Original scientific paper
UDC 572.087.1-057.874

COMPARISON OF INDEXES OF PHYSICAL DEVELOPMENT BIOLOGICAL OBJECTS MEASURED BY ANTHROPOMETRIC AND BIO-IMPEDANCE METHODS

Alexander Zharnov[1], Natallia Bashun[2], Olga Zharnova[3], Natallia Chuhai[2*], Anna Chekel[2]

[1]Faculty of biology and ecology, Yanka Kupala State University of Grodno, Ozheshko 22, 230023 Grodno, Belarus

[*]e-mail: nv.chugai@mail.ru

Abstract

Numerical estimates of individual physical development are currently carried out both on the basis of anthropometric measurements (height, weight, body mass index, waist circumference, hip circumference) taking into account gender and age, and using the registration of the parameters of the body's own physical fields of the biological object. Anthropometric measurements do not represent particular difficulties, while the registration of body parameters is carried out on rather expensive equipment: computed tomography, neutron activation analysis, X-ray densitometry, etc. Correlation between different methods of assessing physical development in the available literature is not shown, which stimulated studies on the comparison of the indices of physical development (Quetelet, Broca, Yarho-Kaupe and Rohrer) with the data of relative fat mass by bioimpedance analysis.

Anthropometrical and bioimpedance measurements for female persons of the youthful age period are presented in this study. In total 96 students participated in the research, average age was 19 ± 1.5 years. The indexes of physical development, connecting the weight and geometry of objects are defined on the basis of anthropometrical data for participating in an experiment. The distribution of relative fatty body weight is determined by the received electric characteristics (fatty weight, rated to all body weight) with use of the Medass analyzer Statistical calculations of the obtained experimental data of indexes of physical development and relative fatty weight are carried out. A pair exponential regression was chosen at a stage of the specification. Its parameters were estimated by method of the smallest squares. The statistical importance of the equation was checked by means of coefficient of determination and Fischer's criterion. The correlation coefficients between indexes of physical development and relative fatty weight are calculated.

As a result of statistical processing of the obtained experimental data correlation coefficients between three main, indexes of physical development and data of fatty body weight of objects are calculated. The maximum coefficient of correlation (b = 0.042) is noted between relative the fatty mass of objects and Quetelet's index. Thus, comparison of indexes of physical development of the studied persons of the youthful age period (the girl of 19 years) measured anthropometrical and bioimpedance by methods testifies to invariable advantage of a research of the body composition in Vivo by means of an indirect method.

The method of the bioimpedance analysis has proved as the reliable, safe and relatively accurate field method of assessment of the body composition. The main difficulty of development of this method is the problem of physiological interpretation of the results of bioimpedance measurements and the use of formulas and the coefficients for assessment of the body composition depending on properties of population. In this work it is shown that percent of fatty weight is the main indicator of physical development of a biological object, but not the body mass index (the Quetelet index).

***Key words**: Index of physical development, Bioimpedance method, Correlation coefficient.*

1. Introduction

The condition of individual physical development is currently one of the priority directions of researches in a number of the countries. The study of the composition of the body is rather new field of medicine, which allocated in the separate direction of researches in the second half of the last century. In this case, the composition of the body means the division of the entire mass of man into several complementary components, [1]. The most widespread is division of whole mass into two components: fat and lean (lean mass, namely body weight, excluding fat). Such division is used as diagnostics of: overweight, obesity, malnutrition and protein-energy deficiency [2]. A various methods including anthropometrical characteristics and researches of parameters of own physical fields of an organism are used for assessment of a condition of physical development [3]. The aim of this research was to compare the indexes of human physical development measured by the classical anthropometric method and the modern method of assessing body composition, namely the bio-impedance method. The bio-impedance method is one of the most common, accessible and least expensive methods of investigation in contradistinction to the registration of body parameters using computed tomography of x-ray densitometry and neural activation analysis.

2. Materials and Methods

Object of a research were of the girls from the circle of student's youth Yanka Kupala State University of Grodno, Belarus, who voluntarily participated in the research. Anthropometrical and bioimpedance measurements for female persons of the youthful age period were studied. In total 96 students participated in the research, and the average age was 19 ± 1.5 years.

The anthropometric parameters (the body's mass and human growth) are used for assessment of a condition of individual physical development. The greatest distribution has Quetelet's index (body mass index BMI) which is calculated as the ratio of the body weight of a person to the square of its growth:

$$k_1 = BMI = \frac{m}{L^2} \tag{1}$$

Where: *m* - body mass (in kilograms), *L* - human height (in meters).

In medical practice, the deviations of the Quetelet k_1 index from normal values (depending on the sex-age category of the person and determined numerically) are related to the probability of the disease. Moreover, the probability of the disease increases with an increase and a decrease in the index k_1. At normal values of an index the probability of disease is minimal. At high values of k_1 mortality from cardiovascular and oncological diseases increases. For low values of k1 increases the mortality due to chronic diseases of the respiratory organs.

In Table 1 is presented the values of the Quetelet index (1) in the norm as functions of the human age [2].

Table 1 - Normal BMI according to age according to WHO (World Health Organization)

Age, years	Normal values of the index
19 - 24	< 20
25 - 34	20 - 25
35 - 44	21 - 26
45 - 54	22 - 27
55 - 64	23 - 28
> 65	24 - 29

The Quetelet's index is recommended to consider the fifth key indicator of activity of an organism for patients with obesity, according to WHO recommendations. The determination of the numerical values of the Quetelet index for individual biological objects allows to determine the risks of both morbidity and mortality [4].

In addition to the Quetelet index, defined as (1), the Yarkho-Kaupe index (2) is used to estimate the physical state of a person in the form of the ratio:

$$k_2 = \frac{m}{L} \tag{2}$$

Where: *m* - body mass (in grams), *L* - human height (in centimeters).

For women at the age of 18 - 20 years at normal physical development in the SI system the Yarkho-Kaupe index changes in the following limits: $32{,}5\frac{kg}{m} \leq k_2 \leq 37\frac{kg}{m}$.

The third index (3) connecting anthropometrical characteristics is the Rorera index:

$$k_3 = \frac{m}{L^3} \tag{3}$$

Normal for the above-stated gender and age category the Rorera index is considered equal to:

$$13\frac{kg}{m^3} \leq k_2 \leq 15\frac{kg}{m^3}$$

Another widespread and well-known index of physical development is the Broca index (4), which has been offered in 1868 by the doctor Paul Broc. He has suggested to calculate the weight as a difference between growth size in centimeters and a constant = 100. In other words "the ideal weight" = growth (in cm) minus 100. This index could not cover the whole range of possible deviations, and therefore was modified by other researchers. There was an urgent need to introduce individual amendments to this index for different age groups of people. Such options have been developed and added; with a growth up to 165 cm: "the ideal weight" = growth (in cm) minus 100, at the same time with a height from 166 to 175 cm, the ideal weight" = growth (in cm) minus 105. And, at last, with a height over 176 cm: the ideal weight" = growth (in cm) minus

110. Such specified index was called the. Sometimes it is also called the Broca-Brugsha index.

$$Broca\ index = growth - 100 \qquad (4)$$

The Broca index shows the numbers of the ideal (relative to the average person) weight for a given growth.

One of the most common methods of studying the body composition of an object is bioimpedance analysis (Martirosov, [3], Nikolaev, [5], Bakker, [6]), based on measurement of components of resistance of an object at transmission of current of variable frequency through it. The total current passing through the water fraction of an organism is determined by the sum of the current passing through the intercellular space and the current flowing in the intracellular space.

When a direct current passes through the cell, surface polarization occurs due to redistribution of charges to opposite electrodes, as well as structural polarization due to charge redistribution throughout the cell volume. Both types of polarization in cells make it difficult to determine the components of the total resistance of the organism. Also, when a direct current passes through the body, the probability of damage to its cells increases.

These disadvantages are significantly reduced when passing through the tissues of currents of variable frequency. In addition, for a sufficiently small value of the current passing through the cells, their resistance is independent of its magnitude and is constant at a fixed frequency of the acting voltage. The active component of the resistance is determined by the ion currents of the intra- and intercellular liquid, the reactive component by the cell membranes. Researches are conducted are usually conducted on two and more than frequencies (Zuev [7], Zuev [8], Grimnes [9]). The general resistance of the object at a frequency of 5 kHz allows one to determine the active resistance of the intercellular fraction of the body, the resistance at 50 kHz (and above) includes both the active resistance of the whole organism and the capacitive resistance of the aggregate of all cells.

The regression equation (5), which includes the active component of the body resistance R_{50} at the frequency of the probing signal f = 50 kHz, the growth of L, the mass m, the age and gender of the person, is used to determine the fatty body mass (m_{fbm}), Kyle, [10, 11]:

$$m_{fbm} = 14{,}94 - \frac{0{,}079 * L^2}{R_{50}} + 0{,}818 * m + 0{,}077 * Age - 0{,}064 * Gender * m - 0{,}231 * L \qquad (5)$$

Earlier in our works we pointed to value of the bioimpedance analysis as somatometric method for assessing human nutritional status Bashun, [12], and Bashun, [13]. This paper presents a comparison of the body fat mass by means of a bioimpedance method to: Quetelet, Brock's indexes, Yarkho-Kaupa, and Rorera defined only according to anthropometrical measurements is presented.

3. Results and Discussion

In the beginning an experiment anthropometrical measurements were taken: growth, weight, body mass index, waist circumference, hip circumference. Then with the same structure for a research the Medass AVS-01 analyzer, connected to the personal computer with the software "Sport" was used. The analyzer allows to measure electric characteristics: active resistance of an object at a frequency of 5 kHz and also active and reactive resistance at a frequency of 50 kHz. The analyzer allows measuring electrical characteristics: active resistance of the object at a frequency of 5 kHz, as well as active and resistance at a frequency of 50 kHz. Based on the data of anthropometric indicators and electrical characteristics measured by the Medass analyzer, a protocol is generated for a person's dynamic state, which determines the basic parameters of a person, from which the fat mass (LM) of the subject is most interesting for the present study.

In the Figure 1 is shown the Quetelet index, calculated by formula (1) for students (women) of the 18-19 age group (N is the number of students). For this age, the value is considered the norm - $BMI \prec 20\frac{кg}{m^2}$, as shown in the Table 1.

For the same group of students (Figure 2) the graphic dependence of fatty body mass calculated according to a formula (3) is presented. To compare this parameter, m_{fbm} was normalized to the whole body mass, i.e. $\frac{m_{fbm}}{m_{bm}}$ characterizes the number of fatty mass per unit mass of the whole body. The norm for this age category is considered $0{,}16 \le \frac{m_{fbm}}{m_{bm}} \le 0{,}2$, if the ratio is carried out $0{,}2 \le \frac{m_{fbm}}{m_{bm}} \le 0{,}24$, then weight is considered superfluous, at $\frac{m_{fbm}}{m_{bm}} \succ 0{,}24$ obesity is noted, at $\frac{m_{fbm}}{m_{bm}} \prec 0{,}12$ is exhaustion.

As it is shown from experimental data, the distribution curves are close to normal, however, if for a case in Figure 2 the maximum falls on the norm for a given age category, in case in Figure 1 the maximum is displaced concerning norm.

A statistical calculation of the experimental data was carried out. A pair exponential regression was selected at the specification stage. Its parameters were estimated by the method of smallest squares. The statistical importance of the equation was verified using the determination coefficient and the Fisher criterion. The correlation coefficient was calculated by a formula (6):

$$b = \frac{xy - x * y}{S^2(x)} \qquad (6)$$

Where: $\overline{x}$, $\overline{y}$, $\overline{xy}$ - selective averages, *S(x)* – selective dispersion.

The correlation coefficient b is 0.042 for the data presented in Figure 1 and 2.

In the Figure 3 and 4 is shown the experimental data of the Yarkho-Kaupe index and the relative fatty body mass for the studied age group of female students.

The correlation coefficient for the data, calculated by formula (6) is b = 0.031.

In the Figure 5 and 6 the experimental data of the Rohrer index (Figure 5) in comparison with the relative fat body mass (Figure 6).

The correlation coefficient for the data of figure 3, calculated by formula (5) is b = - 0.001.

As a result of statistical processing of the obtained experimental data correlation coefficients between three main, indexes of physical development and data of fatty body weight of objects are calculated. The maximum coefficient of correlation (b = 0.042) is noted between relative the fatty mass of objects and Quetelet's index.

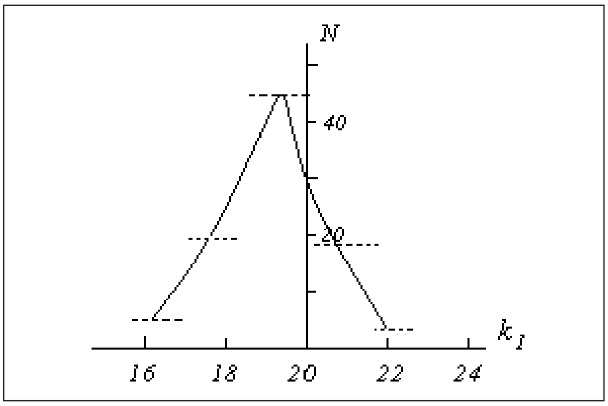

Figure 1. Experimental dependences of the Ketle index k_1

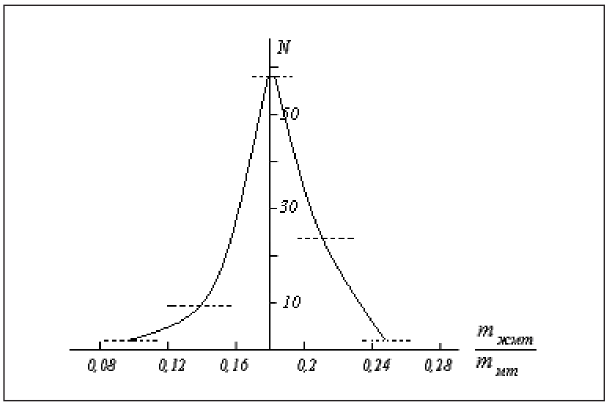

Figure 2. Experimental dependences of the relative fat body mass

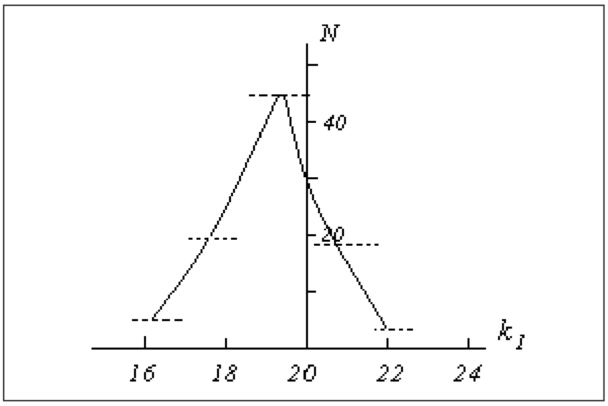

Figure 3. Experimental dependences of the Yarkho-Kaupe index k_2

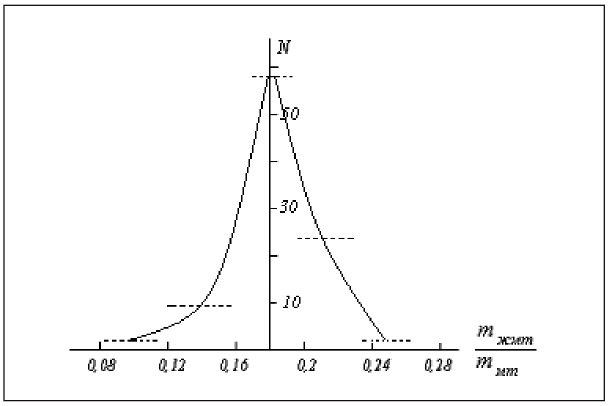

Figure 4. Experimental dependences of the relative fat body mass

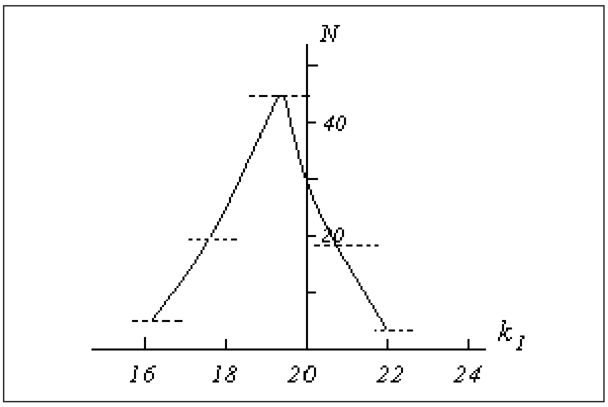

Figure 5. Experimental dependences of the Rohrer index k_3

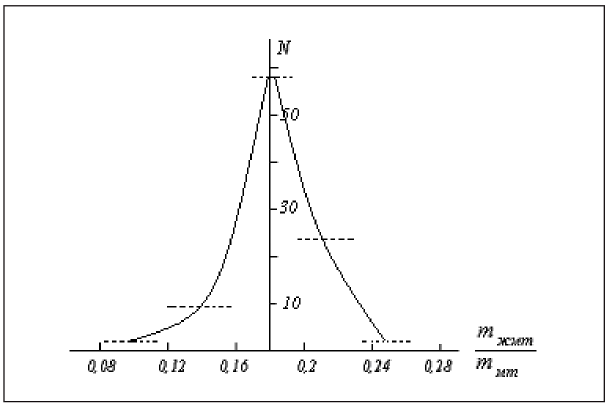

Figure 6. Experimental dependences of the relative fat body mass

Thus, comparison of indexes of physical development of the studied persons of the youthful age period (the girl of 19 years) measured anthropometrical and bioimpedance by methods testifies to invariable advantage of a research of the body composition in Vivo by means of an indirect method. The method of the bioimpedance analysis has proved as the reliable, safe and relatively accurate field method of assessment of the body composition. The main difficulty of development of this method is the problem of physiological interpretation of the results of bioimpedance measurements and the use of formulas and the coefficients for assessment of the body composition depending on properties of population. In this work it is shown that percent of fatty weight is the main indicator of physical development of a biological object, but not the body mass index (the Quetelet index).

4. Conclusions

- Comparison of indexes of physical development of the studied persons of the youthful age period (the girl of 19 years) measured anthropometrical and bioimpedance by methods testifies to invariable advantage of a research of the body composition *in vivo* by means of an indirect method.

- The method of the bioimpedance analysis has proved as the reliable, safe and relatively accurate field method of assessment of the body composition. Main difficulty of development of this method is the problem of physiological interpretation of the results of bioimpedance measurements and the use of formulas and the coefficients for assessment of the body composition depending on properties of population.

- In this work it is shown that percent of fatty weight is the main indicator of physical development of a biological object, but not the body mass index (the Quetelet index).

5. References

[1] Calle E. (1999). *Body-mass index and mortality in a prospective cohort of U.S. adults.* N. Engl. J. Med., Vol. 341, (15), pp. 1097-1105.

[2] Bessesen D. G., Kushnir R. (2004). *Overweight and obesity: prevention, diagnosis and treatment* (in Russian). Binom, Moscow, Russia.

[3] Martirosov E. (2006). *Technologies and methods for determining the composition of the human body* (in Russian). Nauka, Moscow, Russia.

[4] WHO. (2000). *Obesity: preventing and managing the global epidemic*. Report of a WHO Consultation, Geneva, Switzerland.

[5] Nikolaev D. (2009) *Bioimpedance analysis of the composition of the human body* (in Russian). Nauka, Moscow, Russia.

[6] Bakker H. (1977). *Biological variability and lean body mass estimates*. Hum. Biol., 53, pp. 181-225.

[7] Zuev A. (2012). *Equivalent electrical models of biological objects* (in Russian). Russian Journal of Biomechanics, 16, (1), pp. 110-120.

[8] Zuev A. (2014). *Identical electrical models of biological objects* (in Russian). Russian Journal of Biomechanics, 18, (4) pp. 491-497.

[9] Grimnes S. (2008). *Bioimpedance and bioelectricity basics.* Academic Press, New York, USA.

[10] Kyle U. (2004). *Bioelectrical impedance analysis. I. Review of principles and methods.* Clin. Nutr., Vol. 23, pp. 1226-1243.

[11] Kyle U. (2001). *Single prediction equation for bioelectrical impedance analysis in adults aged 20 - 94 years*. Nutrition, 17, pp. 248-253.

[12] Bashun N. (2016) *Formation of bases of a healthy diet in natural science and technology education at the university level*. Journal of Hygienic Engineering and Design, Vol. 16. pp. 45-49.

[13] Bashun *N.* (2017). *Electronic Information Resources as Means of Diagnosis of the Status of Nutrition Persons of Younger Age.* International Journal of Engineering and Applied Sciences, 11. pp. 117-120.