost and recovery heart rates were determined. Tasks performed were analyzed in term of recommended strain level and thermal stress of the workplace.*
***Results**: The nature of the work was static. Overall the job appeared to be moderate in nature with mean working heart rate of 100±5.2beats /min. Majority of the workers showed inadequate recovery heart rate. The thermal stress prevailing was more than the recommend level.*
***Conclusion:** The workers were highly exposed to cumulative circulatory stress which might in long term have a deleterious effect particularly on older workers. Hence ergonomic intervention is required to ameliorate ergonomic stressors, which indicated further scope of study.*
***Key Word:** Brass casting, cardiac strain, heat stress, recovery heart rate, working heart rate.*

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I. Introduction

Stress is a collective factor that taxes the physiological system in turn resulting to strain. The physiological compensatory mechanisms to ultimately overcome stressful condition are collectively term as strain. In the unorganized industrial, sector especially in developing countries like India, majority of manual labor is still obligatory. Occupational health and safety awareness lacks among the workers especially in unorganized industrial sectors. The dismal socio-economic – cultural and nutritional status often compounds the effect and makes the workers vulnerable to various occupational diseases. Manual labor or physical workload is the most common stressors in a workplace commonly causing cardiovascular strain, reflected by increased heart rate and blood pressure. Chronic increases in blood pressure heart rate have been identified as potential risk factors for cardiovascular mortality [1, 2]. The average working and recovery heart rate (heart rate at the end of the work) are used as biomarker to identify the intensity of workload [3]. The present study scenario is a field based study, intending to report the work strain involved in small scale brass casting factory representing one of the informal sectors.

The present study aims are:–
1. Physiological evaluation of work load in terms of heart rate.
2. Evaluating cardiac strain indices in relation to thermal stress.

II. Material And Methods

This is a non-experimental observational cross-sectional study, conducted in Raipur district of state Chhattisgarh, India during the month of August to October 2023.

Study design: Non-experimental observational cross-sectional study method was employed.
Study Location: In the district of Raipur.
Study Duration: Total duration of the study spanned three months and was conducted during the month of August to October 2023.

Selection of subjects:
Inclusion criteria- The subject must be willing to participate in the study as per the design of the study. The subject must be involved in the profession full time with a minimum work experience of five years. The subject should not be suffering from any current diagnosed illness.
Exclusion criteria: - Subjects below eighteen years and above sixty years were excluded.

Sample size estimation:-
A total of 78 subjects were selected from eight different small scale brass casting factories around Raipur district of Chhattisgarh. The workshop of the factories were similar in terms of their total number of workers , daily production , wages paid to workers, size of the working area and working methods. The entire tasks in these factories were performed manually. The workshops were located on the ground floor.

If the population proportion of 50% is considered, a margin of error of 15% and assuming a confidence level of 95%, the minimum calculated sample size for a finite population size of 78 workers was estimated to be 28. Considering an attrition rate of 15%, the final minimum sample size was calculated to be 32 subjects. Initially we have selected 78 subjects according to the study design of the study. Seventeen subjects declined to participates in this selected group, and finally 61 workers were selected, which was more than the minimum estimated sample size.
All the subjects were male

Methodology:
Description of the workplace and task:

Each workshop has a furnace known as "Bhatti" in local language, where brass ingots were melted at a temperature at around 650 degree centigrade. The job involved the production of various parts of machine by brass casting. Mould box is layered with either casting sand or charcoal dust for lubrication and thermal buffering purpose. Fine sands were used for the purpose and to ensure all sand lumps were broken, the sand was finely sieved prior to each cast box preparation. The molten brass metal was then poured with a ladle in the casting box through sprues. The molten brass the gradually solidifies to produce the cast of desire shape. Once the metal solidifies the box was open and the cast replaced and charcoal dust was dispersed. The sprues were removed with hacksaw and the casting was given a finishing touch by drilling, saw filling and polishing.

The steps of various tasks that were associated with this operation are as follows
1. Casting box preparation.
2. Dusting and filtering the casting sand
3. Handling the brass bar
4. Operating the furnace including heating and cleaning.
5. Product finishing.

The workshops have corrugated tin rooftop and no windows for ventilation. At a corner of the room a part of the floor was dug up and surrounded by furnace bricks that were used as a furnace for melting brass ingots.

Two subjects on an average were observed each day by the researchers. It was ensured that all the subjects were regularly involved in their job for at least one week before the study.

Working heart rate (WHR) was measured during steady state of work by obtaining the time of 10 inter-beat intervals of radial pulses using an electronic stopwatch.

Recovery Heart Rate (RHR) was measured in a sitting posture. This was obtained by counting the pulse during the last 30 seconds of each minute in the first, second and third minute of the recovery period, i.e.

from 30 sec to 1 minute after work stops (RHR 1), from 1½ -2 minute (RHR 2) and again from 2½ -3 minute (RHR 3). Index of pulse deceleration (PDI) was calculated as RHR1- RHR3.

The following criteria were used for classification of the recovery pattern. [4]
i) PDI = 10 beats/min and all recovery heart rates below 90, then recovery is normal.
ii) PDI 90 beats/min, then it is considered as no recovery.
The maximal heart rate (HRM): This was estimated according to the prediction equation of Tanaka as HRM=207-0.7(age in years) [5].
Heart rate reserve (HRR): This was calculated as the difference between the maximal and resting Hrs.

Cardiac strain Indices: Net Cardiac Cost (NCC) and Relative Cardiac Cost (RCC) were used as indicators of the cardiac strain and were derived from the working hear rate (WHR) using the values of the Recovery heart rate (RHR), maximum heart rate (HRM) , and the heart rate reserve (HRR) of the subjects. [6-7].These indices give a better estimation of the physiological workload.

The net cardiac cost (NCC) was calculated as the difference between the working heart rate (WHR) and Recovery heart rate (RHR), and the Relative Cardiac Cost (RCC) was calculated by the formula:
RCC= (NCC/HRR) X 100, where HRR is the HR reserve of the subjects

Responses were judged in terms of recommended limits of net cardiac cost and relative cardiac cost, acceptable level of working heart rate and relative aerobic cost, [8] pulse deceleration index and limit of continuous work. [9]

Different environmental parameters viz., natural wet bulb temperature (NWB) and globe temperature (GT) were measured and Wet Bulb Globe Temperature (WBGT) were worked out as an index of heat stress using the equation applicable for indoor environment as follows: WBGT = 0.7 X NWB + 0.3 GT. [10]

Each subject was examined throughout a random habitual work shift whilst he was regularly engaged in his work. During the study, the workers maintained their usual work pattern, work-rest regimen and work pace. No instructions were given to them to control their work method. Measurements were taken as quickly as possible without disturbing the normal work pace of the subjects.

Statistical analysis:

Mean ±SD of different physical characteristics and cardiac profile was obtained by using by using SPSS 16 software.

III. Result

Physical characteristics and some cardiac profile of the subjects are presented in table no1. The mean height and weight could be compared with average Indian standard. However, for five subjects BMI was less than 18 kg/m2 which is considered as energy deficient state. [11]

Table No 1: Physical characteristics and cardiac profile of the subjects.

Parameters	Mean	SD	Minimum	Maximum
Age(years)	37.6	11.5	22	55
Height(cm)	156.2	5.4	153.2	159.2
Weight(kg)	65.3	9.8	52	70
Body Surface Area (m^2)	1.47	0.8	1.32	1.52
Body Mass Index(kg/m^2)	21.3	3.8	18.8	35.2
Resting heart rate(beats/min)	78.2	5.8	65	78
Systolic blood pressure(mm -Hg)	128	12.6	118	130
Diastolic blood pressure(mm-Hg)	92	10.5	85	96
Working Experience(years)	15	6.2	6	37
Maximum heart rate(beats/min)	180.2	8.5	160	195
Hr reserve(beats/min)	97.3	10.8	85	129

Quantification of daily workload in terms of major work periods is summarized in table no 2.

Table No 2: Duration of major work periods

Work period	Mean	SD	Percentage of total work shift
Total shift(hrs)	8.4	0.4	--
Total productive period(hrs)	6.2	0.4	72.2

Total rest period(hrs)	1.8	0.3	21.6
Nonspecific rest pauses (min)	42	5.6	8.6
Specific rest pauses (min)	58	11.2	11.6

The total duration of work shift ranged between 8 and 9 hours as obtained in different work days. Productive hours were calculated as the difference between total work shift and rest periods. Non specific periods include pauses, delay times and time spent in non- specific activities, including gossiping, smoking, toilet etc. Specific rest pauses include time spent for lunch and snacks. The total duration of specific and non – specific periods were categorized as periods of rest and work pauses.

Table No 3: Duration of different tasks.

Tasks	N= no of workers	Duration(hrs)	% of total work period
Cast box preparation	29	5	47
Sand handling	31	2.9	30
Metal handling	42	1.8	15
Furnace operation	30	5.2	59
Product finishing	22	4.8	55

It was observed that a single worker performs two or three tasks. Therefore combining the work pattern of all the subjects for different tasks, a wide variability was obtained in the duration of different task which is conspicuous in table no 3. However the time required for furnace operation was almost similar and accounts for half of the total work shift. This was due to the fact that this was considered as a specialized operation and performed by skilled worker throughout the shift while for other activities the tasks were distributed among the workers.

Table No 4: Cardiac strain in different activities.

Tasks	Duration Mean(hrs) As percentage of total shift	Working Heart Rate (beats per min)	Net Cardiac Cost (beats per min)	Relative cardiac cost (%)
Cast box preparation(n=8)	68	87±3.4	12±3.6	11±2.5
Sand handling(n=7)	67	90±2.8	18±2.1	14±3.2
Metal handling(n=6)	22	100 ±4.6	27±5.4	21±2.7
Furnace operation(n=7)	59	112 ±4.6	42±4.3	39±4.2
Product finishing(n=7)	61	103 ±3.3	24±4.7	21±2.9
All activities(n=17)	82	100±5.2	24±6.5	22±6.7

The cardiac response for different tasks and as well as for all activities is presented in the table no 4. The cardiac response for a particular task was obtained by clustering the response of the workers who spent maximum time period for that particular task in the whole work shift. The average time spend in the different activities is also thus mentioned in the table and expressed as percentage of the total work shift.

The average heart rate for all activities was 100 beats/min .Working heart rate for different tasks ranged between 87 -112 beats /min. with a relative cardiac cost between 11% and 39% with corresponding net cardiac cost between 12 and 42 beats / min. Response were lowest in cast making and sand handling while highest in furnace operation.

The physical stress level involved in different tasks was also judge in relation to the referred limits of certain cardiac strain indices and percentage of workers exceeding those limits for a particular task as presented in table no. 5.

Table No 5: Percentage of workers exceeding recommended limits of strain indices.

Tasks	Strain indices and recommended levels			
	Limit of continuous work= (resting pulse+35beats)	WHR >110beats per min Working heart rate	NCC >30beats per min Net cardiac cost	RCC >30% Relative Cardiac Cost
Cast box preparation	--	--	--	--
Sand handling	--	--	--	--
Metal handling	--	18 %	18%	-
Furnace operation	88%	88%	102%	102%
Product finishing	13%	-	13%	--

The mean of 1^{st}. 2^{nd} and 3^{rd} recovery heart rates were 102.5±10.5, 98.2±12.4 and 94.7±10.4 beats/min respectively. The mean pulse deceleration Index (PDI) was -5.8±4.5.
A total of 58% of worker showed no recovery pattern.

The mean values of wet bulb temperature and globe temperature obtained across all hourly readings in all work days were 87.2±5.4 degree Fahrenheit and 103±4.5 degree Fahrenheit respectively. The WBGT was obtained as 88.8 ±5.2 degree Fahrenheit.

IV. Discussion

The current study was conducted in a real work situation. The primary objective was to obtain the cardiac strain of the workers in responses to different workplace stressors. Heart rate was chosen as the principal parameter because it provides as integrated response to thermal stress, energy requirement and postural demand [12, 13]

Study observations on methods of work revealed that work performed by the workers were predominant static muscular efforts. Majority of the task performed were in sitting posture. Bending and twisting of trunk were observed in cast making, metal bar handling and product finishing. Frequent upper arm movement was observed in sand sieving and furnace bellowing.

Heaviness of different tasks of casting work could be judged in accordance with the scale of heaviness based on working heart rate. [14] The mean heart rate for all activities was 100 beats / min. Thus the overall physical strain of recovery heart rate pattern in Indian context also entitled casting work as a 'moderate' categorized job in nature. [15]

When individual task is consider, the heart rate reactions in casting making confirmed the job to be light, while sand handling, metal bars and product finishing could be classified as moderate intensity tasks. Furnace operation appeared to be heavy in accordance with this heart rate scale.

The values of working heart rate and relative cardiac costs of casting workers could be compared with fisherman engaged in different inland fishing activities like net pulling and catch handling [16- 17] Similar hear rates were obtained in women agriculture workers involved in reaping binding and threshing activities [18] .and confectionary workers involved in sweet making [19].

In the present study the cardiac strain were lower as compared to the physical strain of underground miners engaged in shoveling, drilling and carrying activates [20,21]

The recommended average aerobic strain of 35% with corresponding heart rate of 110 beats per min was suggested as the limit of acceptable work load in Indian context for an 8 hours work period. [8].

From table 5 of result section it can be stated that majority of the workers exceeded the limits cardiac strain during furnace operation; a mild percentage exceeded the limits in metal bar handling and product finishing. In cast preparation and sand handling responses were all within limits.

As per Rutenfranz the acceptable level for a mixed dynamic and static work was considered as 41% of VO_2 max and Evans suggested 45% VO_2 max for self-paced sustained physical work of 1-2 hour's duration .In the present study, none of these limits were exceeded.[22,23]

Thus it could be suggested that the workers were within an adequate safety margin. In this study, it was observed that the workers maintained their own pace and rest cycle. It is also expected that this self-chosen work pace represented an intensity which was subjectively optimal for different tasks.

The recovery hear rate for the majority of the workers were inadequate. Thermal stress of the workplace was the second major factor. For moderate task WBGT of 27.5 -28.5.c with work periods ranging from 100% to 75% of total work shift have been recommended for acclimatizes worker [24]. In this present study the subjects as they have full time involvement and have a work experience of minimum of five years they may be considered as acclimatized workers.

The subjects were regularly involved in their job for at least one week prior to this study.

From the work –rest regimen of the workers throughout the shift, it appeared that the mean WBGT of 87.2 degree Fahrenheit was above the recommended range and had imposed a considerable amount of thermal load on the workers.

A previous study in die-casting activity found that heat stress and exposure duration impose significant effect on human performance.31, this effect was also reflected in our study. Inadequate recovery of heart rate as obtained in the present study could be attributed to the thermal stress along with the static work load as indicated in some earlier studies [25, 26].

The slow recovery also pointed to the insufficiency of cardiovascular capacity as reported earlier [27,28]. Therefore it appears the subjects in this study were exposed to cumulative circulatory stress, which can be a serious health threat particularly for the older working population. From the present study results it may be suggested that the furnace operation might not be suitable for workers above 40 years of age.

In the present study from the study result it is strongly believed that the workers were ignorant about the balance between the job demand and work ability, which may be attributed to the lack of awareness on health and safety issues. Moreover the dismal socioeconomic status compelled the workers to be least concerned for their health and working situation.

V. Conclusion

Since job of casting as observed in the present study involved high degree of static effort and moderately heavy in job, care should be taken to reduce the cumulative effect of heat and ergonomic stressors in order to prevent cumulative fatigue and long term effect.

In this context, a community based occupational health and safety awareness program focused on unorganized workers is essential to make workers appreciate their work condition and to improve their health and safety at workplace. Ergonomic stressors of the work place may be reduced by good house-keeping, furnace shielding, better provision for ventilation, arrangement of work seats and awareness training for the workers can be possible remedial measures.

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