Development Of Female And Male Thermoregulatory Models Using COMSOL

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Abstract

Introduction
Most current thermoregulation models represent the body in significantly simplified forms, e.g., cylinders or spheres. These simple geometries do not fully represent the complexity of bones, organs, etc. contained in the human body. Modern medical technologies allow for more advanced and accurate scans of human cadavers. These medical techniques enable anatomically correct mesh applications to be used for heat transfer simulations that include organs, tissues, and complicated geometry. This paper describes finite element models of female and male thermoregulation with geometry based on medical images.

Model Development
A female and male mesh were created from Duke University's XCAT phantom dataset. Simpleware SanIP Software (SYSNOPSYS) was used to segment and process the data set. These two meshes were imported into COMSOL Multiphysics software for model development of a male and female body with human thermoregulatory mechanisms and heat transfer properties of 13 major organs and tissues, such as the as skin, bones, muscles, fat, and internal organs. Heat transfer simulations were conducted using COMSOL Multiphysics bio - heat transfer module. The models included physiological properties such as density, conductivity, specific heat, blood perfusion, and metabolic rate of all organs, bones, muscles, and fat. Density, conductivity and specific heat were set to constant values for simplified simulations. Additionality, ambient temperature was set to 29°C (thermal neutral conditions).

Simulation Results
The simulation shows the temperature differences throughout the human body for male and female thermoregulation. Figures 1 & 2 show the internal and skin temperature distributions, respectively, of a female, in an ambient temperature of 29°C (thermal neutral conditions). The average skin temperature is 33.52°C with a minimum and maximum of 31.1°C and 36.08°C, respectively. The model displays the temperature distribution of the internal organs which in turn can be analyzed as core temperatures at different locations, e.g., esophagus and rectal temperatures. The simulation resulted in an intestinal maximum temperature of 37.1°C and a minimum temperature of 36.3°C. Additionality, the simulation computed a brain and heart temperature of 37.28°C and 36.97 °C, respectively.

Conclusion
With the use of an anatomically accurate mesh and geometry, COMSOL Multiphysics can be used to simulate human temperature changes at various climate conditions, e.g., heat and cold environments. This simulation tool can be used to analyze and predict how a human body will react to different ambient temperatures and allow for better understanding on how to prevent heat and cold strain and improve human performance.

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Reference

References
1. Castellani MP, Rioux TP, Castellani JW, Potter AW, Notley SR, Xu X. Finite element model of female thermoregulation with geometry based on medical images. J Therm Biol. Apr 2023; 113:103477.
2. Castellani MP, Rioux TP, Castellani JW, Potter AW, Xu X. A geometrically accurate 3-dimensional model of human thermoregulation for transient cold and hot environments. Comput Biol Med. Nov 2021; 138:104892.

Figures used in the abstract

Figure 1 : Figure 1. Steady state temperature distribution of female at ambient temperature 29°C

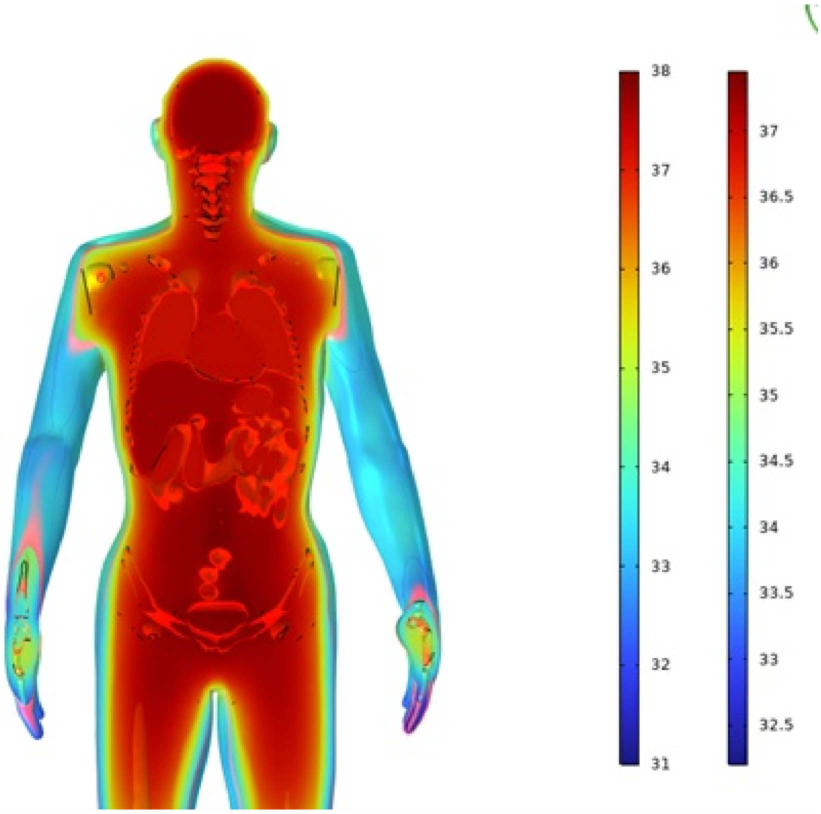

Figure 2 : Figure 2. Temperature distributions at 29°C ambient temperature (female)

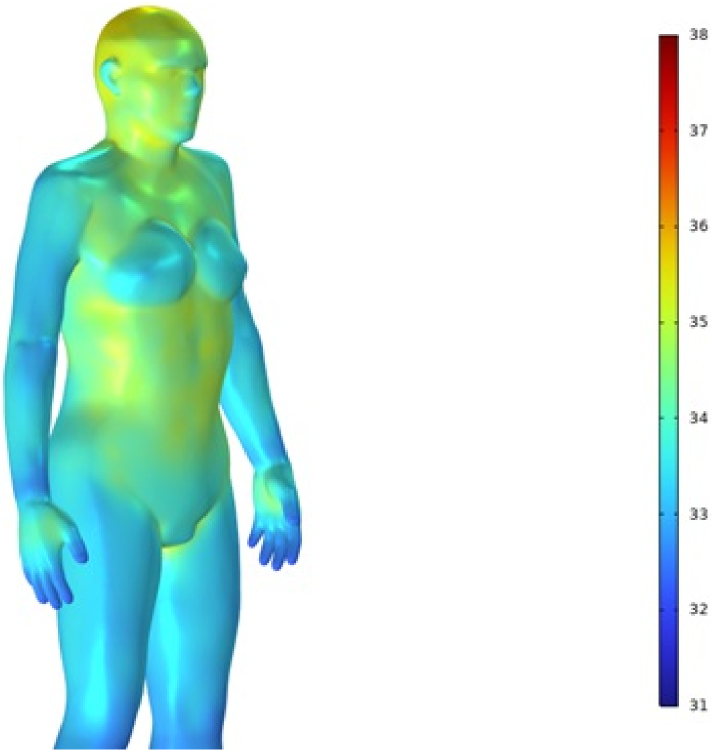

Figure 3 : Figure 3. Skin temperature distributions at 29°C ambient temperature (female)