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Study of the individualization of the passive system Fiala-based human thermophysiological model

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Introduction

Currently, for predicting the physiological response of the human body the indices of thermal stress and physiological models are widely used. These models and indices can, for example, predict the risk of human exposure to the extreme conditions, further define the time limit for staying in these conditions, or to propose preventive measures during using protective clothing, etc. However, the variability of human body reaction to the same thermal stress is a general problem of physiological models' prediction. Most of these models were primarily created for an average person, which can be an issue for prediction of the physiological behaviour of people who do not meet a definition of a typical person. For this reason, approximately since the 1990s, scientists have been studying individualization of the physiological models. A lot of authors published articles in this context, for example, Havenith (1), Zhang et al. (2), van Marken-Lichtenbelt et al. (3), Takada et al. (4), Zhou et al. (5) etc. Most articles are focused on improving the passive system of the models by incorporation equations for calculation individual anthropometric data (for example weight, height etc.) of each individual person. Moreover, some articles incorporate improved equations in the active system due to individualization, for example, the sweat rate, physical fitness, etc.
This article is focused on the individualization of the Fiala-based human thermophysiological model, called FMTK (6), which was created in our department. This article is a demonstration of the ongoing study, for this reason, there are published only preliminary results in this paper.

Methods

As mentioned above this article is focused on FMTK model (6), which was validated for ambient temperature from 5 °C to 48 °C and metabolic rates from 0.8 met to 9 met. Simultaneously the model was applicated for prediction of human thermal stress in protective clothing, where the error of prediction of the mean skin temperature was 0.78 °C, the error of rectal temperature 0.2 °C and mean error of prediction of the local temperatures was 1.25 °C.
There was created "Bodybuilder" in this study, which allows generating individual input data for FMTK model (mass, skin area, height and body fat), and then the sensitivity study for four different people, see **Table 1**, was realized. The height of the person is connected with skin area according to the relation of Du Bois (7), i.e. skin area 1.86 m^2 corresponds with the height of 171.6 cm.
In this study, there was monitored mean skin temperature $T_{sk,m}$ and temperature of hypothalamus T_{hy}. The scenario of thermal load for Klimatex underwear clothing in the temperature range from 23 °C to 30 °C published in (6) was selected for the benchmark test. The person was exposed to variating and repeating metabolic activity 1-3.2 met (10 min – 20 min), see **Figure 1**. Detailed study setting is described in (6).

Table 1. Individual characteristics of four different people

Type	Mass [kg]	Skin area [m^2]	Body fat [%]
Averaged person	73.5	1.86	14.4
Thin person	68.4	1.78	14
Fat person	86.3	2.04	26.7
Thin muscular person	69.3	1.78	9.4

Results and discussion

The graphs in **Figure 1** represent results for selected case Klimatex 30 °C. The results show the influence of the individualized model on the prediction of the mean skin temperature and temperature of the

hypothalamus. It is possible to see, that fat person in comparison for example to thin muscular person is prone to overheating (see the higher temperature of the hypothalamus), it is caused by the higher percent of body fat, which acts as insulation.
However, the differences between the prediction of the temperatures for individual settings are not significant, because the scenario is simulated for warm conditions and the higher skin blood flows offset the resistance offered by peripheral adipose tissue, unlike the cold conditions where the core temperature is significantly affected by the amount of body fatness (8).

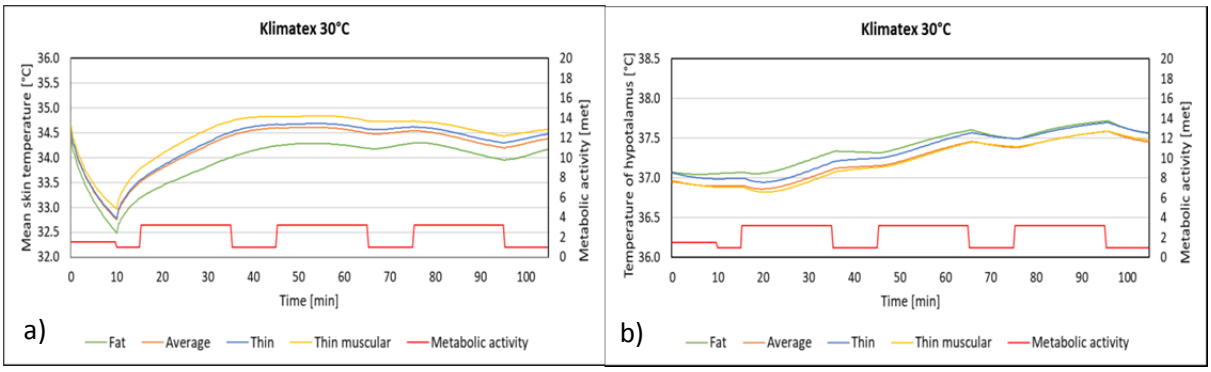

Figure 1. a) Mean skin temperature for Klimatex 30 °C, b) Temperature of hypothalamus for Klimatex 30 °C

Conclusions

This article shows the preliminary results of the ongoing study related to the individualization of FMTK model. In the first step, some anthropometric characteristics of person were individualized by the created module called “Bodybuilder”. Results show, that upgraded model reacts to individualized inputs, see **Figure 1**. The study will continue by improving the “Bodybuilder” and incorporation of individual characteristics into the active system of FMTK model.

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References

1. HAVENITH, G. Individualized model of human thermoregulation for the simulation of heat stress response. *Journal of Applied Physiology* [online]. 2001. Vol. 90, no. 5, p. 1943–1954.
2. ZHANG, H, HUIZENGA, C, ARENS, E and YU, T F. Considering individual physiological differences in a human thermal model. *Journal of Thermal Biology* [online]. 2001. Vol. 26, no. 4–5, p. 401–408. DOI 10.1016/s0306-4565(01)00051-1.
3. VAN MARKEN LICHTENBELT, W. D., FRIJNS, A. J H, FIALA, D., JANSSEN, F. E M, VAN OOIJEN, A. M J and VAN STEENHOVEN, A. A. Effect of individual characteristics on a mathematical model of human thermoregulation. *Journal of Thermal Biology*. 2004. Vol. 29, no. 7–8 SPEC. ISS., p. 577–581. DOI 10.1016/j.jtherbio.2004.08.081.
4. TAKADA, Satoru, KOBAYASHI, Hiroaki and MATSUSHITA, Takayuki. Thermal model of human body fitted with individual characteristics of body temperature regulation. *Building and Environment*. 2009. Vol. 44, no. 3, p. 463–470. DOI 10.1016/j.buildenv.2008.04.007.
5. ZHOU, X, LIAN, Z W and LAN, L. An individualized human thermoregulation model for Chinese adults. *Building and Environment* [online]. 2013. Vol. 70, p. 257–265. DOI 10.1016/j.buildenv.2013.08.031.
6. POKORNÝ, Jan, FIŠER, Jan, FOJTLÍN, Miloš, KOPEČKOVÁ, Barbora, TOMA, Róbert, SLABOTÍNSKÝ, Jiří and JÍCHA, Miroslav. Verification of Fiala-based human thermophysiological model and its application to protective clothing under high metabolic rates. *Building and Environment*. 2017. Vol. 126, p. 13–26. DOI 10.1016/j.buildenv.2017.08.017.
7. DU BOIS, D. and DU BOIS, E. F. A formula to estimate the approximate surface area if height and weight be known. *Arch Intern Med*. 1916. Vol. 17, p. 863–871.
8. HAVENITH, G, COENEN, J M L, KISTEMAKER, L and KENNEY, W L. Relevance of individual characteristics for human heat stress response is dependent on exercise intensity and climate type. *European Journal of Applied Physiology and Occupational Physiology* [online]. 1998. Vol. 77, no. 3, p. 231–241. DOI 10.1007/s004210050327.