

Work load training: enhanced safety standards for Rescue Brigades' operations in the South African mining industry

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As South African mines reach ever-increasing depths the corresponding increase in temperature due to the geothermal gradient and auto-compression heightens the risk of heat-related disorders to underground workers, as well as the early onset of fatigue. This is particularly important when rescue teams are deployed in sealed (unventilated) areas during fire fighting and other emergencies.

The approximately 970 volunteer rescue brigadesman serving the South African mining industry are largely drawn from full-time occupations from mid-management. This implies that by the nature of their daily jobs they are unaccustomed to the extreme physical demands required during rescue and fire fighting operations. The combination of high work rates in harsh environmental conditions, coupled with very high motivational levels, therefore poses a threat to the health and safety of these workers. The paper examines the physiological protection of rescue brigadesmen with specific reference to the scientific development of work load tests.

Introduction

Rescue and fire fighting operations in South African mines are often associated with extremes of heat, poor visibility, irrespirable atmospheres and the dangers inherent to the underground environment in the aftermath of disaster. Obviously, only the highest standards of selection and training are therefore acceptable in establishing a rescue brigadesman corps capable of such demands. To ensure relevance, such standards are under constant scrutiny and, if indicated, revision. A recent example is setting standards for inherent heat tolerance (COMRO Application Report No. 8).

To avoid fatigue, especially in heat, brigadesman operations should be carefully paced, generally at a level within the capabilities of all members of the team. Because physical demands may vary considerably and because operational conditions are not always entirely predictable, it seems obvious that the ability of brigadesman to undertake various tasks or operations should conform to certain standards. In the present context the emphasis falls on the ability to undertake moderate work over extended periods. In more concrete terms, this standard translates to a work rate of at least 40 per cent of maximal work capacity for a period of two hours or more. Any person incapable of sustaining this level of work should be regarded as 'physically unfit' as a rule of thumb.

Basis of assessment

Maximal work capacity (maximal oxygen consumption, maximal aerobic capacity, $VO_2\text{max}$) for South African rescue brigadesman, as determined by an indirect step-test (Van Rensburg et al, 1984), amounts to $3,80 \pm 0,44 \text{ l}\cdot\text{min}^{-1}$ (Table 1). However, since the primary purpose of the assessment is to focus on substandard or inferior performance, or, alternatively, individuals capable only of sedentary work, a 'corrected' $VO_2\text{max}$ (mean $VO_2\text{max}$ minus one standard deviation, i.e. $3,80 - 0,44$ equals $3,36 \text{ l}\cdot\text{min}^{-1}$) was adopted. Assuming a normal statistical distribution, this approach enables identification and characterization of the lower (15 per cent) echelon of the brigadesman corps. The implication, therefore, is that the minimum sustainable work rate for brigadesman, for the

purpose of this assessment, be set at 40 per cent of the 'corrected' mean $VO_2\max$, i.e. $1,34 \text{ l}\cdot\text{min}^{-1}$.

The data recorded in Table 1 should be viewed in perspective. In terms of world standards (Shephard, 1966), comparative figures for a similar age bracket are (means and ranges):

Untrained men : 2,95 (2,20 – 3,47) $\text{l}\cdot\text{min}^{-1}$
 Trained men : 3,91 (2,29 – 4,38) $\text{l}\cdot\text{min}^{-1}$

It should, therefore, be quite apparent that South African rescue brigadesman, as a group could be regarded as a select group. Moreover, the average Body Mass Index or BMI (mass in kg x height in cm squared) amounts to 26,4 which, for all practical purposes is normal. (On the other hand, the data in Table 1 also suggest that in a worst case scenario, some brigadesman may well have been significantly overweight.)

Table 1 PHYSICAL FEATURES OF THE PARTICIPATING RESCUE BRIGADESMAN (MEANS \pm SD)

Title		
Physical features of participating rescue brigadesman (means \pm standard deviation) (n = 100)	Age	32,1 \pm 5.1 yrs
	Mass	83,7 \pm 11,5kg
	Height	1,78 \pm 0,6m
	$VO_2\max^*$	3,80 \pm 0,44 $\text{l}\cdot\text{min}^{-1}$

* Indirectly assessed by means of a step test (Van Rensburg et al, 1984)

Component elements of work load training

The respective components are lifting sandbags, transportation of pipesticks over simulated obstacles, negotiating a maze while transporting heavy equipment, level travelling while transporting heavy equipment, and travelling in confined spaces simulated by means of a 'rat cage'. The unit mass of all items to be lifted or carried amounted to 25kg.

These components were selected to represent the majority of tasks routinely undertaken during brigadesman operations. A balance has been struck between strenuous upper body tasks (e.g. lifting), combined upper and lower body tasks (e.g. transporting) and travelling tasks which include both transporting equipment and moving through confined spaces.

The energy cost of each component was determined by measuring the oxygen requirements of current rescue brigadesman, who volunteered on the basis of informed consent. Portable respirometers were used and the results corrected for standard temperature and pressure. The basic data are presented in Table 2.

Table 2 METABOLIC DEMANDS ASSOCIATED WITH THE VARIOUS COMPONENTS IN ONE CIRCUIT

Components	Mean oxygen requirements in litres
Sandbags (10 bags)	3,4
Pipesticks (8 sticks)	7,4
Maze (one circuit)	9,8
Travelling/transporting	2,8
Rat cage (one circuit)	10,3
TOTAL	33,7

Following a trial period of three months during which various combinations of components were investigated, the most feasible balance appears to be obtained from a circuit which consists of the above components being followed in the sequence as listed and then repeating these components, again in the same sequence, but with the exception of negotiating the maze for a second time. The total mean oxygen consumption for the circuit, as can be calculated from the above data, amounts to 57,1 l. (In view of certain logistical requirements the sequences followed at the various stations differ slightly. However, the overall demand does not differ from one station to the next.)

Assessment protocol and categorization

Assessment is related to the time (t) taken by each brigadesman to complete the circuit under full operational conditions. The categorization system is based on the overall oxygen requirement (Total O₂) and the standard of a minimum sustainable work rate (WR) of 1,34 l.min⁻¹. Since work rate can be expressed in terms of oxygen consumed per unit time, i.e.

$$WR = \text{Total } O_2 / t$$

it follows that by rearrangement and substitution the minimum acceptable time can be calculated as follows:

$$\begin{aligned} t &= \text{Total } O_2 / WR \\ &= 57,1 / 1,34 \\ &= 43 (42,61) \text{ minutes} \end{aligned}$$

In practice, the 'cut-off' figure of 43 minutes, as calculated above, can be adjusted either up or down for the purpose of convenience, e.g. 40 or 45 minutes. If needed, a categorization system can be developed depending on specific requirements. For example, one approach is to use 10 % intervals of the 'corrected' VO₂max for rescue brigadesman, e.g. 70, 60, 50 % (etc) of 3,36 l.min⁻¹. This can be used to simplify performance ratings (Table 3).

Table 3 CONCEPTUAL WORK LOAD TRAINING CATEGORIZATION SYSTEM

Time recorded Minutes	Work rate range (% of 'corrected' mean VO₂max)	Category	Interpretation (example)
< 24	>70	A	Excellent
24 – 28	60 – 69	B	Very Good
29 – 34	50 – 59	C	Good
35 – 43	40 – 40	D	Acceptable
> 43	< 40	E	Reject/caution

Performance distribution

Initial results obtained from the respective MRS (Mine Rescue Service) stations on the performance of brigadesman undergoing work load training are given in Figure 1.

Five-minute intervals were used and the respective, fractions of the brigadesman corps not making the grade would be:

- Cut-off at 40 minutes : 6,8%
- Cut-off at 45 minutes : 2,5%

These fractions, irrespective of the precise cut-off used, are not significant even in terms of the total corps of about 970 men. The point, however, is that on the assumption that brigades operate as close-knit teams, the 'weak links' in the chain can be identified and excluded. This underlines the basic philosophy of work load training.

General discussion

Rescue brigadesman often encounter and have to deal with extremely harsh operational conditions. The safety of an individual team member is inextricably linked to that of the entire team. Accordingly, selection standards should not only be comprehensive but also realistic. On a physical basis the main elements in this regard can be summarised as

- medical fitness and surveillance
- heat tolerance, and
- the recently developed 'work load training' concept.

Teams invariable consist of members who, at least outwardly, differ in many respects. In this respect the present method of assessment does not discriminate significantly (or intentionally) between heavier (generally stronger) or lighter (generally nimbler) members within the same team. On the other hand, inasmuch as the assessment is designed primarily to identify the 'high risk' individual or 'weak link', team members can do much through either power or endurance training to improve their performance. MRS does, indeed, encourage this, especially where other existing skills or experience are of crucial importance.

The present protocol and categorisation system can be used, or adapted, to achieve specific objectives. Firstly, it could be used as a selection criterion for rescue brigadesman. In the present context, it should be emphasised the purpose is to identify individuals (recruits or existing brigadesman) who are not capable of performing even sedentary, self-paced work. Secondly, work load training provides the means to assess individuals on an ongoing basis with special reference to the detection of trends. A third possibility, which has not been exploited to date, is the selection and establishment of

super or elite teams. This may have relevance in, for example, specific operations known for their supernormal physical demands.

In conclusion: work load training represents an invaluable evaluation tool with respect to the physical capabilities of rescue brigadesman. However, despite its merits, it is not an alternative to good medical examinations, including surveillance, or to heat tolerance tests, and should, therefore, be used in conjunction with these assessments.

Acknowledgement

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