

EFFECT OF A PERSONAL AMBIENT VENTILATION SYSTEM ON PHYSIOLOGICAL STRAIN DURING HEAT STRESS WEARING BODY-ARMOUR

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INTRODUCTION

The use of ballistic protective gear (e.g. ceramic vest or body armour) in heat load conditions during physical activities increase the need of a reduction in the physiological strain by auxiliary devices. Various methods for cooling have been studied, including liquid or air cooling systems [1-6], ice vest [7-9], water spraying [10], PCM vest [11], and extremities immersion in chilled water [9, 12-14]. Although these methods may deliver sufficient cooling power to reduce the heat strain, they are not suitable for use in field operations, where power source is required, and long duration (>6 h) of effective cooling is necessary. Thus, in the recent years, there has been a need for a lightweight, low energy consuming cooling system that would be suitable for a long term use in the battlefield and that would maintain the soldier's performance. In 2006, a new cooling vest (CV) was tested that is based on environmental air ventilation along the torso, thereby enhancing sweat evaporation [15]. The CV was able to attenuate the physiological strain levels during exercise. However, a few improvements were suggested and implemented in order to achieve a more substantial cooling effect. In the current study, which is a continuation of the study conducted in 2006, the effect of the improved CV was examined and evaluated.

METHODS

Twelve healthy volunteers participated in the study. In the first part, the volunteers performed a 6-day acclimatization protocol that included 2 hours of walking on a treadmill at 5 km/hr and 2% inclination in heat load conditions (40°C with 40% relative humidity). In the second part, 10 of the 12 volunteers completed all of the 4 planned exposures that included exercise under two climate conditions, 40°C with 30% humidity (40/30) and 30°C with 70% humidity (30/70) with the ventilation system (COOL) and without it (NOCOOL). The CV was worn over a polyester T-shirt, and under the BDU and the light body armour vest. Each exposure lasted 125 minutes: after 5 min. of sitting, the subjects performed 2 segments of 50 min. walk on a treadmill (5km/hr, 5% inclination) followed by 10 minutes of rest. Throughout the exposures the following physiological data have been monitored: core temperature (T_{rec}), 3-sites skin temperature (T_{sk}), and heart rate (HR). In addition, the participants were asked to rate their perceived exertion (RPE). Weighted mean skin temperature (\bar{T}_{sk}), Physiological Strain Index (PSI), Sweat rate (m_{sw}) and heat storage rate at the first walking bout (S_1) were calculated. Environmental conditions were monitored continuously.

RESULTS

The results indicate that the use of CV reduced the physiological strain in comparison to the exposures without the system. Under both conditions, 40/30 and 30/70, the CV reduced the rise of the body temperature, ΔT_{rec} ($T_{rec_{115}} - T_{rec_0}$), in $0.37 \pm 0.23^\circ\text{C}$ and $0.21 \pm 0.22^\circ\text{C}$, respectively, for COOL vs. NOCOOL ($p < 0.001$). Utilization of the CV resulted in a moderated rise of \bar{T}_{sk} ($p < 0.001$) and HR ($p < 0.01$). S_1 was reduced by 36% ($p < 0.005$) and 12% (NS), m_{sw} was reduced by 21% and 23% ($p < 0.005$), and the PSI value at the 115th min was reduced by 31% and 16% ($p < 0.005$) (Fig. 1) for 40/30 and 30/70, respectively, for COOL compared to NOCOOL. The ratings of perceived exertion were not significantly different for COOL vs. NOCOOL.

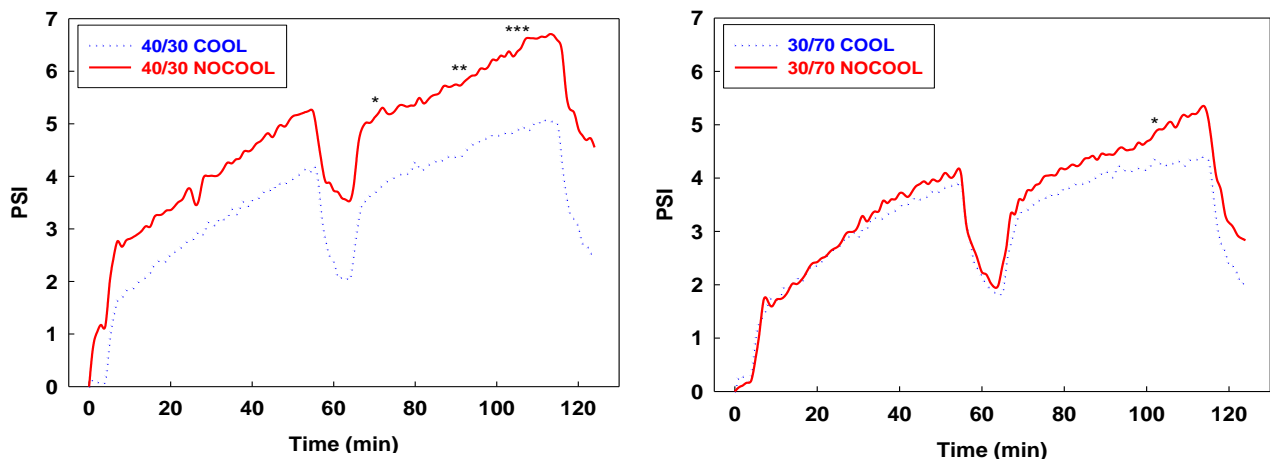


Figure 1. Mean PSI of the subjects during the 40/30 climate condition ($n=10$), and during the 30/70 climate condition ($n=9$) with and without the cooling vest (COOL and NOCOOL).

* denotes subject attrition.

CONCLUSIONS

The ventilation system that was tested in this study was effective in reducing the physiological strain while exercising in heat load. The CV was found to be more effective under 40/30 than 30/70 climate condition, since relative humidity has higher effect on cooling effectiveness in this method of personal ventilation. Thus, utilization of this CV will be more substantial for desert area operations. The main implications, other than reduction of the thermal and cardiovascular strain, are mainly in the sweat rate. Reduction of more than 20% of the sweat rate obtained in this study may save about 2 litres of water a day for each soldier from the amount of water required to maintain fluid balance.

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