

## **CARDIOVASCULAR LOAD ASSESSMENT OF COAL MINE SHOVELERS IN WEST BENGAL, INDIA: A COMPARISON BETWEEN MIDDLE AGE GROUPS**

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Cardiovascular load of underground shovelers was assessed in terms of heart rate changes at work in haulage coalmines. Twenty underground shovelers of two different age groups (those of age 31-39 and those of age 40-49) served as subjects. Working heart rate was significantly higher ( $p < 0.01$ ) in the older group (138.2 beats/min) than in the younger group (130.4 beats/min). Though the net cardiac cost did not differ significantly between the groups (64.8 beats/min and 69.4 beats/min in younger and older groups, respectively), difference in the relative cardiac cost (54.17% and 64.86% in younger and older groups, respectively) proved to be highly significant ( $p < 0.001$ ). The heart rate up to the third minute of recovery showed significant differences between the groups ( $p < 0.01$ ). While analysis of physiological responses indicated that the task was very strenuous irrespective of age, cardiac strain was found to be more excessive in the older subjects if continued. The arduous nature of the working environment in the coalfaces was also reported.

**Key words:** underground shoveling; heart rate; recovery period; coal mine.

### INTRODUCTION

While presently the overall load of physical work performed in coal mines has been reduced, many unique physical and environmental demands still exist (Gallagher, 1999). Even though the mechanization in mining industry in India has made its inroads, the need for muscular power and manual tools such as shovels is still highly evident in the task of coal removal in underground mines where the nature of work together with their environments unquestionably puts a lot of physiological stress on workers. Mincheva (1986) observed the work capacity of coal miners decreased with age. Since the workers in a gang have to do the same type of activity, aging is bound to have an added effect on their health.

In India, however, few studies have reported on work stress evaluation of underground coal miners. Therefore, the present study was conducted to evaluate the physiological workload along with the trend of recovery patterns in coal miners working in underground coalfaces.

### METHODS

#### *Subjects and tasks done*

Twenty male shovelers chosen from the Raniganj coal belt of Eastern Coalfields, West Bengal, India served as subjects. Those with any symptoms or clinical signs of cardiovascular, musculoskeletal or neurological disorders were excluded. Of the 20 subjects, 10 were in their 40s, and the other 10

were in their 30s in age. Table 1 shows their physical characteristics.

The workers in the coal mine were "piece-rated" (wages proportional to coal lifting) with respect to groups, comprising two shovelers and two carriers. They carried out the task in phases ( $49 \pm 9.35$  minutes) till the basket assigned for them were filled up. It was seen that the shovelers usually scooped 8-10 times to fill up one basket during the working period. The weight of each coal-loaded basket and scoop was found to be 55-65 kg and 5.5-7.0 kg, respectively.

Table 1. Physical characteristics of the subjects. Values are given in mean  $\pm$  SD.

Age group	Age (years)	Height (cm)	Weight (kg)	Resting HR (beats/min)	Experience (years)
31-39 yrs (n=10)	32.9 $\pm 2.2$	166.5 $\pm 5.2$	57.0 $\pm 5.6$	63.4 $\pm 4.3$	12.7 $\pm 2.3$
40-49 yrs (n=10)	43.9 $\pm 2.2$	163.0 $\pm 4.7$	53.7 $\pm 8.7$	68.8 $\pm 3.3$	22.4 $\pm 2.8$

#### *Measurements of somatic, behavioral, and environmental variables*

Measurements of heart rate were achieved by monitoring time for 10 beats by means of a stethoscope. The resting heart rate was taken after allowing the subject in a comfortably reclining position at least for 30 minutes prior to their day's work at the surface. The working heart rate (WHR) was determined at two-minute intervals throughout the working phase. Maximum heart rate was computed based on the recommendation proposed by the American Heart Association whereas recovery heart rate (RHR) was measured during the last 30 seconds in each minute of the recovery time for a period of 3 minutes (Brouha, 1960). Net cardiac cost (NCC) was obtained in beats/min as the difference of working and resting heart rate of the subjects. To depict the relative intensity of workload, relative cardiac cost (RCC) at a given workload was calculated as the percentage of NCC against the heart rate reserve (HRR) of a particular individual, HRR being the difference between maximal and resting heart rates. The rate of shoveling (scoops/minute) was calculated after noting down the number of scoops to fill up one basket and the time taken for it for each individual during the period of activity.

Dry bulb temperature (DB), wet bulb temperature (WB), natural wet bulb temperature (nWB) and air velocity were recorded as environmental variables. Subsequently, effective temperature (ET) and wet bulb globe temperature (WBGT) values were obtained as an index to get an average picture of the ambient conditions in which the miners were working.

## RESULTS AND DISCUSSION

The rate of shoveling was found to be 20 scoops/min and 22 scoops/min for the older and younger groups, respectively (Table 2), which were substantially above the generally recommended limits of scooping rate even for the duration of less than one hour. The difference between the age groups was statistically insignificant.

The physical strain experienced by two shovelers of different age groups during a phase of 55 minutes is depicted in Figure 1. A gradually increasing trend along with occasional fluctuations in heart rate was evident for both subjects. While the incidental declines in heart rate appeared to indicate the self-pace nature of the workers, the rebounds in heart rate were presumably due to static muscular components involved in shoveling, e. g. prolonged standing and stooping forward along with bending sidewise during scooping of loaded coal to the basket. It is notable that heart rate tended to be somewhat higher in average in the older subject than in the younger subject, despite the fact that, as mentioned above, the rate of shoveling was not significantly different between the age groups.

Table 2. Comparison of cardiovascular variables between the age groups.

Variables	Age 31-39 (n=10)		Age 40-49 (n=10)		<i>t</i> -test
	Mean	SD	Mean	SD	
Working heart rate (beats/min)	130.4	5.0	138.2	6.7	<i>p</i> < 0.01
Net cardiac cost (beats/min)	67.0	5.9	69.4	4.5	Not significant
Heart rate reserve (beats/min)	123.7	5.1	107.3	5.0	<i>p</i> < 0.001
Relative cardiac cost (%)	54.2	4.4	64.9	6.0	<i>p</i> < 0.001
Recovery heart rate 1 (beats/min)	118.6	5.7	128.8	8.3	<i>p</i> < 0.01
Recovery heart rate 2 (beats/min)	113.6	7.4	124.8	7.6	<i>p</i> < 0.01
Recovery heart rate 3 (beats/min)	110.0	8.5	123.0	8.1	<i>p</i> < 0.01
Shoveling rate (scoop/min)	22.0	1.9	20.0	3.8	Not significant



Fig. 1. Heart rate patterns during and after shoveling work of two subjects different in age. Observation was made at 2-minute intervals.

Average physiological responses during work and recovery periods of the shoveling task are compared between the age groups in Table 2. Associated environmental conditions are presented in Table 3.

Table 3. Environmental conditions prevailing in underground shoveling. For abbreviations, see text.

Variables	Mean	SD	Range
nWB (°C)	31.0	0.7	29.5-32.5
DB (°C)	32.0	0.8	30.5-33.5
WB (°C)	30.5	0.6	29.5-31.5
Humidity (%)	89.5	1.6	85.0-93.0
Air velocity (m/sec)	0.3	0.07	0.22-0.50
ET (°C)	30.1	0.6	29.0-31.5
WBGT (°C)	31.3	0.7	30.0-32.8

The shoveling task was found to be 'very heavy' as the mean WHR was 138.2 beats/min and 130.4 beats/min for the older and younger groups, respectively. The difference between the groups was statistically significant ( $p < 0.01$ ). The peak heart rate was also found to be higher in older workers (150 beats/min) compared to younger individuals (140 beats/min), which is an indication of higher strain on older worker for a similar period of activity. While the NCC, 67.0 for younger and 69.4 for older group, pointed to the very heavy nature of the work again, the difference between the groups remained insignificant. The RCC values was also higher in older group (64.86 %) than in younger group (54.17 %) and the difference was statistically significant ( $p < 0.001$ ).

The DB ( $32.03 \pm 0.81$  °C) and WB ( $30.5 \pm 0.64$  °C) temperatures were found to be in the close ranges along with the very sluggish air movement ( $0.34 \pm 0.07$  m.sec<sup>-1</sup>) in coalfaces reflected the high humidity factor during work. ET and WBGT were found to be far higher than the permissible threshold values as proposed by the WHO and American Conference of Governmental Industrial Hygienists (ACGIH) for heavy type of workload. (ACGIH, 1981).

The mean RHR patterns suggested unsatisfied recovery for both groups indicating the extremely heavy nature of the shoveling tasks (Samanta et.al., 1984). The sustained and slow recovery patterns apparently related to the insufficient capacity of the workers for the job. The tasks were even more strenuous for the older workers since the RHRs for the first three minutes were significantly ( $p < 0.01$ ) higher in the older group than in the younger group. The trend indicated that the job would cause excessive cardiovascular strain if continued for the older workers since they had to work in groups for the completion of the assigned tasks. For the younger workers, it also showed an indication of impending strains under such poor environmental conditions.

## CONCLUSION

The high cardiac strains imposed on the coal mine shovelers in completing the task assigned was exhibited irrespective of their ages. The environmental conditions were a major area of concern and engineering controls could be implemented for improving the present situations. Since the older shovelers working in groups were forced to maintain the same pace as with younger counterparts, better teamwork arrangements along with a suitable rate of work appeared important for mitigating the strains. A more detailed study in conjunction with the work continued over a shift is necessary.

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