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The influence of body mass on its elemental status

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Abstract. The study is devoted to assessing the effectiveness of the developed methodology for the multivariate analysis of the mutual influence when identifying of the elemental status of an organism. In a multidimensional space, the coordinates of which are the concentrations of elements, patients with the same body mass are located on the hyperplane. In order to carry out calculations related to the assessment of the influence of mass, it is necessary to break up a cloud of patient data on the hyperplates in increments of mass. As a reference element, when estimating the distance of the calculated point for each hyperplate, the beam of norms is chosen as introduced in the previous study, and the angle of rotation of the beam drawn to the calculated point is measured from the intersection line of the plane of equal mass and the plane of a given concentration. The calculations take into account only areas of high or low concentration of the element. In this case, the intersection lines of the plane of equal mass and the planes of a given concentration of each element form a set of rays on the plane of equal mass. The position of the calculated point in relation to this population allows us to assess the degree and direction of the influence of the selected element on all others. The advantage of the developed technique is the reduction of multidimensional analysis to the evaluation of two parameters - distance and angle of rotation.

1. Introduction

The elemental status of an organism is one of the fundamental indicators of health [1, 2, 3]. The use of multidimensional space as a way of representing a large amount of information used to diagnose the elemental status provides many advantages [4, 5]. To this end, in a multidimensional space, along the axes of coordinates, values are deposited estimating the weight content of each of the chemical elements and the elemental status is represented by the elemental status of a particular patient. In this space, it becomes possible to integrate the study with the allocation of local areas, reflecting the adaptation of the indigenous population to the conditions of a particular biogeochemical province. Integral research requires appropriate methods and criteria. Consider one of the methods of their formation.

2. Theory

The ideas of multidimensional space were expressed in the 18th century by I. Kant and J. D'Alamber, and multidimensional geometry was constructed by A. Cayley, G. Grassmann and L. Schlegel in the past century [6].

The representation of an organism in the multidimensional space of elements has many advantages, including the fact that the sum of all coordinates will be equal to the weight of the organism. However,



this approach is not convenient due to the large range of changes in the concentrations of elements. Scaling helps to improve the situation. We define the corresponding coefficients.

For the body to function properly, the ratio between the elements is important [7]. If the weight contents of the elements are coordinates in the multidimensional space x_i , then the locus of the points having the same relationship between the coordinates will be the ray emanating from the origin, described by the equation

$$x_i = tx_{Ai} \quad (1)$$

where x_{Ai} are the components of the radius of the vector defining this ray, t is an arbitrary parameter that allows the point representing the organism to run along the ray depending on its mass.

As noted in the introduction, the sum of all coordinates, which determines the mass of the body, is also important. The locus of points with the same sum of coordinates in a multidimensional space is the hyperplane, described by the equation

$$\sum_{i=1}^n x_i + D = 0 \quad (2)$$

where n is the number of elements taken into account.

A distinctive feature of this formula is the unit coefficients at all coordinates. For two coordinates, this property has a straight line running at an angle of 45 degrees to the axes of coordinates. On such a line for each point, an increase in one coordinate leads to an equal decrease in the other, so that the sum of the coordinates will be saved.

Similar reasoning in three-dimensional space leads to a plane inclined at equal angles to all coordinate planes; the hyperplane, which can be called the hyperplane of equal contributions, should have the same property.

Therefore, in order to preserve the properties of an equal contribution in formula (2), the coordinates must be equal. However, the actual weight content of elements can differ greatly from each other, since some elements in the body are micrograms (microelements), and others are kilograms (macroelements). To overcome this problem, we use scaling factors. Figure 1 shows the histograms of the average content of each of the 24 elements arranged in ascending order.

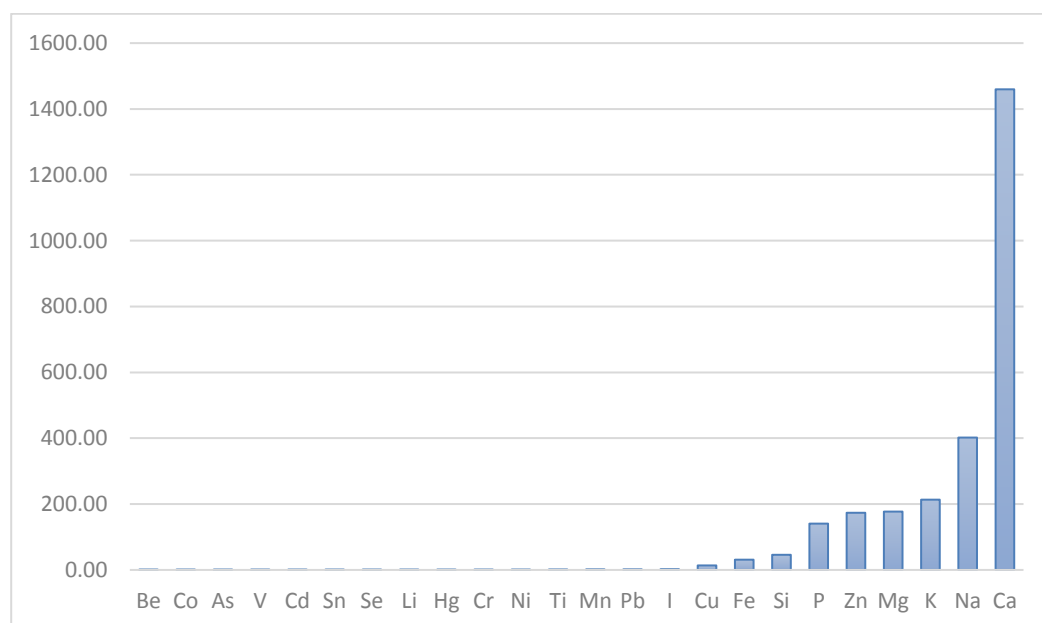


Figure 1. Determination of scaling factors

Let us take the average level of these histograms as the reference level. The obtained values of the scaling factors are summarized in the table.

Table 1. Values of scaling factors for each element

Element	Coeff.	Element	Coeff.	Element	Coeff.	Element	Coeff.
Be	14311,57	Se	378,87	Mn	74,16	P	0,79
Co	2680,58	Li	254,93	Pb	73,62	Zn	0,64
As	1823,31	Hg	237,5	I	56,57	Mg	0,63
V	1010,12	Cr	219,74	Cu	8,17	K	0,52
Cd	636,21	Ni	183,84	Fe	3,57	Na	0,28
Sn	520,61	Ti	93,6	Si	2,42	Ca	0,08

The beam of norms can be constructed using the statistics of the selected technological process. To determine the position of the vector defining the beam by formula (1) taking into account the scale factors, we use the method described in [4]. This method differs from the usual least squares method only in that the distance between the points is taken in the plane of equal contributions.

$$\sum_{j=1}^m x_{ij} (\sum_{k \neq i, k=1}^n x_{Ak})^2 + x_{Ai} \sum_{k \neq i, k=1}^n x_{Ak} (\sum_{j=1}^m x_{ij} - \sum_{j=1}^m \sum_{i=1}^n x_{ij}) = 0, i = 1, \dots, n \quad (3)$$

Here x_{ij} is the i -th coordinate of the j -th organism, the total coordinates (elements) n , and organisms m .

However, in practice, the depicting point describing the organism will deviate in the plane of equal contributions from the point of intersection of this plane with the ray of norms.

The difference between a specific organism and the norm (deviation from the norm beam) can be estimated by two parameters determined in the plane of equal contributions: the distance of the imaging point from the intersection point of the norm beam and the plane of equal contributions and the angle of rotation of the beam to the imaging point in this plane.

To determine the distance of the imaging point B, you must first construct a plane of equal contributions passing through it. To do this, we substitute its coordinates into equation (2) and find the parameter D . Finally, the hyperplane equation

$$\sum_{i=1}^n x_i - \sum_{i=1}^n x_{Bi} = 0 \quad (4)$$

Now it is necessary to find the point C, the intersection of the norm ray with the plane thus defined, for which we substitute the coordinates (1) into equation (4) and determine the desired point C through the parameter t

$$t_C = \frac{\sum_{i=1}^n x_{Bi}}{\sum_{i=1}^n x_{Ai}} \quad (5)$$

As a result, the distance is estimated by the following formula

$$\rho = \sqrt{\sum_{i=1}^n (x_{Bi} - \frac{\sum_{k=1}^n x_{Bk}}{\sum_{k=1}^n x_{Ak}} x_{Ai})^2} \quad (6)$$

The angle of rotation of the beam on the imaging point in the plane of equal contributions must be counted from some line. Let us take in this quality the line of intersection of the constant plane along the supporting (first) element with the plane of equal contributions. The equation of this line is as follows.

$$\begin{cases} \sum_{i=1}^n x_i - \sum_{i=1}^n x_{Bi} = 0 \\ x_1 = \text{const} = x_{C1} \end{cases} \quad (7)$$

For simplicity, we translate the definition of this line as a line passing through two points - C and E, where the last point is the point of intersection of the line given by system (7) and the coordinate plane

formed by the first and second coordinate axes. The second coordinate of point E is found by substituting the second equation (7) into the first

$$x_{C1} + x_{E2} + 0 + \dots + 0 - \sum_{i=1}^n x_{Bi} = 0. \quad (8)$$

From here

$$x_{E2} = \sum_{i=1}^n x_{Bi} - x_{C1}. \quad (9)$$

The angle between the straight lines CB and CE is determined by the scalar product

$$\cos \varphi = \frac{|\overline{CE} \cdot \overline{CB}|}{|\overline{CE}| |\overline{CB}|}. \quad (10)$$

From here

$$\varphi = \arccos \frac{|\sum_{i=1}^n x_{Bi} - x_{C1} - x_{C2})(x_{B2} - x_{C2}) + \sum_{i=3}^n x_{Ci}(x_{Bi} - x_{Ci})|}{\sqrt{(\sum_{i=1}^n x_{Bi} - x_{C1} - x_{C2})^2 + \sum_{i=3}^n x_{Ci}^2} \sqrt{\sum_{i=1}^n (x_{Bi} - x_{Ci})^2}}. \quad (11)$$

Using this technique, information of a multidimensional space is integrated in only three indicators: the mass of the organism, the distance of the imaging point from the intersection point with the norm beam and the angle of rotation of the ray onto the imaging point.

3. Model

To identify the dependence of the influence of one element on another [8.9] on the mass of the organism, it is necessary to organize a study with a successive change in mass, and with it to organize a shift of the plane of equal contributions, for example, with a step Δt , as shown in Figure 2, which

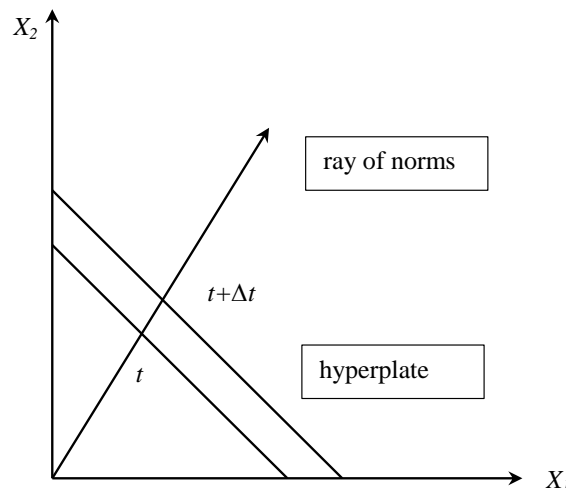


Figure 2. Hyperplateline allocation scheme

will divide the space by hyperplates. For the calculation, we will use only data on organisms representing points (points with coordinates that are the corresponding scaled concentrations of elements in a given organism) which fall into the corresponding hyperplates. To take into account the effect of cases of exceeding the concentration of the element under consideration, the condition that the representative point falls into the hyperplate in question is as follows

$$\begin{cases} \sum_{i=1}^n x_{ij} > D = -t \sum_{i=1}^n x_{Ai} \\ \sum_{i=1}^n x_{ij} < D = -(t + \Delta t) \sum_{i=1}^n x_{Ai} \\ x_{ij} > C_i, \quad i = 1, \dots, n, j = 1, \dots, m \end{cases} \quad (12)$$

Now suppose that conditions (12) are satisfied by m representing points. To reveal the interrelationships of the elements, it is then necessary to consider only m points satisfying conditions (12). For all other elements The change in position of the midpoint with respect to the norm determined for all data is evaluated.

This means that all points from the set m included in this hyperplane are considered. Further, the calculation is made according to the formulas (10) - (12) and the graphs of the parameters (11) and (12) depending on the body mass are plotted.

The presence of the relationship between the concentrations of individual elements is judged directly by each coordinate.

4. Data and methods

The calculations are based on an extensive database formed as a result of a comprehensive clinical and physiological examination and determination of the elemental composition of biosubstrates of 910 people of different sex and age. Hair and nails were used as biosubstrates. Despite the long period of exposure, such biosubstrates have been used for a long time for general measurements and, in particular, there is extensive experience in detecting and measuring the content of metals in the human body [10].

Determination of the content of chemical elements in biosubstrates, was carried out by atomic emission and mass spectrometry. Using an Elan 9000 mass spectrometer (Perkin Elmer, USA), the contents of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Si, Sn, Ti, V were determined, and The Optima 2000 V emission spectrometer (Perkin Elmer, USA) was used to determine Ca, Mg, P, Zn, K, Na. In total, data were obtained on the content of 24 chemical elements.

The effect of increased calcium concentration, both integral on all elements, and separately on the content of potassium, sodium and cobalt was investigated.

5. Results and discussion

The results of the research are presented in Figures 3-7. Studies have shown the overall integral effect of increased calcium content on the remaining elements. In this case, the direction of influence is maintained (the angle $\varphi = 89^\circ$ in Figure 4 is approximately preserved), and the distance from the norms increases as the body mass increases - Figure 3.

Other results show separately taken elements. The concentration of potassium (Figure 5) and sodium (Figure 6) increases as the body mass rises to an average value of 80 kg, and then begins to fall quite sharply. The cobalt concentration (Figure 7) has the appearance of an inverted bell, which is also predominantly located up to average weight.

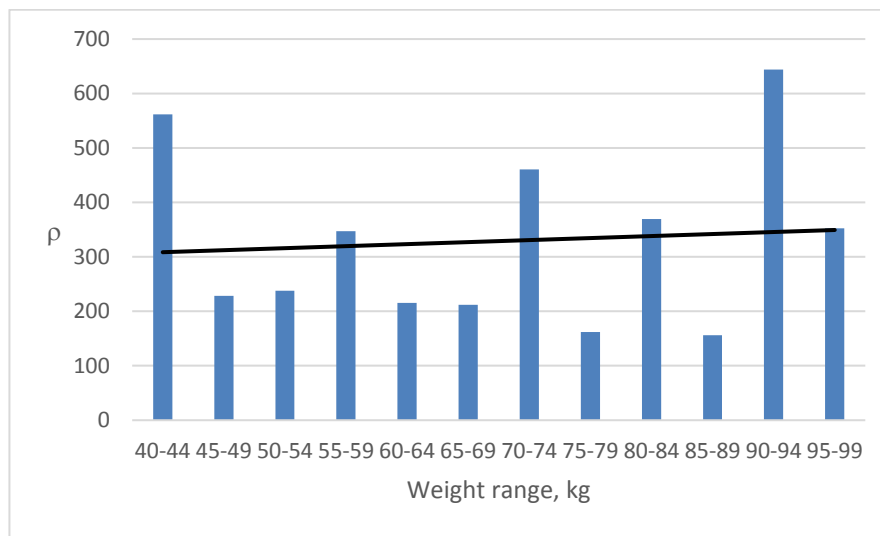


Figure 3. The dependence of the integral distance from the norm

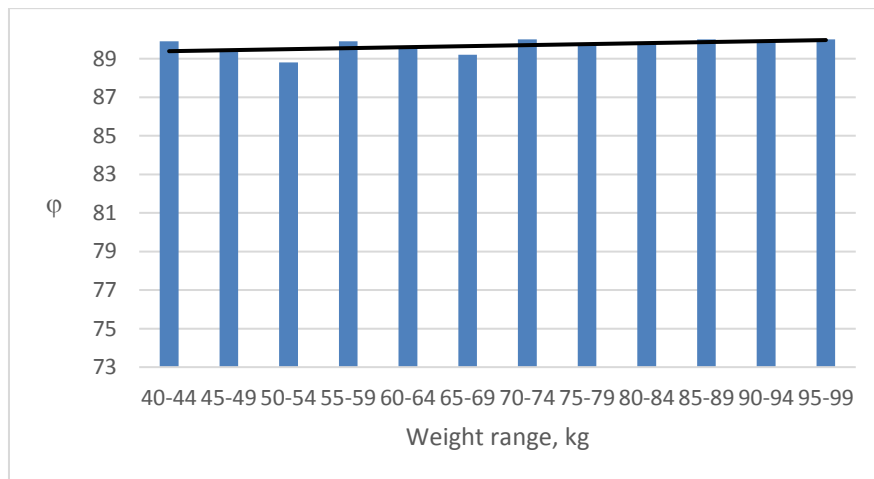


Figure 4. The dependence of the integral angle of rotation of the beam on the imaging point in the plane of equal contributions

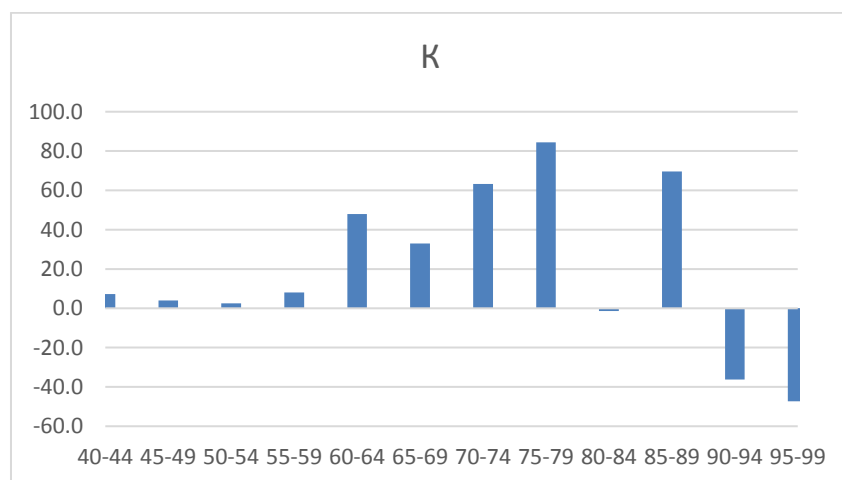


Figure 5. Changes in the concentration of potassium at elevated concentrations of calcium depending on the mass of the body

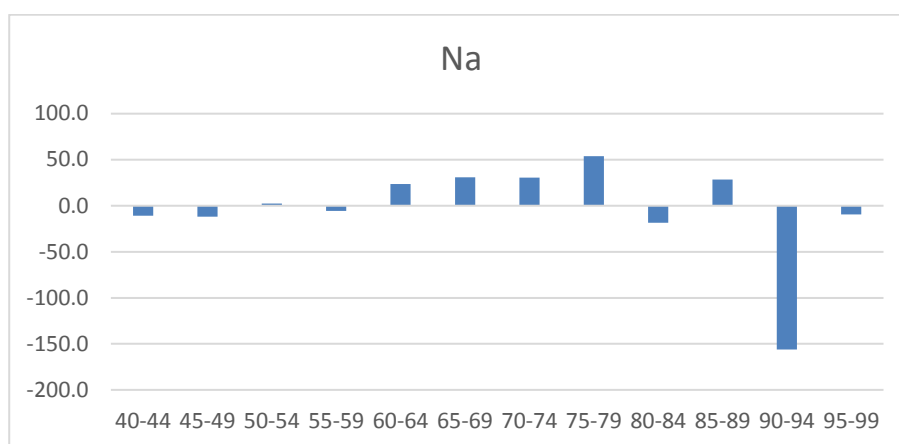


Figure 6. Changes in the concentration of sodium at elevated concentrations of calcium, depending on the mass of the body

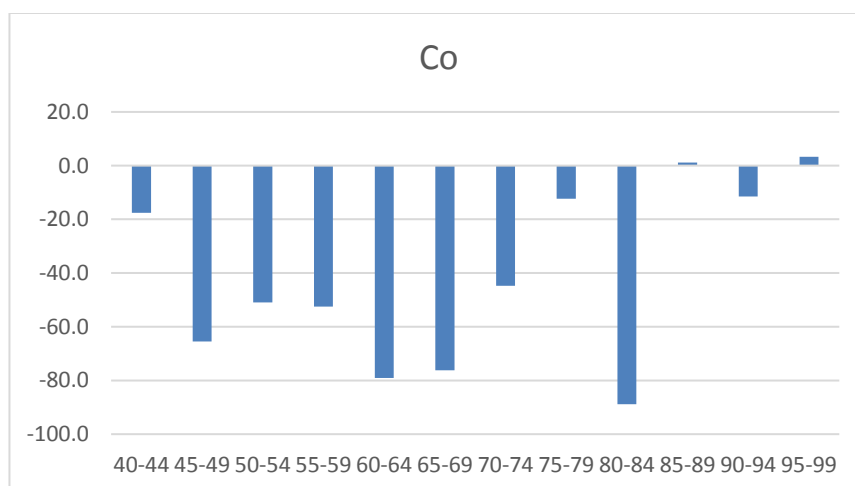


Figure 7. Change in cobalt concentration at elevated calcium concentration depending on body mass

6. Conclusion

Thus, the influence of the mass of the organism on its elemental status exists, is associated with the average mass of the human body and can affect differently. A method of integral assessment of this influence was developed, which reduces the evaluation procedure to the analysis of three parameters, the body mass, the distance of the subject from the norm and the direction to the point representing the subject in the multidimensional space of elements.

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