





Nonhomogeneous heat transfer simulation using a female human model

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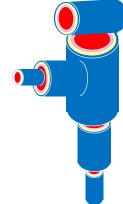
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Introduction



- Human thermoregulatory models have been developed and applied since early 1960s
- Most human body models have been constructed from cylinders and ellipses using CAD software
- Medical images can be used to create a more accurate representation of the human body
- Purpose of the study is to use a geometrically and anatomically accurate mesh to perform heat transfer analysis and create temperature profiles in the human body



Multiple cylinders or elliptical-cylinder







Average American Female Height:1.62 m (~5' 4") Weight: 66 kg (~145 lbs.) Body Fat: 36.1% Age: 36 year Volume: 0.0445 m³ Surface Area: 0.777m²

Vertices: 566,830 Tetrahedra: 2,985,530 Triangles: 802,750 Edge elements: 13,020 (Segars et al Med Phys 2010, Simpleware Inc)





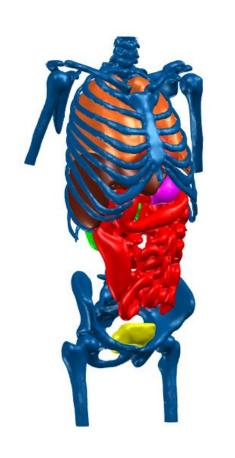


Organs Muscle

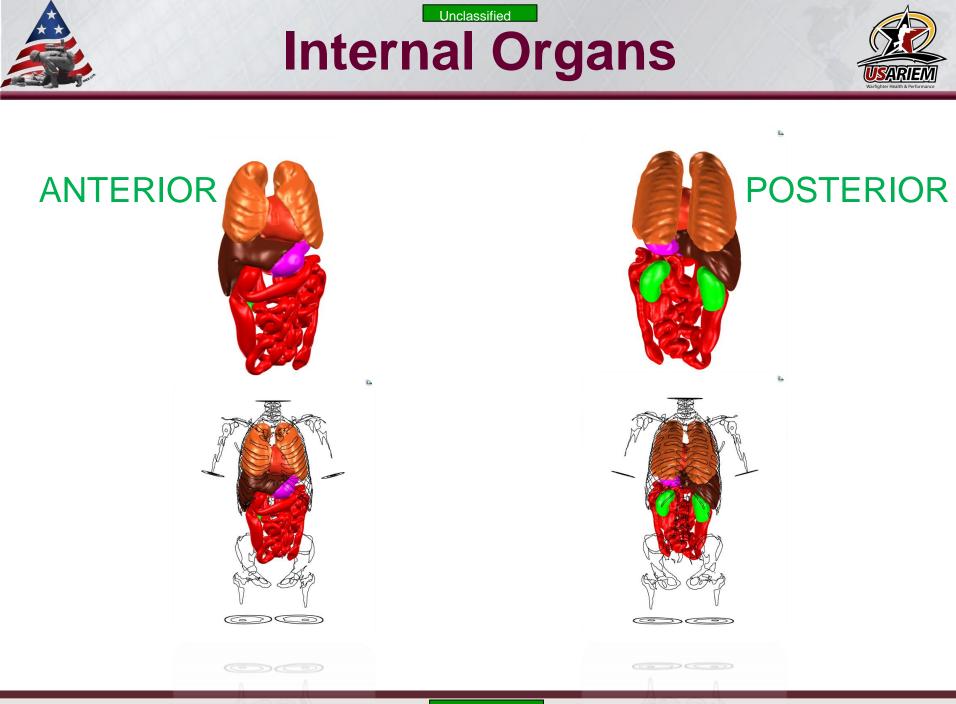




















BIOLOGICAL HEAT TRANSFER WITHIN THE BODY:

$$\rho c_p \frac{\partial T}{\partial t} = \lambda \nabla^2 T + Q + \omega_b \rho_b c_b (T_b - T)$$

HEAT FLUX AT THE SURFACE:

$$q = (h_c + h_r) \cdot (T - T_a) + E$$



Comsol Implementation

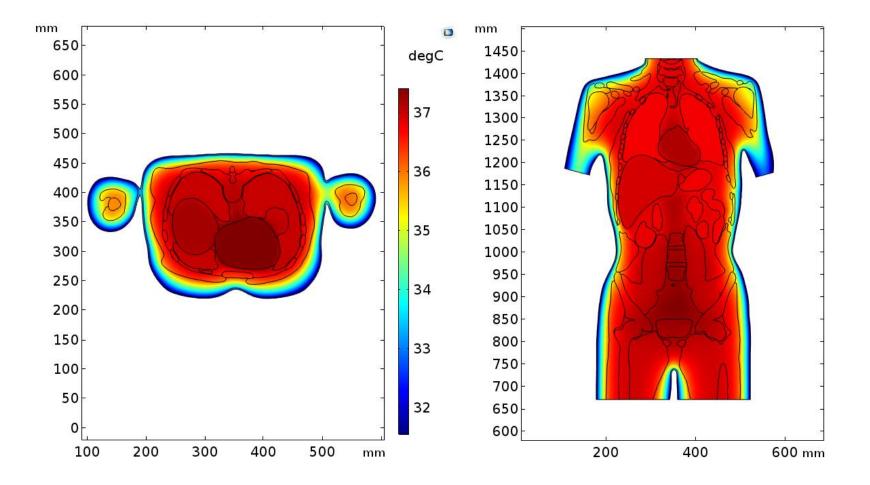


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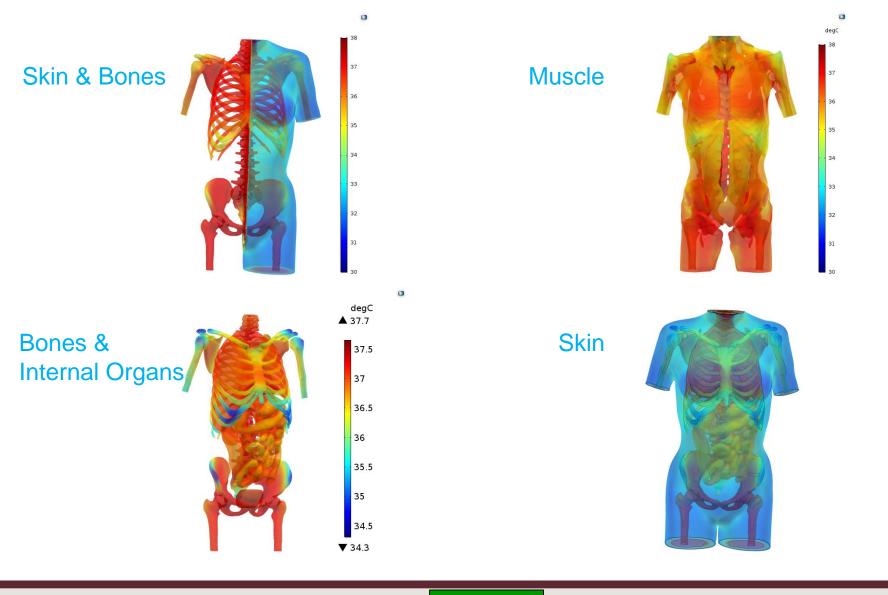








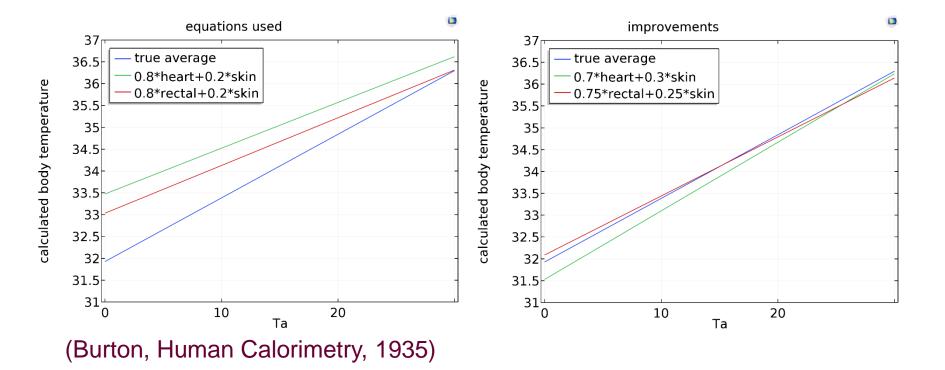




Calculating Average Body Temperature Application Example 1

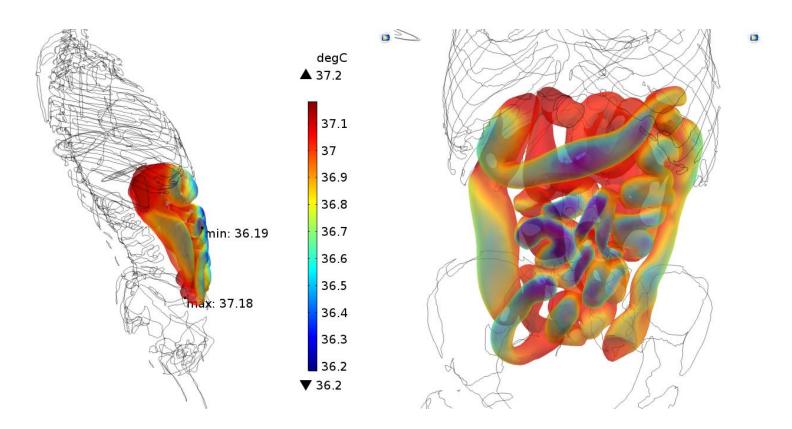












Consistent with the finding from Goodman et al. Influence of Sensor Ingestion Timing on Consistency of Temperature Measures (Med. Sci. Sports Exerc, Vol. 41, No. 3, pp. 597–602, 2009)





CONCLUSION

- The simulations provide an accurate assessment of the human body temperature with respect to the inhomogeneity
- Detailed data can be obtained from the simulations, which would be difficult to obtain during human studies, and can aid in study design and result analysis
- Finite element methods (e.g., COMSOL Multiphysics[™]) and geometries of nonhomogeneous human bodies can be used to create a new approach in modeling physiology