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METHODS

Mathematical Model of Human Body Surface Area

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A novel universal mathematical model for calculation of human body surface area with maximum accuracy is proposed.

Key Words *human, body surface area*

Body surface area, a principal characteristic of the organism widely used in experimental medicine and clinical practice, is calculated by few empirical formulae [2-5]. The accuracy of these estimations is uncertain, and results significantly differ from each other. Our aim was to find the optimum strategy for solving this problem.

Our consideration was based on the geometrical rule that the surface area of the body (S) can be derived from its volume according to the equation: $S=\mathrm{k}\times V^{2/3}$ (**1**), where k is a coefficient depending on the shape of the body. If a human subject with parameters (V_0, S_0, k_0, H_0 — *height)* is taken as a reference model, than other humans represent either geometrical duplicates (or isomers, with $\mathrm{k}=\mathrm{k}_0$) or stretched copies of this model (allomers, with $\mathrm{k}<\mathrm{k}_0$ or $\mathrm{k}>\mathrm{k}_0$). Equation (**1**) is valid only for humans with identical shapes and, therefore, of is limited usage.

By stretching a cube of volume V_0 to a parallelepiped with the same volume and shape coefficient $\mathrm{k}=\mathrm{k}_0$, we can obtain a geometrical equivalent of the reference human with the surface area S_0. In this case $\mathrm{k}_0=(4C_0^{3/2}+2)/C_0$ (**2**), where C_0 is the ratio of the parallelepiped (H) and cube heights. It can be proved that the total surface area of any parallelepiped (either isomer or allomer) is calculated from the reference one by the equation: $S_n=S_0(H_n/H_0)^{\mathrm{d}}(V_n/V_0)^{2/3-\mathrm{d}/3}$ (*3*), where S_n, H_n, V_n are parameters of the new parallelepiped, and d is an individual index of the reference parallelepiped derived from C_0. One can calculate index d for any equivolume copy (allomer) of the reference parallelepiped by putting parameters of the allomer into equation (**3**).

Since equation (**3**) does not depend on the shape of the stretched body, it is also applicable to humans. We took a man with body weight of M_0=70 kg, density 1.064 g/cm^3, height H_0=170 cm, and S_0=18,000 cm^2 and a women with M_0=58 kg, density 1.034 g/cm^3, H_0=160 cm, and S_0=16,000 cm^2 as reference models [1] Using method of geometrical simulation, and calculating individual indices d, we obtained equations for calculating body surface area in man: $S_n=H_n^{0.461}\times M_n^{0.513}\times 190.766$ (**4**); women $H_n^{0.461}\times M_n^{0.513}\times 192.036$ (**5**); and irrespective of sex: $S_n=H_n^{0.461}\times M_n^{0.513}\times 191.563$ (**6**). After fractions had been round off, these equations looked as $S_n=(H_n\times M_n)^{1/2}\times 165.0$ (**7**), $S_n=(H_n\times M_n)^{1/2}\times 166.1$ (**8**), and $S_n=(H_n*M_n)^{1/2}\times 165.7$ (**9**), respectively.

The relative error of estimation of human body surface area by formulae (**4, 5, 7, 8**) did not exceed, respectively, 0.1, 0.1, 0.8, and 0.8% of the surface area of reference parallelepipeds with the same values of V and k. In averaged formulae (**5, 6**) and (**8, 9**) this error increased to 0.3 and 1.0%. For comparison, F. Benedict's formula: $S_n=1{,}100\times M^{2/3}$ [2]; H. Costeff's formula: $S_n=10{,}000\times(4M_n+7)(M_n+90)$ [4]; formula of D. Du Bois *et al.*: $S_n=\mathrm{H}_n^{0.725}\times M_n^{0.425}\times 71.84$ [5]; and formula of S. Brody *et al.*: $S_n=\mathrm{H}_n^{0.40}\times M_n^{0.53}\times 240$ [3] gave the following accuracy of the estimates calculated for

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the reference man: 3.8, -0.35, 0.54, and -1.14%, respectively. If applied to allomers of the reference man, these errors changed to -4.68, -8.48, 5.38, and 2.34% (when H_n=1.2 H_0 and M_n=M_0) and to 12.82, 8.31, -4.25, -0.11% (when $H_n={}^1/_{1.2}$ H_0 and M_n=M_0), respectively. Thus, formula [3] gave the best estimation. However, in practice, formulae [2] and [3] are most frequently used. At the same time, empirical character of formula [3] can be easily demonstrated by applying it to an isomer of the reference man with H_n=1.2H_0 and M_n= M_0×1.2^3. According to the formula, coefficient k decreased in this case from 10.919142 to 10.908739, which contradicts to equation (**1**). In contrast, according to formulae (**4, 5, 7, 8**) coefficient k remains constant for all geometrically identical copies (isomers) of the reference human. Thus, equation (**3**) can be considered as a universal model for human body surface area, which is applicable to infinite number of shape variants taken as a reference model and characterized by individual parameters H_0, V_0, S_0, and d.

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