Dynamic Simulation of Human Heat Transfer and Thermal Comfort

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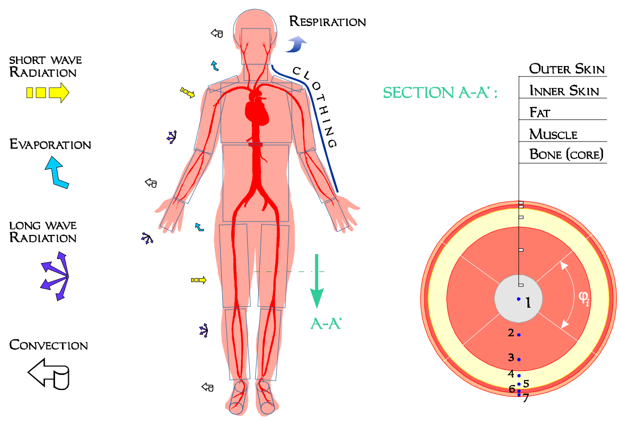
INTRODUCTION

Computer simulation of the human thermoregulatory system has been a valuable research tool contributing to a deeper understanding of the principles of human thermoregulation. Besides physiological research, however there is a growing interest to predict human physiological and comfort responses also in other disciplines of science including meteorology.

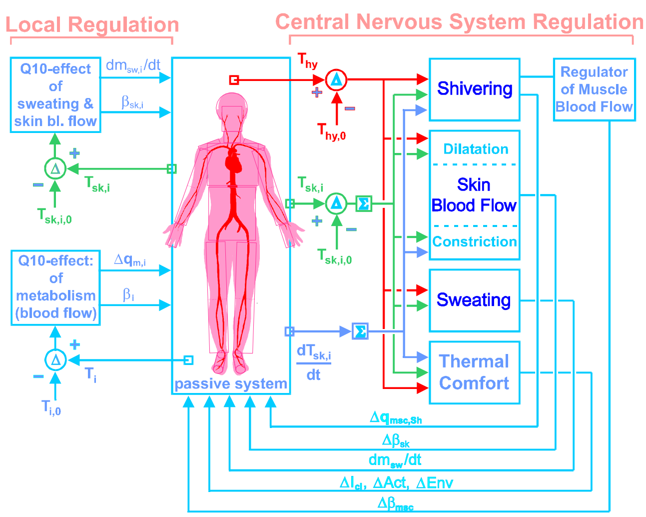
METHODS

The *Fiala Model* of human heat transfer and thermal comfort is based on six year's research work carried out at HfT Stuttgart and De Montfort University, UK. The multi-node, dynamic mathematical model incorporates two interacting systems of thermoregulation: the controlling, active system and the controlled passive system.

The passive system (Fiala et al. 1999) is a multi-segmental, multi-layered representation of the human body with spatial subdivisions which includes a detailed representation of the anatomic, thermophysical and thermophysiological properties of the human body. The model accounts for phenomena of human heat transfer that occur inside the body (blood circulation, metabolic heat-generation, -conduction, and -accumulation) and at its surface (free and forced surface convection, long- and shortwave radiation, skin moisture -evaporation, -diffusion, and -accumulation).



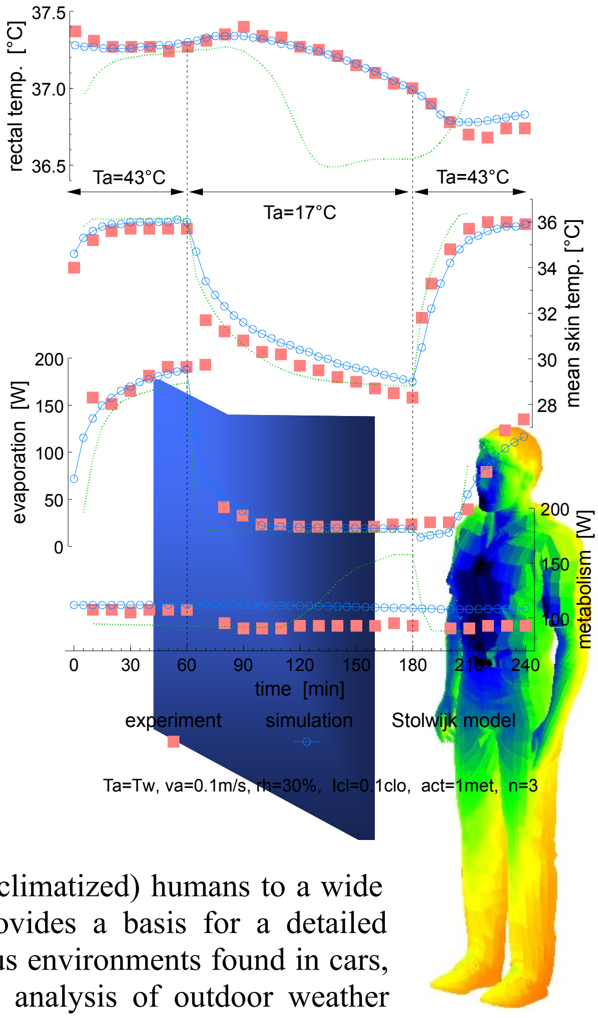
The active system model (Fiala et al. 2001) simulates responses of the human thermoregulatory system, i.e. suppression (vasoconstriction) and elevation (vasodilatation) of the cutaneous blood flow, sweat moisture excretion and changes in the metabolic heat production by shivering thermogenesis. The active system was developed by means of statistical regression analysis using measured responses obtained from steady and transient exposures to cold stress, cold, moderate, warm and hot stress conditions, and exercise intensities between 0.8 - 8 met.

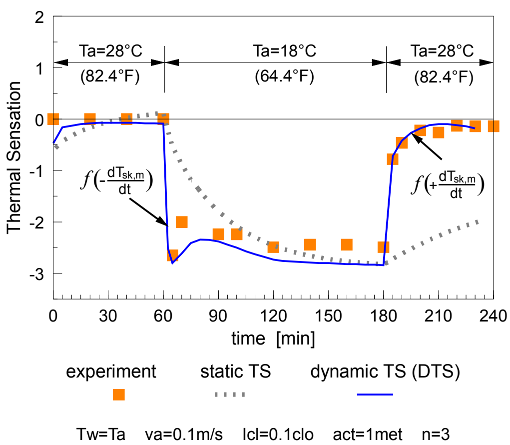


The simulation system incorporates a dynamic thermal comfort model which predicts human perceptual responses from physiological states of the body. The comfort model has been derived by regression analysis using measured thermal sensation votes obtained from over 2000 male and female subjects.

RESULTS

The thermoregulatory and comfort models have been validated against independent experimental data for wide ranging of indoor climate conditions and showed good agreement with measured regulatory responses, mean and local skin temperatures, internal temperatures and thermal sensation responses for the spectrum of conditions and personal circumstances investigated (Fiala et al. 2001, 2003, Richards and Fiala 2004).





CONCLUSIONS

The model can be used to study responses of (unacclimatized) humans to a wide ranging indoor climate conditions. The model provides a basis for a detailed analysis of the transient and complex inhomogeneous environments found in cars, buildings and other man-made spaces and for the analysis of outdoor weather conditions. An extensive validation study is currently underway as part of the COST730 Validation Exercise, to examine the performance of the model for boundary conditions specific to outdoor climates.

The model has found applications, e.g. in medical engineering to predict temperature and regulatory responses of anaesthetised patients, in the car industry to predict passengers' responses to the transient and asymmetric boundary conditions found inside car cabins, in biometeorology, textile research, some military applications, and the thermal comfort analysis of buildings and individual built components.

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