Heat Stress Management

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1. INTRODUCTION

Human responses to heat stress exhibit considerable variation. At lower levels of heat stress, the main signs are behavioural changes, but exposure to mild to moderate heat stress results in subtle to substantial decrements in ability to perform tasks involving intellectual input, concentration and alertness. At higher levels of heat stress, the impact appears to become more 'physiological' in nature: the consequences of high environmental heat loads can be expressed in terms of impaired work capacity and, ultimately, the development of heat disorders. Heat related illnesses associated with sustained exertion in hot environments include a spectrum of disorders such as dehydration, heat cramps, heat exhaustion and heat stroke (Hubbard and Armstrong, 1989; Gardner et al., 1996).

In occupations where an augmented metabolic heat production is coupled with high environmental heat loads, the introduction of personal protection strategies becomes relevant in the interests of health and safety. This was highlighted by a number of unfortunate heat-related fatalities involving rescue brigadesmen in the South African mining industry.

In order to develop strategies to safeguard rescue brigadesmen during their operations, an intensive research programme was initiated to develop practical and effective heat stress management procedures (Schutte et al., 1984). This paper describes the various components of the heat stress management programme and the scientific basis thereof.

2. HEAT STRESS MANAGEMENT

Heat stress management is a multifaceted approach towards promoting health, safety and work performance through minimising human heat strain and the incidence of heat disorders. It consists of two essential elements, namely the assessment of overall fitness to work in heat, and the introduction of safe work practices during rescue or similar operations.

In essence, heat stress management, which is a risk management approach, reduces risk by removing high-risk individuals from the specific population and, through the implementation of countermeasures, strives to minimise the risk of developing heat disorders during work in heat. Countermeasures include the use of the Emergency Heat Stress Index (EHSI) to calculate stay times, body cooling garments, and awareness training.

2.1 Overall fitness for work in heat

It is obvious that although most individuals would, in a qualitative sense, exhibit similar response patterns to heat, the actual response pattern for any given individual is a function of a variety of factors (Havenith, 1997). These determinants can be broadly divided into two categories, namely *inherent* determinants, i.e. those over which the individual has no control, and *external* determinants, i.e. those over which the individual has some control or which he voluntarily accepts. In the latter category, the most important are nutrition and hydration, whereas the former includes factors such as maximum work capacity, age and body dimensions.

In the present context, overall fitness for work in heat will depend on the outcome of a purpose-designed medical examination, with special emphasis on features that would rule out physical work or exertion in heat (Epstein, 1990; Donoghue and Bates, 2000), and an assessment of heat tolerance in a climatic chamber.

2.2 Heat tolerance testing

The primary objective of the Heat Tolerance Test (HTT) is to identify gross or inherent heat intolerance (i.e. individuals with an unacceptable risk of developing excessively high levels of hyperthermia during work in heat). An acceptably low risk is regarded as a less than a one-in-a-million chance of developing a rectal temperature in excess of 40,0 °C. The decision to regard a one-in-a-million chance of developing rectal temperatures in excess of 40,0 °C as the upper limit of risk is based primarily on both clinical and experimental data (Shibolet et al. 1976), which suggest that hyperthermic tissue damage is an unlikely consequence of temperature elevations not exceeding 40,5 °C. The choice of 40,0 °C should, therefore, be viewed as an added precaution, the safety margin of which being further enhanced by adopting a risk factor of one-in-a-million.

The HTT used in the South African mining industry consists of bench-stepping for 60 minutes in a climatic chamber at an external work rate of 54 W (positive component), in an environment with a dry-bulb temperature of 33.2°C and a wet-bulb temperature of 31.7°C. The air movement in the climatic chamber is controlled within the range of 0.3 to 0.5 $m.s^{-1}$ (Kielblock et al., 1985).

The assessment of relative heat tolerance is based on the body temperature recorded at the end of the 60-minute bench-stepping exercise. Any person whose body temperature does not exceed a given value at the end of the test is classified as 'heat tolerant'. This implies that that person is fit to undertake physically demanding work in a 'hot' environment. Individuals with body temperatures above the given value on completion of the test are considered to be heat intolerant and will not be allocated to work in 'hot' areas.

Results obtained during the development of the HTT indicated that the rectal temperature response during the HTT is the best predictor of heat tolerance, and that a heat tolerance test of one hour is as effective as a two-hour procedure in detecting heat tolerant individuals. Oral temperature responses during the HTT can also be used as predictor of heat tolerance, but it has a significantly poorer discriminatory power than rectal temperatures, i.e. a substantial proportion of heat tolerant individuals would not be detected during the heat tolerance test when oral temperatures are used for classification instead of rectal temperatures.

It is interesting to note that the results obtained during the development of the HTT indicated that rescue brigadesmen are in general unacclimatised to heat. When comparing the physiological responses of the brigadesmen from collieries, 'cool' and 'hot' mines, the differences in mean rectal temperatures and heart rates of the respective groups at the end of two hours of work in heat in a climatic chamber were statistically insignificant. The group from the 'hot' mines, however, had a mean total sweat rate which was statistically significantly higher than those pertaining to the groups representing the collieries and the 'cool' mines.

2.3 Tolerance times during work in abnormally hot environments

Certain emergency work and rescue operations have to be undertaken in environments where heat loads often exceed limits for routine work. In this regard an 'abnormally hot' environment is defined as one where either the dry-bulb temperature exceeds 37°C or the wet-bulb temperature exceeds 32.5°C.

In view of the need to protect workers exposed to abnormally hot environmental temperatures, a study was undertaken to determine safe exposure limits (Schutte et al., 1994). The formulation of the limits was based on the criterion that a heat exposed individual should experience a negligible risk of developing dangerously elevated body temperatures. In order to provide a database for risk assessment, certain physiological responses of heat tolerant men were determined at various combinations of thermal conditions and work rate in a climatic chamber. These physiological responses were used to predict tolerance times as a function of thermal stress and work rate. Examples of predicted tolerance times are given in the table below:

Table 1: Tolerance times corresponding to certain drop out rates at a moderate work rate.

Wet-bulb (°C)	Dry-bulb (°C)	1 % drop out	10 % drop out	50 % drop out
32.5	50.0	50 min	70 min	107 min
35.0	50.0	48 min	54 min	62 min
37.5	50.0	30 min	33 min	38 min
40.0	50.0	17 min	22 min	28 min

In the interest of simplicity the environmental heat load, when based on wet- and dry- bulb temperatures, can be expressed as the arithmetic mean of these temperatures. This **'Emergency Heat Stress Index'** (EHSI) is based on the Israeli Discomfort Index (DI) and is used by rescue brigadesmen to calculate safe stay times during operations in heat.

2.4 Body cooling garments

Several types of body-cooling garment have been developed and evaluated to date (Schutte & de Klerk, 2001). In general, the principle of operation is to provide a cool micro-environment around the wearer to facilitate the removal of metabolic heat from the body and to block heat exchange with the outer environment, thereby controlling the wearer's heat stress.

The benefit conferred by body cooling garments suggest that, at EHSI values of 40 Experimental results indicated that at 40°C and below, tolerance times can be extended by approximately 30 minutes. This reduces quite sharply above an EHSI of 40°C and the maximum recommended extended time should not exceed 20-25 minutes.

Although it could be argued that these benefits are not substantial in terms of the investment, the extent of protection may well be crucial from a survival point of view. A further consideration is that the well-being and safety of an entire team could be jeopardized by the premature collapse of any single member. It is, therefore, recommended that body cooling garments be worn to provide added protection, especially where conditions cannot be predicted.

2.5 Awareness training

Three factors are of the utmost importance to ensure the success of the preventative measures outlined above. In the first instance, the operative word is 'awareness', and Bruening (1990) states that "… awareness of potential heat stress hazards … is just as effective … as any engineering control or protective gear".

Secondly, the maintenance of optimum levels of hydration during work in heat is essential, and it not surprising that water has often been described as the primary weapon against heat-related injuries (Kielblock, 2001). Sweat is produced solely to provide water for evaporative heat dissipation. Despite this thermoregulatory benefit, profuse sweating may lead to dehydration and as such constitutes a potential threat to continued normal body function. The reason is plain: sweat production is ultimately dependent on an adequate intake of water.

Finally, work rates cannot be prescribed or limited where emergency work has to be undertaken, especially not where life is at stake. However, in the assessment of physical demands likely to be imposed it is important to stress the importance of self-pacing to avoid the early onset of fatigue. Once this happens it is virtually impossible to recover substantially while faced with high environmental heat loads.

3. CONCLUSION

An analysis of fatalities occurring amongst rescue brigadesmen during actual operational conditions suggests that some of these incidents have their origin in poor tolerance to work in heat. Heat stress management provides a mechanism to detect medical and physical contraindications for work in heat, as well as gross heat intolerance. The ability to calculate safe tolerance times and the implementation of safe work practices further contribute to minimizing the risk of contracting heat-related illnesses and the dangers incident to such an event.

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