REMOVAL OF METABOLIC HEAT BY INTERMITTENT AND CONTINUOUS PERSONAL CONDITIONING

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INTRODUCTION

Heat extraction characteristics of personal liquid conditioning garments (LCGs) have generally been derived from experiments with resting, or mildly exercising subjects exposed to hot environments. There is little, or no information concerning heat extraction capability where the heat source is predominantly metabolic. Similarly, studies of the ergonomic aspects of LCGs have tended to concentrate on the sedentary subject. The major difficulty for the ambulatory user is the need to be tethered to a fixed supply, with subsequent restriction of movement. Provision of a portable conditioning unit overcomes this difficulty but may reduce load carriage capability of the user, and impose further ergonomic problems. One potential solution could be to provide cooling during the rest periods of a work/rest routine. We have set out to determine the heat extraction capacity of a liquid cooled vest (LCV) when worn by intermittently exercising subjects in a thermoneutral environment. Further, to compare work tolerance of these subjects when personal conditioning is provided either continuously, or during rest only.

METHOD

Six fit male volunteer subjects took part in the study, mean age was 26.5 yrs, height 177.8 cm, weight 77.6 Kg and treadmill specific peak oxygen uptake 4.09 l/min. With ethical committee approval each subject attempted three 90 minute intermittent work routines (20 mins work/10 mins rest) in a thermoneutral environment (T_{air} 22°C). At least 48 hours separated each exposure. Work consisted of walking on an inclined treadmill (2%) at 4.5 Km/hr with the addition of carrying a box (40cm x 24cm x 22cm) weighing 16 Kg for 30 seconds in every minute. Mean ($\pm$ standard deviation) oxygen uptake for the task was 1.93 $\pm$ 0.32 l/min. Rest was undertaken in the standing posture, during which time subjects were encouraged to drink freely.

For all experiments subjects wore highly insulative chemical protective clothing, including gloves and respirator and an LCV. This garment, worn next to the skin, covered the torso and upper arm, approximately 20% of total body surface area and has been described in detail by Richardson and co-workers (1988). Cooling was supplied either continuously, during rest, or not at all; the fluid inlet temperature was 20°C, flow rate 1.0 l/min.

Core temperature was measured by thermistors in either auditory canal (T_{ac}), with skin temperature measured at 4 sites, chest, back, upper arm and thigh. Heart rate was visually displayed on an oscilloscope from a 3 lead ecg system and was recorded every 15 seconds. Nude body weight losses and fluid intakes were recorded. Subjective Ratings of Perceived Exertion (RPE; Borg 1970) and subjective assessment of thermal comfort, based on a method adapted from Corlett & Bishop (1976) were recorded at the end of each work and rest period respectively. Heat extraction of the LCV was calculated from the temperature difference between the vest inlet and outlet temperatures, mass flow and specific heat of the coolant. Subject withdrawal criteria and, hence, tolerance times were heart rate exceeding 180 bpm, T_{ac} exceeding 38.5°C, or subjective distress. Results were analysed using Analysis of Variance and Newman - Keul, or Freidman's non-parametric test where appropriate.

RESULTS

Mean heat extractions by the LCV were 34.5 ($\pm$ 5.8) watts during intermittent cooling and 29.5 ($\pm$ 3.5) watts during continual cooling. There was a clear decline in heat extraction with time during rest, whereas with continual cooling heat extraction remained relatively constant throughout.

Mean tolerance times were, no cooling 47.2 ($\pm$ 11.1) min; intermittent cooling 61.3 ($\pm$ 23.9 min); and continual cooling 85.3 ($\pm$ 11.4) min; significantly more ($P < 0.01$) than for the other two conditions. Subject withdrawal was invariably due to heart rate exceeding 180 bpm. Between condition comparisons of core and skin temperature and heart rate could not be made because of withdrawal of subjects after the first work period. However, at the time of the first subject withdrawal (40 minutes) the highest core and skin temperatures and heart rate were observed in the no-cooling vv, the lowest in the continuous cooling condition. Body weight loss was significantly less following continuous cooling, (16.7g/min; $P < 0.05$), compared to the other two conditions (26g/min) but with no significant differences in fluid intake (10ml/min for all conditions).

Cooling, in either condition had no significant effect on RPE, the overall rating being "somewhat hard work" at the end of the first work period. Subjective ratings of thermal comfort at the end of the first rest period were close to thermal neutrality for both cwliig conditions, and with votes significantly higher ($P < 0.05$) for no cooling.

DISCUSSION

Vest heat extractions were considerably less than the reported 150 watts (Richardson et al 1988), or calculated metabolic heat extraction of 69 watts (Hayes et al 1986). Both workers used a similar LCV to that employed in this study. The discrepancy between these sets of findings and the present study may he explained in terms of differing environmental heat loads and clothing physical characteristics. Subject posture and exercise form may also have been contributory factors. Nevertheless, even the small rate of heat extraction achieved with continuous cooling was sufficient to allow the subjects to work twice as long as when not cooled. It should also be noted that in 3 subjects tolerance time was increased by intermittent cooling. Further studies are *required* to examine the possibility of work tolerance in protective clothing being increased by intermittent cooling.

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