INFORMATION TECHNOLOGY FOR PREDICTION OF HUMAN STATE DURING EXERCISE

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INTRODUCTION

The theoretical prediction of human functional state during exercise in the extreme conditions of environment refers to the actual tasks Information technologies refer to the most effective methods, that predict behavior of physiological systems .It makes possible to know consequences and to make necessary preventative actions. Information technologies were developed on the basement of the mathematical models describing interaction of man with environment [1]. They allow getting not only qualitative but quantitative estimations of physiological processes in human organism during exercise. It is possible to model practically uncountable numbers of the variants and combinations, which characterize human physical activity, clothing and environment.

METHODS

The information technologies based on the complex of the mathematical models that describe dynamical variations in the physiological processes of the human organism during exercise, variations of the environment and clothing. The mathematical description of the multycompartmental models is the system of differential and algebraic equations that describes energetic processes in the human organism. The order of the system of equations depends on the approximation of the human organism that takes place in the model.

Heat balance equation for working skeletal muscles includes heat production, heat transfer by blood flows and heat conduction between internal organs and skin.

$$c_{ij}m_{ij}\frac{dT_{ij}}{dt} = M_{ij} - a_{ij\text{-}1}\lambda_{ij\text{-}1}\ \ T_{ij} - T_{ij\text{-}1}\ \ - a_{ij}\lambda_{ij}\ \ T_{ij+1} - T_{ij}\ \ - W_{ij\text{-}1}\rho_b c_b\ \ T_{ij} - T_b\ \ .$$

Equation for blood temperature:

$$V_b\rho_b c_b\frac{dT_b}{dt} = \sum_{i=1}^{N}\sum_{j=1}^{N} W_{ij}\rho_b c_b T_{ij} - W_b\rho_b c_b T_b - v\rho_e r\ \ \rho_{ex} - \rho_{in}\ \ .$$

Skin blood flow:

$$W_s = W_s^* - S_{hy}\ \ T_{hy}^* - T_{hy}\ \ - S_{s1}\ \ T_s^* - T_s\ \ .$$

Sweat evaporation:

$$E_s = E_s^* - S_{hy}\ \ T_{hy}^* - T_{hy}\ \ - S_{s3}\ \ T_s^* - T_s\ \ .$$

Heart rate during exercise:

$$f = 20 \cdot T_b - 661 + \ 0.1 \cdot 1.16 \cdot M\ \ .$$

Where T – temperature, t – time, c – specific heat, M – exercise, λ – coefficient of the heat conduction, ρ – density, m – weight, a –surface, W – blood flow, E – evaporation from skin, V_b – blood volume, v – ventilation, W_b – cardiac output, S – sensitivity of the center thermal regulation, r –specific heat evaporation, f – heat rate; indexes: *i*, *j* – number of cylinder, *b* – blood, *e* – environment, *in* и *ex* – inspired and expired air, *hy* – brain, *s* – skin, * – initial value.

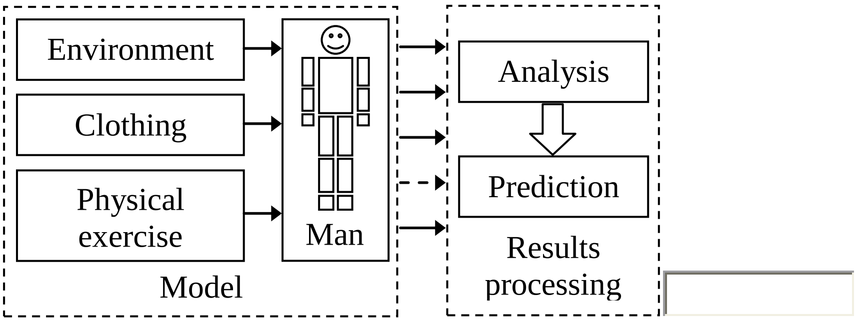

Fig.1. Block-scheme of Information technology for prediction of human state during exercise.

Information technology includes characteristics of environment, clothing, physical activity and man (fig.1). The model allows imitating different kinds of physical activity power and duration of exercise. The database of fabrics contains thermal isolation, material thickness, evaporative resistance and coefficient of the permeability. Environment is presented via temperature, humidity and air velocity. Technology allows correcting thermal sensitivity of the central and peripheral nervous systems for the modeling adaptive human properties.

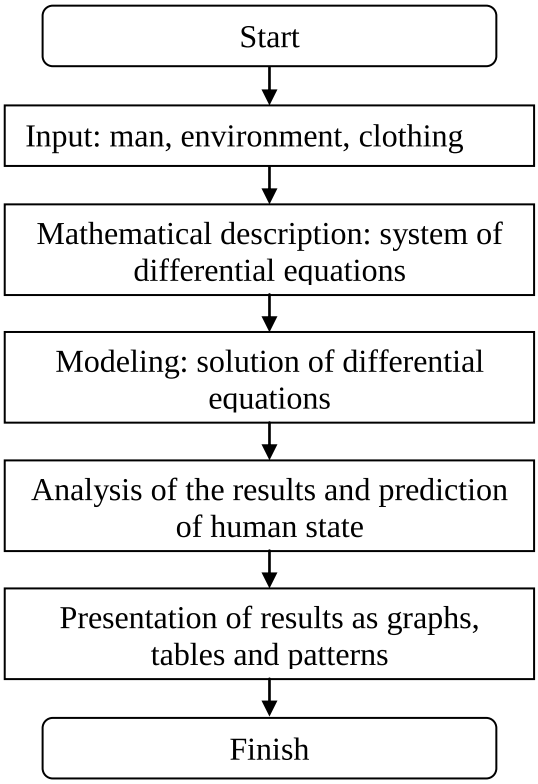

Fig.2. The algorithm of the computer experiment.

In fig.2 it is shown the algorithm of the information technology. The technologies are connected with Web to search for demanding data.

RESULTS

Information technology allows watching dynamic changes of temperatures, heat flows, heart rate, heart output, organ blood flows, metabolic rate in skeletal muscles, sweat rate, dripping and evaporative sweat rate, total water losses and many other physiological values during exercise.

In fig.3 it is shown fragment of information technology for input of environment and exercise characteristics for the computer experiment. Man is running: during 30 minutes exercise power is 500 W, than it decreases to 300 W. Exercise duration is 1.5 hours. Air temperature is 30°C, humidity is 50%, wind speed 0.3 m/sec, man wears tracksuit (shorts and T-shirt).

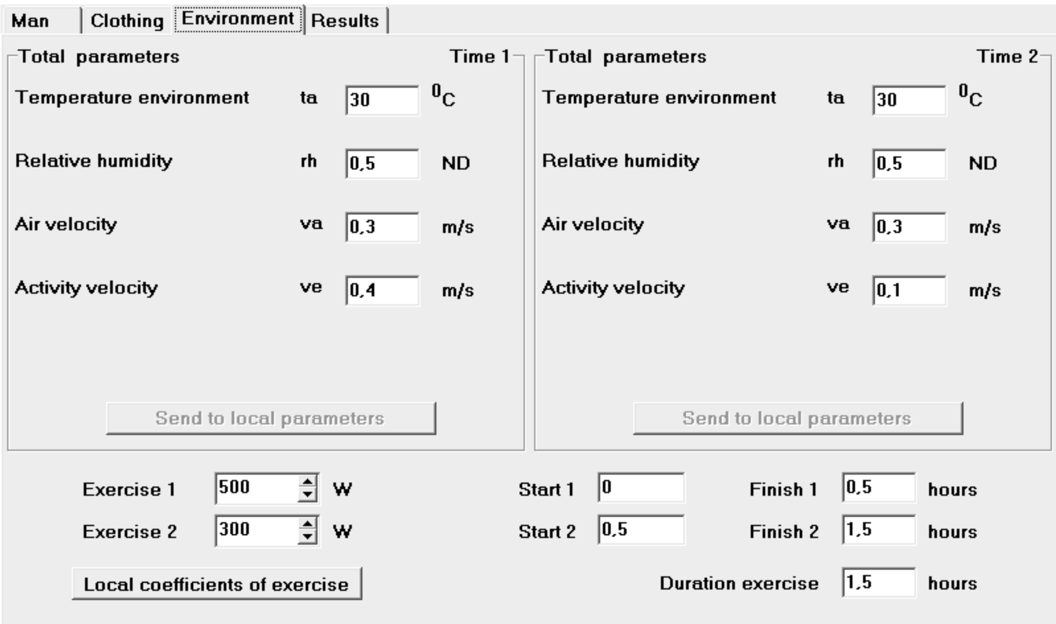

Fig.3 Form for information technology input initial data.

There are some results of the computer experiment in fig.4: heart rate, blood flow in active muscles, sweat rate and temperatures. Physical activity as a rule goes with functional boost of human body temperature that evokes efficient responses of physiological systems

There is the variation of the heart rate from 74 beats/min to 142 beats/min at the first phase of exercise and lowering to 110 beats/min at the final phase (fig.4a). To get necessary oxygen to the active muscles heart output increases practically proportionally to the power of physical exercise. The blood flow in skeletal muscle is equal 150 l/h in the first phase and 90 l/h in the second phase (fig.4b). The sweat evaporation increases deeply to 520 g/h under the start exercise (500 W). In the second phase (300 W), it decreases to 300 g/h integrally at the all experiment water losses are not more than 2% from body weight. It means there is no danger to dehydration of organism (fig.4c) [3, 4, 5]. The dynamic increase of blood, muscles and skin temperatures are shown in fig.4d. The temperatures variations depend on power and duration exercise.

Prediction of human state in this experiment allows concluding there are no danger hazards for human organism. Circulatory and fluid-and-electrolyte systems appeared effective and didn't out of tolerance of human functional reserves. It's became available because of conditions for skin evaporation. In this case air humidity and clothes properties had promoted for the heat withdrawal through sweat evaporation into environment. Exactly evaporation allowed to take away surpluses of metabolic heat and to prevent overheating of organism.

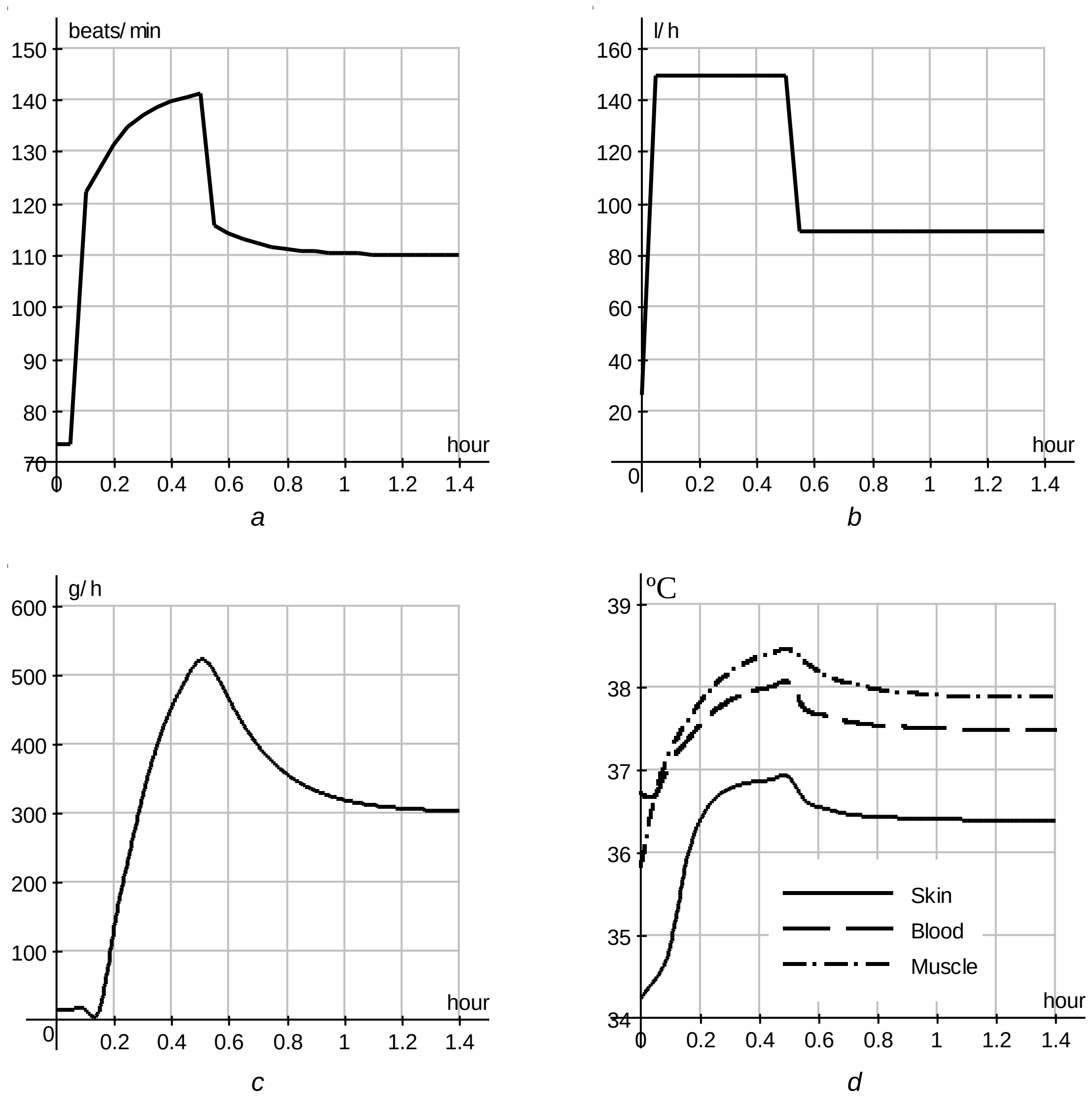

Fig.4. Results of computer experiment under 500 W (from 0÷0.5 hour) and 300 W (from 0.5÷1.5 hour): a - heart rate, b – blood flow in skeletal muscles, c – sweat rate, d - temperatures.

Thus, by means of technology it was possible to estimate quantitatively control responses of an organism during physical activity. Comparison with experiments in man showed model validation [4].

CONCLUSIONS

The model allows to predict dynamics of a human functional state during physical activity in different conditions of environment and wearing various clothing. Modeling maybe useful for choice of available power and duration of exercise in definite environment and for choice of comfortable clothing. The model can be used for the analysis extremely dangerous situations and taking correct decisions.

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