BLOOD LACTIC ACID IN DETERMINING THE HEAVINESS OF DIFFERENT MINING WORK

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Summary: This study includes investigation on 25 coal miners of different categories during their actual work underground in an Indian mine. The items of investigation are changes in (i) oxygen uptake, (ii) heart rate, (iii) oral temperature and (iv) blood lactic acid in work in comparison to condition at rest. Records have also been made about the thermal environment under which the work has been carried out. The results of the study have shown that changes in blood lactic acid follow the changes in oxygen uptake and therefore, can be used as index for determining the work intensity. But for getting an idea about the overall strain in work, thermal environment also has to be taken into consideration and in this heart rate gives a better indication of overall physiological strain in actual work than the oxygen uptake and blood lactic acid which are not much affected due to the environmental-stress.

Key words: oxygen uptake lactic acid oral temperature fatigue thermal environment effective temperature work intensity

INTRODUCTION

Though there have been many studies in Western countries on the physiological assessment of various types of miners' work (8, 9, 11, 12, 15, 16), there is no report about change in blood lactic acid level involved in such work, though it is an important index in the determination of heaviness of a manual work and particularly in determining the anaerobic part of it. With a view to finding out how far this index correlates with the other common physiological indices, such as oxygen uptake, heart rate, body temperature etc. and which of these indices can be considered as the most suitable one for determining the severity of work under mining condition, this study of Indian miners employed in a coal mine was undertaken.

MATERIALS AND METHODS

This study included investigation on 25 coal miners engaged in different mining operations as stated below :—

Category of work	No. of subjects
Pick Mining	4
Shovelling	6
Loading	5
Drilling	6
Machine driving	4

The subjects were all of good physique and in the age group of 25-35 years. All the subjects have been working in the mine for a number of years. They were naturally well acclimatised in mining environment, and were trained in the work they had been doing. This study concerned the following items for investigation:

(1) Thermal environment of the work places in the mine in terms of dry bulb and wet bulb temperatures and air movement. Whirling hydrometer was used for the measurement of the temperatures and a Kata thermometer for air velocity. Relative humidity (R.H.), effective temperature (E.T.) were then computed from a standard nomogram by using these data.

(2) Determination of oxygen uptake (VO_2) during actual mining work from the analysis of breath sample and minute ventilation according to the standard method reported earlier by this laboratory, (5) A.K.M. respirometer was used for collection of breath samples and recording of ventilation.

(3) Heart rates, determined manually by a Stethoscope placed on the chest during the various phases of work.

(4) Determination of oral temperature before and after work by a clinical thermometer placed under the tongue for 3 minutes or more until it recorded a steady temperature.

(5) Determination of lactic acid concentration in the blood, collected from finger tip before and after the work.

The lactic acid concentration in blood was determined according to the method of Barker and Summerson (3) as modified by Strom (17). The principle underlying this method depends on the oxidation of lactic acid to acetaldehyde by concentrated H_2SO_4. The acetaldehyde is then determined colorimetrically from its reaction with para-hydroxyphenyl in presence of cupric ion.

RESULTS AND DISCUSSION

Table I presents the results of a survey of thermal environment prevalent at the various working places in the mine. This includes dry bulb wet bulb temperatures and air velocity. The corresponding R.H. values and E. T. have also been calculated and shown.

TABLE I: Environmental conditions of the working places of the mine.
(Mean and range of values found)

Pit No.	*Actual working place*				
	D.B. °*C*	*W.B.* °*C*	*R.H.* %	*Air velocity* *cm/min*	*E.T.* °*C*
Pit 6 (bottom)	32 8 (29.4-34.7)	32.2 (28.9-34.4)	96 (94-100)	761 (305-1676)	32.2 (28.9-34.2)
Pit 4 (west)	30.2 (28.3-31.7)	29.6 (32.8-31.1)	96 (94-98)	914 (457-2743)	29.6 (27.6-31.1)
Pit 4 (seam IX)	30.9 (28.9-32.2)	30.3 (28.3-31.7)	98 (94-100)	701 (366-1402)	30.3 (28.3-31.7)
Pit 5 (bottom)	33.6 (32.2-34.7)	33.2 (31.7-34.4)	96 (92-100)	610 (549-762)	33.1 (31.7-34.2)

D.B. = Dry bulb temperature
W.B. = Wet bulb temperature
R.H. = Relative humidity
E.T. = Effective temperature

Table II presents a summary of the results of various physiological responses of the miners during their work in different mining operations. These include VO_2, heart rate, oral temperature and the changes in lactic acid concentration in blood along with environmental condition (effective temperature) under which these work were performed.

For easy comparison, the finding of VO_2, heart rate and blood lactic acid concentration in the different types of work have also been presented graphically in Fig 1.

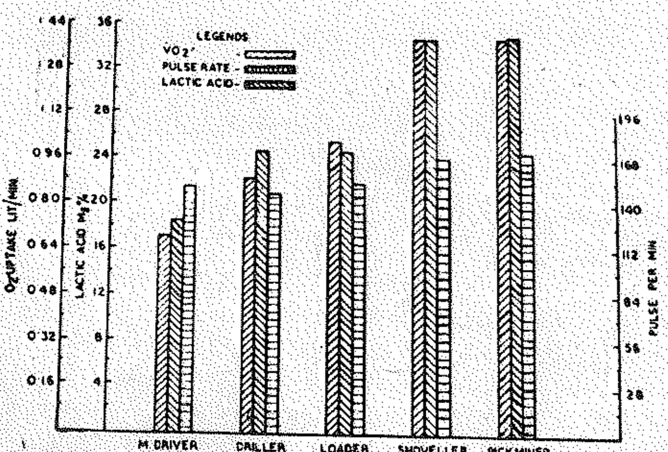

FIG I SHOWING THE RELATION OF LACTIC ACID ACCUMULATION IN BLOOD WITH VO_2 AND HEART RATE CHANGES IN VARIOUS MINING OPERATIONS

TABLE II: Physiological responses in various mining work in relation to the lactic acid concentration in blood.

Category of worker and No. of subject	*Age (yr)*	*Body weight (kg)*	*Uptake (lit/min.) STPD*	*Peak-heart rate (beats/min)*	*Oral temperature (°C)*	*Blood lactic acid (mgm per 100 cc blood)*		*Effective temperature of the working places (°C)*
						Pre-working value	*Post-working value*	
Pickminer (4)	M. 28.4 S.E. ± 2.1	52.3 ±2.5	1.408 ±0.015	158 ±3	38.0 ±0.05	11.7 ±1.2	34.8 ±3.4	29.5 ±0.7
Shoveller (6)	M. 26.8 S.E. ± 1.6	47.9 ±2.8	1.394 ±0.121	166 ±6	38.0 ±0.1	11.1 ±0.9	34.8 ±4.3	31.0 ±0.6
Load-carrier (5)	M. 25.4 S.E. ± 2.0	45.0 ±1.7	1.034 ±0.028	152 ±5	37.8 ±0.1	11.9 ±0.6	24.6 ±0.4	32.0 ±0.6
Machine- Driver (4)	M. 30.8 S.E. ± 2.0	47·5 ±1,1	0.690 ±0.041	116 ±5	37.9 ±0.05	10.9 ±0.8	19.5 ±2.6	33.2 ±0.6
Driller (6)	M. 32.5 S.E. ± 2.4	47.8 ±0.8	0.879 ±0.075	146 ±6	37.9 ±0.04	11.0 ±1.0	24.6 ±2.0	30.1 ±0.4

M = Mean ; S.E. — Standard error.

It has been reported by Scandinavian workers (2, 7) that trained subjects can do sustained work without accumulation of fatigue, if the VO_2 is within the safe limit of 50% of $MaxVO_2$ and this keeps the heart rate below 130/min. Similar trend has also been reported from this laboratory for Indian workers (5). In a recent publicatiom, Henschel (10) also supported the view that at sub-maximal level (30% to 50% of $MaxVO_2$) physical work is independent of age and can be done without experiencing undue fatigue.

In the publication (5) from this laboratory, it has been reported that the average $MaxVO_2$ of the Indian miners is around 2 lits/min. It will be observed from Table II that VO_2 involved in various mining operations is mostly above 50% of the $MaxVO_2$, except in cases of drilling and machine driving. In case of drilling, there is only one case where VO_2 is more than 50% of this level (1.162 lit/min). This is perhaps due to drilling in stone instead of coal. The heart rate changes under normal environmental condition are well correlated linearly with the VO_2 changes at sub-maximal work loads. But the heart rates corresponding to all the work mentioned above are found comparatively higher than expected under normal condition. Eeven in cases where VO_2 is within this safe limit (50% of $MaxVO_2$), the heart rate has been much higher than 130/min. This additional strain on the heart must be due to the effect of adverse thermal environment prevalent in the mine. In case of the pick miners and shovellers also, heart rates appear to be higher than what may be expected even for such heavy work-load (as evident in terms of VO_2) under normal condition.

Lind (13) has recommended certain 'prescriptive zones' for climatic stress for different work intensity on the basis of equilibrium rectal temperature. When we compare our data of after work oral temperatures (which is usually 1°F [0.5°C] below the rectal temperature), with his findings it is found that these are above what may be expected only under the work stress, supporting the view that this must be the impact of higher environmental temperature.

In Great Britain for everyday mining work, a thermal environmental limit of E.T. 83°F (28.3°C) has been prescribed. In India also, a controlled study on thermal stress in textile industry (6) has been the basis for recommending a range of temperatures between 85°F D.B./85°F W.B. (29.5°C/29.5°C) and 110°F D.B./82°F W.B. (43.3°C D.B./27.7°C W.B.) as the safe upper limit for moderate work, provided the rate of air movement is not less than 100 ft (30 m) per minute.

But in the present study the environmental temperature has been much higher. It is thus clear that the environmental thermal stress in the mining work under discussion is above all recommended levels and this must be the reason for higher heart rate and higher oral temperature.

While considering the question of biochemical changes in blood, namely lactic acid during work, it has been reported by some workers (1) that change in the blood lactic acid concentration is a good index in determining the heaviness of the work. Lactic acid is present in blood in a small concentration (about 8-10 *mgm*%) even in resting condition. But under physical exercise, this value goes on increasing perhaps due to incapability of the muscle to utilise adequate oxygen needed for generating the required energy by oxidative combustion only.

If we look to the lactic acid concentration in blood after various mining work (Table II), it will be found that is has increased in every case, the extent of increase being proportional to the work stress (as shown by VO_2). But unlike heart rate there has not been any undue increase in its concentration suggesting any influence of adverse environmental temperature on lactic acid level. This has been brought out more clearly in the Fig. 1. Here, the lactic acid concentration is found to follow the pattern of oxygen uptake, whereas the heart rate takes a different course. The latter must be due to the effect of adverse thermal stress on heart rate, which has gone above the expected level for such work intensity under normal condition, but the VO_2 and lactic acid level have not been influenced by the thermal stress.

Brouha (4) has mentioned blood lactic acid concentration level of 21 *mgm%* for moderate work. It will be found from Table II that the blood lactic acid levels for loading, drilling and machine driving correspond to this value which also corresponds to the same work classification suggested by Minard (14) on the basis of oxygen uptake as shown in Table III-A. The

TABLE III-A: Work classification of various mining work according to Minard (14) in respect of oxygen uptake and energy expenditure.

Nature of work	O_2 *uptake lit/min STPD*	*Energy expenditure Kcal/hr.**	*Blood lactic (acid mg%)***	*Work classification*
Pick-mining	1.408	422.4	34.8	Heavy
Shovelling	1.394	358.2	34.8	Heavy
Loading	1.034	310.2	24.6	Moderate
Drilling	0.690	207.0	19.5	Moderate
Machine-driving	0.879	264.0	24.6	Moderate

*Kilocalories are computed on the basis of 5 Kcal/lit/min. oxygen uptake.

**Blood lactic acid as found for the miners under this study has been given for comparison.

lactic acid concentrations for pick-miners and shovellers are higher and may be considered to support the 'heavy' classification for them according to VO_2. Thus, it is found that lactic acid concentration in blood corresponds well with the VO_2 or energy cost of a work which is the measure of its heaviness.

But if we consider heart rates observed in these workers and compare them to those used by Minard (14) in his work classification, it is found to be one stage higher as shown in Table III-B. Oral temperatures also show similar pattern.

This is considered due to the extra effect of adverse thermal environment. Thus, it is evident that mining environment which is usually adverse being hot and humid transforms moderate work to heavy and heavy work to very heavy as shown by higher heart rates, but this effect is not fully reflected in the changes in VO_2 or blood lactic acid.

TABLE III-B: Work classification of various mining work according to Minard (14) in respect of heart rate/min.

Nature of work	*Heart rate/min*	*Work classification*
Pick-mining	168	Very heavy
Shovelling	166	Very heavy
Loading	152	Heavy
Drilling	146	Heavy
Machine-driving	145	Heavy

CONCLUSION

From the results and their discussion in this study, it is evident that while VO_2 and lactic acid concentration of blood give good indication of physiological strain in respect to work-load, they fail to reflect the strain due to adverse thermal environment. The heart rate and the body temperature which under normal condition follow the same trend as VO_2, on the other hand appear to give overall strain by their higher values due to combined effects of environmental and work stresses. Determination of blood lactic acid does not provide any additional information over VO_2 in ascertaining the overall impact of work and thermal stress. But excess lactic acid concentration in blood may be used to give an idea about the anaerobic part of the work, which is important in determining the accumulation of fatigue in worker. However, it is felt that if any single index is desired to be used for deciding about the suitability of any work situation (particularly if the thermal environment is adverse) the heart rate (and not VO_2 or lactic acid level of blood) may be the best one for such purpose. But for determining the work intensity, VO_2, and blood lactic acid concentration are definitely more useful.

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