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METHODOLOGICAL ASPECTS OF EVALUATING A HOMEOSTASIS OF A BIOLOGICAL OBJECT

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A biological object (BO) can be defined as a physico-chemical system existing in the environment at steady state. Various anatomical, physiological, and behavioral adaptations have been developed to ensure a steady state in all BOs (from the morphologically simple to the most complex). They are aimed at the formation of various forms of adaptation at all levels of organization of biological object: molecular, cellular, tissue-organ, organism etc. [1, 2]. The dynamic constancy of the internal environment of the BO and its fluctuations within the acceptable limits are determined by the so-called homeostasis, characterized by homeostatic parameters (constants). Knowledge of the state of human homeostasis allows early registration of the onset of any processes in the body; evaluate the effectiveness of any effect on the body, adjust the tactics and dosage of any therapy; evaluate side effects from any manipulations, lifestyle changes; evaluate the ability to perform complex camera work in extreme conditions (controllers, pilots, sailors, special forces, rescuers etc.).

In describing and evaluating homeostasis, a number of methodological approaches are used that rely on a large variety of indicators. In particular, physiological, psychological, complex and structural methods are distinguished among methodological approaches to the assessment of functional status. There are methods of assessment based on one of the subsystems of the organism [3], based on the determination of the functional state of the system [4]; stress assessment of immune regulation mechanisms [5], etc. The disadvantages of these approaches are the inability to account for random influences, both external and internal. This does not take into account the degree of preservation of the functioning of the organism in general, and in very rare cases defines the functioning of a particular system. That is why the urgent task is to create a methodology for homeostasis assessment, which is based on the principle of systematicity, which will explore the human body as a whole structure. [7].

To assess the state of homeostasis of such a complex object as the human body, it is proposed to use polyparametric information technologies for a comprehensive systematic approach to determining the correlation of parameters that characterize the interaction of each of the subsystems of the organism. Figure 1 shows a block diagram of obtaining and converting measurement information about the values of the organism. The measurement unit converts the measured values $X_1^*,...,X_k^*$ of the controlled values into the estimate Y^* of the parameter Y, where $a_1,..., a_p$ – are the coefficients of the mathematical model of transformation:

$$M[Y]=F(M[X_1],...M[X_k]). \tag{1}$$

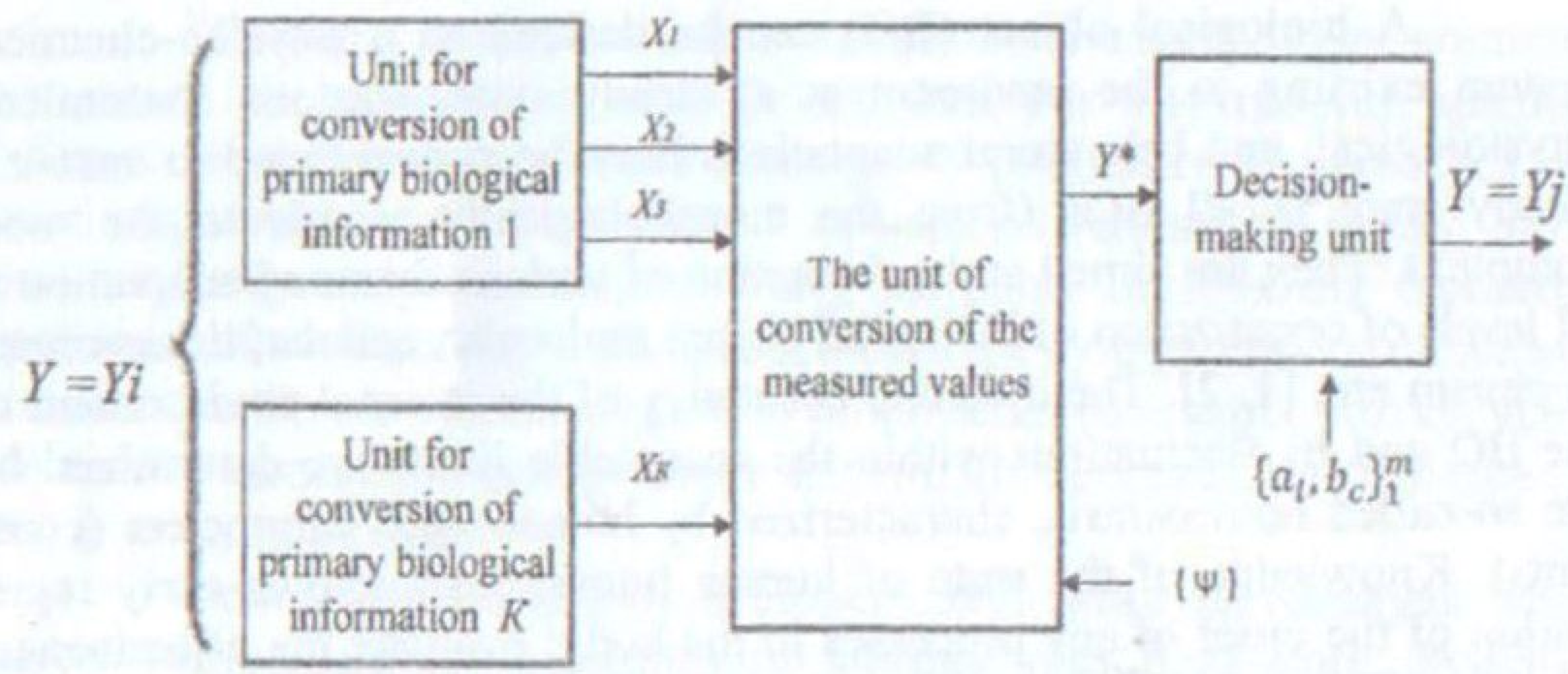

Fig. 1. Structural diagram of information model of homeostasis index transformations

Such a structure is equivalent to a diagnostic information system with k input measuring channels. The coefficients $a_1,...a_p$ are estimated at the stage of studying the object of diagnosis by sampling volume n for each of the fixed quantities $Y_j, j=\overline{1,m}$ levels of parameter Y. The decision-making unit makes the choice $\{a_l, b_c\}_1^m$ of one $y_j\{a_l, b_c\}_1^m$ of many y_{j1}^m

decisions about the value of Y after comparing Y^{*} with the norm $(a_l,b_l), l=\overline{1,m}$ according to the choice rule decision:

$$\forall Y^{*}\left[Y^{*}\in\left(a_j,b_j\right)\rightarrow Y^{*}\in Y_j\right]. \qquad (2)$$

The set $\{\psi\}$ are factors that influence the correctness of the choice of the model of transformation $\bar{F}(\bullet)$ and the accuracy of the estimation of the coefficients $a_1,\ldots, a_p$ of this model [6].

We find an estimate of the amount of information about the parameter Y, considering that the width Δ of the tolerance intervals $\left(a_j,b_j\right), j=\overline{1,k}$ is the same, and the total number is equal to k. In this form, the amount of information is determined by the difference between the original $H(Y)$ and the conditional $H(Y|Y_j)$ entropy [10]: $I = H(Y) - H(Y|Y_j)$, where, $H\left(Y\right)=-\sum_{j=1}^{k}\left[\int_{a_j}^{b_j} f(y)dy\right]\ln\left[\int_{a_j}^{b_j} f(y)dy\right]$; $f(y)$ – the density distribution of the value Y in the range A_y [7].

We find the conditional entropy by the conditional probability $P(Y_i|Y_j)$ that the true value of M[Y] = Y_j, while the result of the solution y_j gives the value $Y = Y_j$: $H\left(Y|Y_j\right)=-\sum_{i=1}^{k}P\left(Y_i|Y_j\right)\ln P\left(Y_i|Y_j\right)$

If the distribution of values of $Y_1,\ldots, Y_\kappa$ is equally probable and the law of distribution of deviations of Y^{*} from the actual value of M[Y]= const is normal, if the variance of this deviation is σ_y^2, we have:

$$H\left(Y\right)=\ln\frac{A_y}{\Delta} \rightarrow H\left(Y|Y_j\right)=\ln\frac{\sigma_y\sqrt{2\pi e}}{\Delta}. \qquad (3)$$

Estimation of the amount of information, taking into account expressions (5), (6) will take the form:

$$I=\ln\frac{A_y}{\sigma_y\sqrt{2\pi e}}. \qquad (4)$$

In this case, the variance σ_y^2 can be represented as:

$$\sigma_y^2=\Delta_\psi^2\left(1+k\sigma_X^2\right)n^{-1} \qquad (5)$$

In multiple measurements of parameter Y, expression (5) will take the form: $\sigma_y^2 = \Delta_\psi^2 \left(1 + \frac{k}{N}\sigma_X^2\right) n^{-1}$.

Substituting expression into equation (4) we obtain:

$$I = \ln \frac{A_y}{\Delta_\psi^2 \sqrt{2\pi e \left(\frac{1}{k} + \frac{\sigma_X^2}{N}\right)}} \sqrt{\frac{n}{k}}. \quad (6)$$

Expression (6) can be considered as the amount of expected information about the studied value of Y for the variance σ_x^2 of the input values $X_1,..., X_\kappa$. The presence in the denominator, under the logarithm of the expression, the displacement Δ_ψ determines the magnitude of systematic displacements that cannot be eliminated when estimating the coefficients of the measurement transformation model. The latter indicates the importance of the training phase of the diagnostic system.

The considered approach allows to obtain a decision-making system for the state of human homeostasis based on the integral source index, obtained by input parameters, which are interconnected random variables and contain variations and have systematic displacements.

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