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MEETING ABSTRACT Open Access

Quantitative evaluation of personal protective ensembles relative to heat strain

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Introduction

Personal protective equipment (PPE) exacerbates heat strain experienced by users through: (a) increases in thermal (R_t) and evaporative (R_{et}) resistances; and (b) increases in metabolic rate ($\dot{M}$) during physical activity driven in large part by ensemble weight. This study aimed to quantify the effects of PPE R_t & R_{et} and ensemble weight on heat strain during walking.

Methods

Stepwise thermal manikin (TM) testing and modeling were used to analyse a three-layer PPE ensemble (weight 37.4 kg). Layers: uniform (A); body armour and combat load (B); chemical protective clothing (C). The PPE was tested on a TM to measure R_t & R_{et}, starting with layer A and then adding an additional layer in each step. $\dot{M}$ during walking at 1.22 $m.s^{-1}$, adjusted ($\dot{M}_{adj}$) for the layer weight, were 300, 404 and 428W for configurations with A, A+B and A+B+C, respectively. A human thermoregulatory model was used to predict endurance time (ET, min) for each configuration at a fixed $\dot{M}$ ($\dot{M}_{fix}$) of 300 W and at its $\dot{M}_{adj}$. ET was defined as time needed for the core temperature to rise to 39 °C.

Results

The left figure indicates the fractional contribution of each layer to R_t & R_{et} of the whole system (A+B+C). The right figure is the predicted ET, showing influences of B or B+C in comparison with A. The difference between A and A+B-$\dot{M}_{fix}$ indicates ET reduction due to R_t & R_{et} with added B, and the difference between A+B-$\dot{M}_{fix}$ and A+B-$\dot{M}_{adj}$ indicates ET reduction due to the

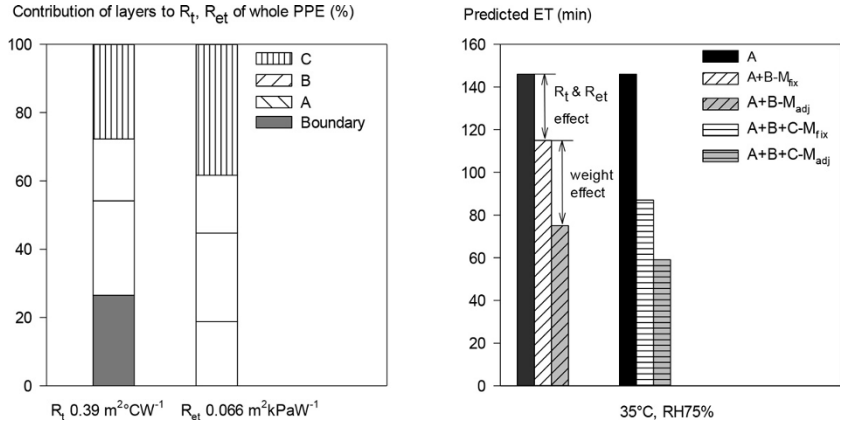

Figure 1

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weight of B. Thus compared with ET for A of 146 min, the R_t & R_{et} of B reduce ET by 31 min while the added weight reduces ET by 40 min further. Similarly, the increased R_t & R_{et} of B+C reduce ET by 59 min, while the added weight reduces ET by 28 min.

Discussion

This study (a) reveals the fractional contributions of PPE resistances by layer, (b) demonstrates the effects of PPE weight on ET and quantifies ET reduction due to increases in $\dot{M}$ associated with PPE weights, and (c) isolate the contributions of two different PPE properties, R_t & R_{et} and ensemble weight, to predicted heat strain. Impacts of each PPE layer on ET can be quantified by this approach.

Conclusion

This study provides a new systematic approach to understanding more the aetiology of heat strain, and to designing PPE to maximise user protection while minimizing heat strain.

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