Influence of Head Cooling by Phase Change Materials on the Core Body Temperature and Head Temperature using a 3D Whole Body Model

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Introduction: Phase change materials (PCM) in the solid form absorb and store the heat energy transferred from the surface of the human body to the PCM. The *hypothesis* of this research was that the transfer of heat energy from the human body to the PCM will lead to a decrease in body temperature during intense exercise conditions. The *objective* of this study was to evaluate the influence of head cooling due to PCM on the core body temperature (T_c) and head temperature (T_h) using a 3D whole body computational model.

Methods: The major computational subdomains of the human body model were defined as the muscle, head and internal organs. The temperature profile of the human body was determined using the a) Pennes bio heat equation and b) Energy balance equation to determine the change in temperature field within a whole body model during a computational sequence [1]. The model simulated a realistic human being exercising on a treadmill at a constant walking intensity of 1.8 m/s for 90 min with an initial 5 minute ramp up period [1]. A salt hydrate PCM with a melting temperature of 28°C was used to impart external cooling to the head region. The computational model was solved to obtain the transient response of T_c and T_h.

Results and Discussion: Figure 1 shows the numerical values of T_c and T_h for exercise conditions with and without external cooling. During exercise with sweating and no external cooling, the relative difference of T_c and T_h ($\Delta T_{ch\_baseline}$) at the end of 90 minutes of exercise was computed to be 0.15°C. However when an external cooling of 232.8 W/m^2 was provided to the head subdomain, a difference of 0.27°C ($\Delta T_{ch\_ext.cool}$) was observed. Therefore the percentage difference between $\Delta T_{ch\_ext.cool}$ and $\Delta T_{ch\_baseline}$ at the end of 90 minutes was calculated to be 80 % (($\Delta T_{ch\_ext.cool}$ - $\Delta T_{ch\_baseline}$)/$\Delta T_{ch\_baseline}$).The variation noted in the values of T_h in relation to T_c was high because the head was directly cooled by the PCM. The delay in heat transfer from the head to the other sub domains resulted in negligible changes in T_c.

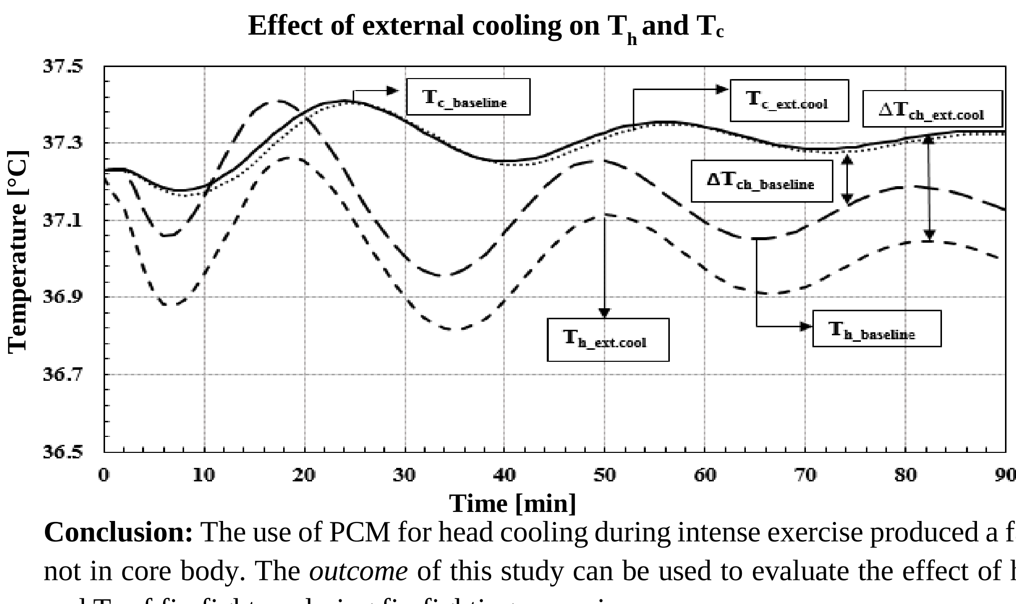

Figure 1. Computed T_c and T_h for the human body model during exercise a) without external cooling i.e. baseline b) with external head cooling of 232.8 W/m^2.

Conclusion: The use of PCM for head cooling during intense exercise produced a favorable cooling in the head but not in core body. The *outcome* of this study can be used to evaluate the effect of head cooling due to PCM on T_c and T_h of firefighters during firefighting scenarios.

References:

[1] Paul AK et al. Predicting temperature changes during cold water immersion and exercise scenarios: Applications of a tissue-blood interactive whole body model. Numerical heat transfer A- Application. 2014; 68:6, 598-618.