THE THERMAL DISCOMFORT OF WEARING BALLISTIC VESTS

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INTRODUCTION

Ballistic protective vests protect the upper body from injury by fragmentation weapons. The vests are made from multiple layers of fabric and have considerable weight and thickness. The increased protection is thus paid for by increased physiological stress. During work in warm conditions the body temperature, temperature sensation, sweat rate, and humidity sensation may increase. When working in a cool environment a ballistic vest may provide increased comfort. It is the purpose of this study to relate the thermal sensation when wearing a vest to the sensation without the vest. Most studies on the thermal effects of body armour have focussed on the tolerance when worn in hot, dry or warm, humid environments (Yarger et al, 1968, 1969; Haisman and Goldman 1974). Here it will be attempted to state a simple rule for the thermal effect of a vest for a range of climates, varying from cool to warm. The hypothesis is that the vest acts like a jacket, shifting the preferential temperature down by a certain number of degrees, the more so with a higher work rate.

METHODS

On five successive days, a total of 73 subjects were tested. On each day 14 to 15 subjects were exposed to different climates and work rates in two climatic chambers. The group was split in five subgroups of three subjects, wearing either one out of four vests or no vest over fatigues. The climates used were 15, 20, 25, and 30 °C, all at 50% R.H., and the work rates were light (standing and walking slowly) and moderately hard (walking and bench stepping). These climates and work rates were systematically changed, but for each subject the clothing ensemble remained the same. All subjects did eight sessions of 30 min duration on a day, separated by 15 min rest periods in a room of neutral temperature. Subjects were assigned to groups with either a decreasing (group dc) or an increasing (group ic) order of thermal stress and each vest was equally represented in both groups. Increasing thermal stress results from higher air temperature, or higher work rate at equal air temperature. In the analysis the dc/ic effect is explicitly included, together with work rate, temperature, and vest.

At min 0, 15, and 30 of each session the skin temperature at the chest was measured and by means of rating scales the temperature sensation and the humidity sensation under the vest and of the whole body were recorded. The scale for temperature was: 3 = hot, 2 = uncomfortable warm, 1 = comfortable warm, 0 = neutral, -1 = comfortable cool, -2 = uncomfortable cool and for humidity: 3 = wet everywhere, 2 = locally wet, 1 = slightly humid, 0 = neutral, -1 = dry.

The temperature and humidity sensations and the chest temperature have been analyzed with analysis of variance and a regression technique.

RESULTS

The rest period was long enough to create similar starting conditions. The chest temperature starts at 33°C and increases with time, depending on the air temperature and vest worn. The work rate has only a slight effect on chest temperature. At the end of the session the temperature still increases, but relatively slow. The temperature sensation for the whole body follows the same lines, but the effect of air temperature and work rate seems to be stronger than in chest temperature. The humidity sensation for the whole body is hardly dependent on the vest, but more on work rate and air temperature.

Between the vests there were no significant differences found at the end of the sessions, but there was a significant effect of wearing a vest as compared to no vest. In the warmest condition in this test subjects felt 'uncomfortable warm' and 'locally wet'. The effect of wearing a vest per se can be evaluated as a 3°C increase in chest temperature, a 1.0 step in local temperature and 1.2 step in local humidity sensation at the chest, a .5 step in whole body temperature sensation and a .2 step in whole body humidity sensation.

Increasing the work rate from light to moderately hard has hardly an effect on chest temperature, but the temperature sensation increases by half a step and the humidity sensation by almost a full step (Fig. 1). Thermal strain was rated slightly but significantly higher by the ic than by the dc group.

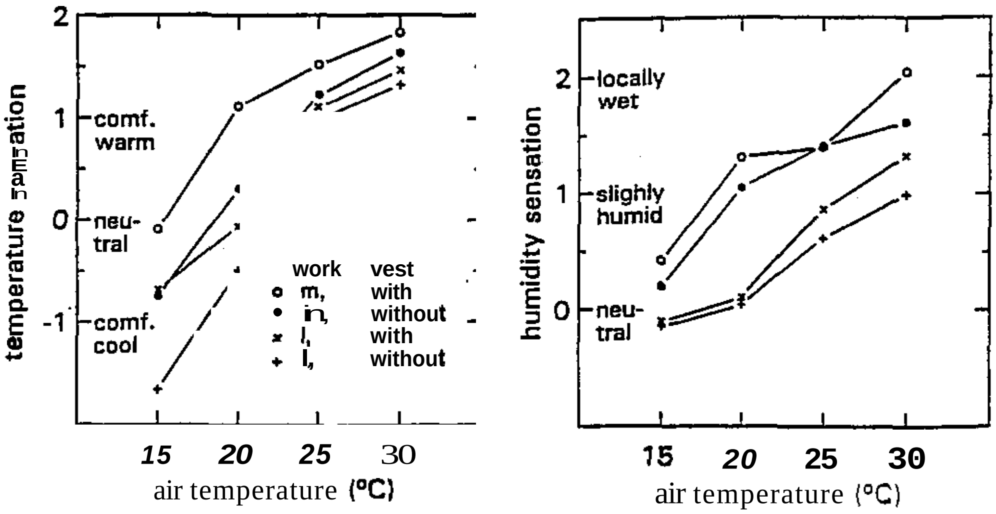

Fig. 1 Temperature and humidity sensation at the end of the session for the whole body as a function of air temperature and work rate.

The regression analysis resulted in the following regression equations:

$Tsen = -33 + .15 * T_{air} + .6 * \text{work rate} + .5 * \text{vest}$ (r=.73)

$Vsen = -1.8 + .1 * T_{air} + .7 * \text{work rate} + 2 * \text{vest}$ (r=.64)

$Tchest = 27.2 + 21 * T_{air} + .4 * \text{work rate} + 5.1 * \text{vest} - .11 * T_{air} * \text{vest}$ (r=.82)

With air temperature (T_{air}) in °C, work rate= 0 for light and 1 for moderately hard and vest= 0 for no vest and 1 for wearing a vest.

The results suggest that an adequate description of the effect of wearing a vest can be given by specification of the difference in preferred T_{air}, compared to not wearing a vest. The shift of T_{air} is according to the equations slightly over 3°C for the whole body temperature sensation and 2°C for the whole body humidity sensation. The local effects are not so easily described since there are interactions between ambient temperature and wearing a vest, resulting in a larger effect for cool than for warm ambients. The average effect of wearing a vest is a shift in temperature of 5°C for local temperature sensation, a shift of 10°C for local humidity sensation, and a shift of 17°C for chest temperature. A similar shift in T_{air} to account for the effect of work rate would be 4°C for whole body temperature sensation and 7°C for whole body humidity sensation. The shifts for the local sensations and the chest temperature are comparable to those for the whole body, so that working with a vest does not cause specific thermal problems under the vest, but rather all over the body. Insufficient data are available to carry out a similar analysis on physiological data.

CONCLUSIONS

- Moderately hard working persons, wearing fatigues and vest will feel 'uncomfortable warm' and 'locally wet' after 30 min in a 30°C environment. This is not much warmer than when they were not wearing a vest. The sensations still increase after 30 min.
- The whole-body thermal effect of wearing a ballistic vest over fatigues can be compensated by a decrease in air temperature of 3°C. This was confirmed over a range of air temperatures from 15 to 30°C.
- Increasing the work rate from 'light' to 'moderately hard' requires a compensation of 4°C in air temperature.

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