NBC SUIT VENTILATION ALLEVIATES THE PHYSIOLOGICAL STRAIN

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INTRODUCTION

Environmental heat load combined with physical exertion induces a thermal stress that might be above the compensable level, and thus, may lead to an excessive rise in body core temperature [1, 2]. This is further exacerbated by wearing NBC protective garments, which limit to a great extent heat dissipation by sweat evaporation [1]. To prevent the excessive rise in body temperature, work–rest cycles were defined, with emphasis on providing enough time for the body core to cool. Researchers have also searched for effective auxiliary methods to enhance heat dissipation, including liquid or air active cooling systems [3-8], ice vest [9-11], water spraying [12], PCM vest [13], and extremities immersion in chilled water [11, 14-16]. Although these methods may deliver sufficient cooling power to reduce the heat strain, it is noteworthy, however, that many of the cooling systems are cumbersome and heavy. A new Cooling System (CS) was developed that is based on a blower that supplies ~300 L/min of filtered environmental air. The blower and filters are carried by an especially designed carriage straps that are worn under the NBC garment, and include a manifold that directs the air to the torso and lower extremities areas. The aim of this study was to evaluate the effect of the CS on the physiological strain while wearing NBC suit and exercising in heat load.

METHODS

Twelve healthy volunteers participated in this study. In the first part, all the volunteers performed a 6-day acclimation protocol that consisted of 2 hours of walking on a treadmill at 5 km/hr and 2% inclination in heat load conditions (40^{o}C with 40% relative humidity). In the second part, all the participants were exposed to 4 different combinations of climate (35^{o}C with 40% relative humidity (RH) (35/40) and 30^{o}C and 60% RH (30/60)) and cooling. Each exposure was 125 min: after 5 min of sitting, the participants performed 2 segments of 45 min walk on a treadmill (5 km/hr, 2% inclination) followed by 15 minutes of rest, wearing an impermeable NBC protective suit with and without the ventilation system (COOL and NOCOOL). Eleven participants completed the 2 planned exposures for climate condition 35/40 and only 8 completed the 2 planned exposures for climate condition 30/60. Throughout the exposures the following physiological variables have been monitored: core temperature (T_{rec}), 3-sites skin temperature (T_{sk}), and heart rate (HR). In addition, the subjects were asked to rate their perceived exertion (RPE). Weighted mean skin temperature ($\overline{T}_{sk}$), Physiological Strain Index (PSI), Sweat rate

(m_{sw}) and heat storage rate at the first walking bout (S) were calculated. Environmental conditions were monitored continuously.

RESULTS

The results indicate that the use of ventilation system substantially reduced the physiological strain in comparison to the exposures without the system. For 35/40 condition, tolerance time was increased twofold for COOL vs. NOCOOL: 119 vs. 61 min and for 30/60 125 vs. 109 min. The utilization of the CS reduced the physiological strain in all the variables as depicted by table 1 and Fig. 1. The ratings of perceived exertion were significantly different for COOL vs. NOCOOL only for 30/60 climate condition at the 115th minute.

Table 1. Mean±SD of the physiological strain reduction as depicted by the following variables: ΔT_{rec}, $\overline{T}_{sk}$, ΔHR and PSI at the 45 min time point, S_1 for the first work cycle and m_{sw} for the whole exposure, for COOL vs. NOCOOL at two climate conditions: 35^{o}C with 40% RH and 30^{o}C with 60% RH. All the differences are statistically significant ($p<0.05$).

	ΔT_{rec} (^{o}C)	$\overline{T}_{sk}$ (^{o}C)	**ΔHR** (bpm)	**PSI** (%)	**S** (Watt)	**m_{sw}** (%)
35/40	0.60±0.14	1.5±0.48	26±12	37	78	32%
30/60	0.36±0.18	1.0±0.35	18±10	32	45	39%

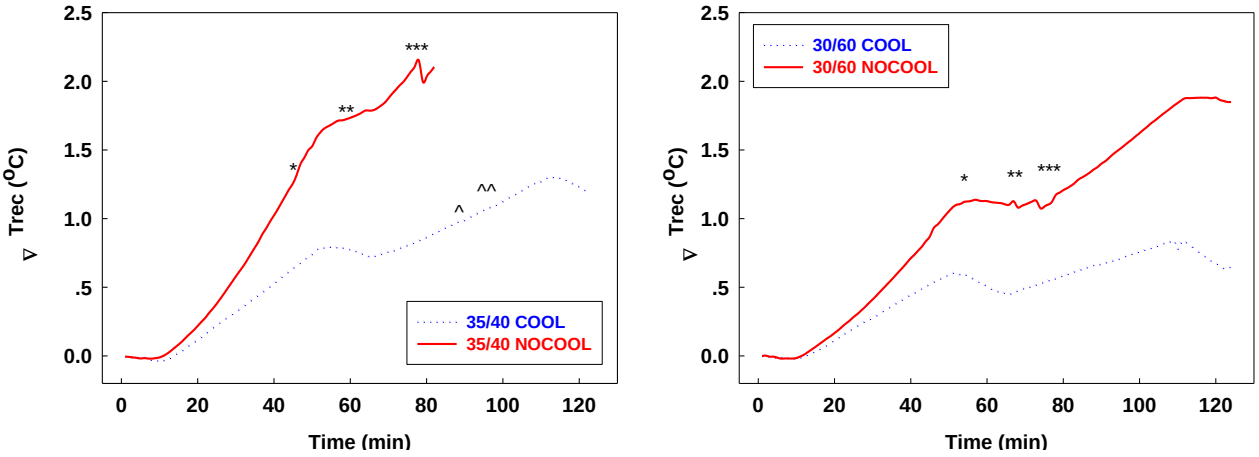

Figure 1. Mean ΔT_{rec} of the subjects during the 35/40 climate condition (n=11), and during the 30/60 climate condition (n=8) with and without the cooling vest (COOL and NOCOOL).
For 35/40 * n=10, ** n=5, *** n=3, ^ n=10, ^ n=9. For 30/60 * n=7, ** n=6.

CONCLUSIONS

The cooling system that was tested in this study was highly effective in reducing the physiological strain while working in heat load. The CS was found to be more effective under 35/40 than 30/60 climate condition, since environmental humidity has high effect on cooling effectiveness in this method of personal ventilation. The CS carriage system allows carrying its weight in an efficient way, so its contribution to the metabolic rate is very low compared to its contribution for heat dissipation. The utilization of such system, may allow to substantially prolong the work cycles while reducing the risk for heat injury. The main implications, other than the reduction of the thermal and cardiovascular strain, are mainly in the sweat rate. The reduction of more than 30% of the sweat rate obtained in this study may save a few litres of water a day for each worker from the amount of water required to maintain fluid balance.

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