THE EFFECTS OF COOLING GARMENTS DURING MODERATE WORK LOAD IN A WARM ENVIRONMENT

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INTRODUCTION

Men working in warm environments are threatened by heat stress and moreover often feel uncomfortable because of uncontrolled sweating. In the past, special garments have been developed in order to prevent hazardous heat stress and to keep men as comfortable as possible.

Systems which dissipate metabolic heat by small tubes distributed over the skin covered by the garment had shown advantage in comparison to others, e.g. vests filled with ice.

Two fields deal with the problems of cooling men via special garments. First there is the construction of the cooling suit itself, e.g. the geometric distribution of the cooling tubes, the kind of garment material and the area covering the skin. In the second place there is the algorithm, which handles the application of inlet temperature and flow.

The following study was undertaken to compare three systems of water perfused suits which differed in the constructional parameters mentioned above (2 whole body suits, 1 cooling vest). Moreover, we used this study to compare the results here to those from another series of experiments, in which subjects could choose the inlet temperature according to their own subjective feeling (Hexamer et al., 1992).

METHOD

Five young men participated in this study. The experiments took place in a climatic chamber at a temperature of 35°C and 40% rel. humidity. After a time of equilibration, the subjects exercised at a load of 75W for 75 minutes on an ergometer in the semi-supine position. Thereafter they recovered for 30 minutes.

Parameters measured were core temperature, mean skin temperature, mean body temperature, oxygen consumption, production of CO_2, blood pressure, heart frequency, stroke volume, sweat production and the amount of energy dissipated hy the cooling system. The inlet temperature of the water perfused suits was constantly held at 18°C. This temperature was chosen in regard to the results of the experiments mentioned above, in which subjects chose temperatures from 9°C up to 25°C. Therefore we tolerated the well known fact that cooling with 18°C at the beginning of exercise may induce vasoconstriction, and then removal of heat will not be optimal (Nunneley et al., 1971)

Each subject tested the three cooling systems and, as a control, did another course wearing only shorts and light shoes.

RESULTS

The rise in core temperature during exercise was about 0.7°C. No significant differences could he seen between the cooling system experiments (CSE) and the control experiment (CE) regarding the amount of rise in temperature, but with respect to the dynamic of temperame change it rose twice as quickly during the CSE than in the CE. Another influence on core temperature could be seen during the time of recovery after the 75-minute work load. The amount of decrease in core temperature in the CE was only one half of that seen in the CSE. Decreasing of core temperature took only about half the time in the CSE compared to the CE. The changes in core temperature are in accordance with former investigations, where heat storage in the central body had been described to be obligatory at the start of exercise. (Webb, 1968; Werner, 1984).

Mean skin temperature (average of 9 spot probes) was about 2.5°C lower in the CSE. Cardiac parameters had been affected only little or not at all during all kinds of experiments. Neither heart frequency nor stroke volume showed any difference evoked by different experimental setups.

Mean arterial pressure increased by 4 mmHg in the CE and up to 8 mmHg in the CSE. Decrease in diastolic pressure was affected clearly (-9 mmHg) in the CE, but only little in the CSE.

In the CSE, consumption of oxygen was 40-50 ml/min higher as compared to the valnes in the CE.

Sweating rate was the parameter that showed the most significant differences between CSE and CE and between the different systems themselves. Mean water loss was 800 ml in the CE, but only 400, 500 and 650 ml in the different suits, respectively.

The mean amount of energy removed by the two whole body systems was 170W and 200W. As the subjects produced some 430W (measured via oxygen comsumption) the major part of the metabolic heat was still evaporated.

CONCLUSIONS

The important physiological parameters, which should be supported by cooling garments showed no differences between CSE and CE, so physiological regulation could cope with the chosen environmental conditions.

But this does not mean that the cooling suits did not show any effects at all: a signifcant influence could be seen with respect to the sweating rate. As it is not possible to prevent sweating completly, halving of the water loss can be regarded as a good result (Webb et al., 1968). The lower loss of water in the experiments with the snit showing the best effect could enable a subject to exercise for twice as long if water were not replaced and the subject were to become dehydrated.

Differences in blood pressure and the dynamic of core temperature changes seemed to be due to a peripheral vasoconstriction because of the lower skin temperature. The vasoconstriction induced by low skin temperature showed an effect, which could become important if environmental conditions were to get harder: if skin blood flow and muscle blood flow must compete and the body becomes heat stressed, a temperature induced vasoconstriction of skin blood vessels could prevent blood pressure regulation from failing. This would be a clear advantage in spite of the fact that heat removal is not optimal.

If the whole body is covered by the snit, the algorithm which controls cooling seems to have a greater influence than constructional details of the suits. In these experiments with constant conditions, the differences between the suits were less than in the experiments with various inlet temperahues (Hexamer et al., 1992). An optimal use of cooling garments requires a flexible handling of inlet temperature, including the fact that an "overcooling" could prevent an imminent break down of circulatory regulation.

Some subjects complained of a cool feeling at the trunk, whereas the exercising legs tolerated the inlet temperatnre very well.

The following conclusions can be drawn:

1) A well thought out algorithm is of more importance than constructional details of different cooling suits
2) Even if evaporation is still the major system for heat removal, there are positive effects of cooling garments on the circulatory system and the comfort feeling
3) At least two different circuits of water should be used, e.g. lower body/upper body or trunk/extremities

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