Evaluation of Heat Stress Prediction for Structural Internal Firefighting Scenario

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Abstract

Firefighters face hazardous conditions that can induce negative physiological and psychological responses, more specifically heat strain. The Predicted Heat Strain model (PHS, ISO7933) enables the determination of heat strain while considering clothing properties, environment and activity in predictive calculations. However, PHS was originally developed for industrial applications. For suggesting potential adjustments in ISO 7933 for firefighter work, this study aimed to evaluate PHS algorithms for firefighters under simulated structural interior firefighting activities (SIF).

Four firefighters wearing turnout gear performed pre-work and recovery at room temperature, and intermittent activities in a climate-controlled room (Ta = 44.4 ± 0.2 °C, RH = 27.8 ± 1.6 %, va < 0.15 m/s). Clothing thermal insulation and evaporative resistance were determined using a thermal manikin. Skin (Tsk) and rectal temperatures (Trec), and body water loss (mwl) were compared with PHS predictions using two online tools that allow input of intermittent conditions – FAME Lab (PHSFL) and the Lund University modified PHS (PHSLU).

Experimental Trec did not differ significantly from the PHSLU predictions. For PHSFL, Trec became significantly lower at the end of heat exposure and during recovery. Experimental Tsk was initially lower than predicted by PHSFL. Predicted Tsk decreased more rapidly than measured values at the end of radiation period for PHSLU, while reduction in PHSFL occurred slightly later. Both models predicted Tsk values that were lower than the experimental data throughout the recovery period. Overall the PHS models gave reasonably accurate predictions for both Trec and Tsk in this scenario (RMSD < SD), but mwl (> 1000 g) exceeded significantly measured one (630 ± 209 g).

The models may not adequately account for thermal inertia of the clothing system and/or heat distribution within it. Considering other scenarios and existing literature, it is clear that the PHS model requires adjustments for realistic predictions under firefighter conditions. Further detailed analysis is needed to determine the necessary modifications.

Keywords: firefighter, protective clothing, predicted heat strain, heat stress, physiological responses