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Application of Bioimpedance Analysis of Female Body Compositionin the Training Process of Fitness Orientation

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Abstract

The article presents the material of the results of studying the components of body weight composition of female students of higher educational establishments using computer measuring technology of bioimpedance. Special features of the are the basic parts of forming the indicators of general and special performance in sports and fitness. Along with this, the body changes under the influence of the specifics of training loads and under the influence of increasing physical and functional fitness of students. Therefore, the information about the components of body weight composition allows to individualize physical activity on training sessions using a variety of physical exercises and kinds of sports. Female students with higher of bioelectrical indicators (phase angle, reactance), the active cell mass (ACM) and the percentage of the active cell mass dominate in the physical and functional fitness relatively students with low indexes. These differences are statistically significant (P <0.05). Their response of the cardiovascular system is also significantly lower (P <0.05) during the running load in the aerobic mode power supply. Pedagogical technology of the construction of training process on the basis of monitoring the components of body weight composition with the provision of this information to the students contributes to the high interest in their training sessions of active exercises and of certain kinds of sports. It contributes to the positive dynamics of physical fitness and body correction of the practicing female students.

Keywords: *physical and functional preparedness, body composition monitoring, bioimpedance analysis, bioelectrical and anthropometric indicators, motorical tests.*

1. Introduction

Recently, the studies of the components of human body weight composition have in vivo acquired an increasing importance. Currently, this area of biomedical research emerged as an independent scientific direction, called the science of the components of body composition (Heymsfield et al., 2005). The current stage of development of this science is characterized by an increase in the role of new technologies and methods of research (Ellis, 2000; Martirosov et al., 2006). The results of numerous studies suggest that the components of human body weight composition have a significant connection with the indicators of the physical and functional fitness, human performance, with his adaptation to environmental conditions, as well as with the features of professional and sport activities. The study of body composition plays a key role in the diagnosis of obesity, osteoporosis, hypertension, it is significant with some other diseases, and allows you to predict accurately the risk of their development

In modern conditions, the bioimpedance measuring is most widely used to determine body composition, ie a contact method of measuring the electrical conductivity of biological tissues, which enables to evaluate broadly morphological and physiological parameters of the organism. In the bioimpedance analysis active resistance and reactance of the human body or its segments at different frequencies are measured. On their basis, characteristics of body composition, such as fat, lean, cell and skeletal muscle mass, volume and distribution of water in the organism are calculated. The implementation of modern technologies and research methods can improve the reliability and efficiency of evaluation of indicators of human body composition. Moreover, currently existing methods provide an opportunity to study body composition at all levels of the organization of biological systems: elemental, molecular, cellular, organ-tissue, as well as at the level of the whole organism (Martirosov A.G. et al., 2006).

In bioimpedance analysis anthropometric and bioelectrical parameters are distinguished. The bioelectric parameters are: active resistance - R (ohms); reactance - X_C (ohms); phase angle - φ (degree). Active (ohmic) resistance characterizes the ability of tissues to heat dissipation of electric current. Material substrate of active resistance in a biological object are liquid (cellular and extracellular), which has an ability to an ionic conduction mechanism. Reactive (capacitive) reactance is characterized by phase shifting the current relatively the voltage due to the capacitive properties of the cell membrane that can accumulate electric charge on their surface. The substrate of reactive reactance is cell membranes. Phase angle is the arctangent of the ratio of reactance to resistance to a certain frequency of the current. The anthropometric parameters are: sex, age (year), body weight (kg), body length (cm), body mass index (kg/m^2), waist circumference (cm), hip circumference (cm), the index of waist/hips. The ratio of waist/hips characterizes the human body type. This type is mainly determined by hereditary factors and manifests itself in the peculiarities of the distribution of muscle mass and fat deposits [Hedman, 1980]. The most popular is the Quetelet index or body mass index (BMI), calculated as the ratio of weight in kilograms to the square of the body length in meters: BMI = body weight (kg) / body length (m^2).

On the basis of anthropometric and bioelectrical parameters the basal metabolic rate (kcal / day) is determined – it is a characteristic of human energy metabolism. Also relative basal metabolism is calculated as the quotient of basal metabolism to the body surface area (m^2). The share exchange allows you to compare the intensity of energy consumption of different people. (Ivanov G.G. et al., 2000).

2. Methods and Materials

The research has been conducted at the Department of Physical Education of Mari State University from 2010 to 2015. We studied the dynamics of body composition of the students of the Institute of Medicine and Science, as well as the physical functional fitness depending on indicators of body composition. The study included 80 female students who were divided into two groups depending on the value of the phase angle, resistance and reactance. The basis of the division into groups was based on the rating system: students with a high index were assigned to the first group, with less - to the second. In this experiment, diagnostics of the components of body weight composition were carried out with the help of bioimpedance analyzer ABC-01 "Medass" using a personal computer (PC) programs.

To determine physical and functional fitness, female students of the studied groups performed motor tests: running 100 meters, running 2,000 meters, running 30 minutes without switching to walking, crouching on the left and on the right leg alternately, standing on a gymnastic bench, hands resting on a smooth wall, lifting the body from the supine position (exercise for the abdominal press), long-jump from the resting position, flexibility (bending forward, sitting on the floor), carpal dynamometry. Determination of functional training is: the reaction of the cardiovascular system to aerobic running (blood pressure systolic and diastolic, heart rate), vital capacity (VC).

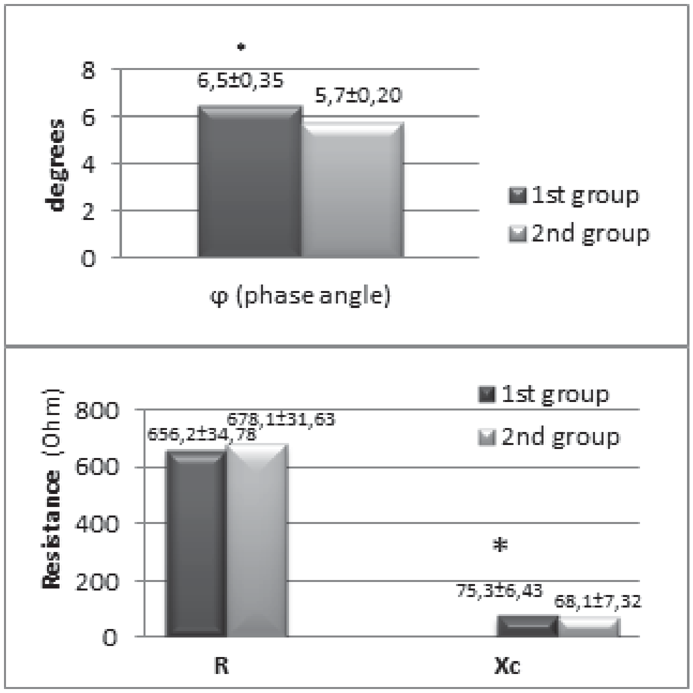
3. Results and Their Discussion

The table 1 and in the figure 1 show the average bioelectric performance of female students of the 1st and 2nd groups.

Table 1. Average bioelectric indices of female students of the 1st and 2nd groups.

№ п/п	Indices	1st group	2nd group
1	Phase angle (degree)*	6,5±0,35	5,7±0,20
2	Active resistance (ohms)	656,2±34,78	678,1±31,63
3	Reactance (ohms)*	75,3±6,43	68,1±7,32

Note: * - statistically significant differences (P <0,05).



Note: * - statistically significant differences (P <0.05).

Figure 1. Average bioelectric parameters (phase angle (ϕ), resistance (R), reactance (X_c)) of the students of the 1st and 2nd groups.

The results indicate that the rate of phase angle of the 1st group of students is greater than the phase angle of the 2nd group of students by 0.83 degrees, which is statistically significant (P <0.05). The phase angle characterizes the capacitive properties of cell membranes and viability of biological tissues: it is believed that the greater the phase angle, the better the condition of the tissue. The average dimension of the phase angle and capacitance reflect a higher concentration of active cell mass and are treated in sports medicine as evidence of fitness [Abrikosova M.A., 1981]. Clinical standards of the phase angle are: less than 4.4 degrees - significantly lower than normal; from 4.4 to 5.4 degrees - below normal; from 5.4 to 7.8 degrees - normal; more than 7.8 degrees - above the norm [Martirosov E.G. et al., 2006].

Indicator of reactance also has a statistically significant differences (P <0.05). Lower dimensions of capacitance resistance are associated with the violation of the dielectric properties of cell membranes and the increase of the proportion of broken cells in the organism. Conversely, increasing indicators of the capacitive impedance reflect higher functional state of the cells' membranes and, therefore, the cells themselves. The reactance and phase angle characterize the features of biological tissues (Baumgartner et al., 1988; Lukaski et al., 1988).

The results of anthropometric indices are presented in the Table 2 and Figure 2.

Table 2. Average anthropometric indices of female students of the 1st and 2nd groups.

№ п/п	Indices	1st group	2nd group
1	Body length (cm)	162,2±8,97	162,6±6,64
2	Body weight (kg)	54,9±7,33	53,0±4,50
3	Waist circumference (cm)	67,8±4,15	66,8±8,83
4	Hip circumference (sm)	94,0±4,35	90,2±7,62
5	Index of waist/hips.	0,7±0,39	0,7±0,38
6	Index of body weight	20,8±1,58	19,9±1,36

Note: * - statistically significant differences (P <0.05).

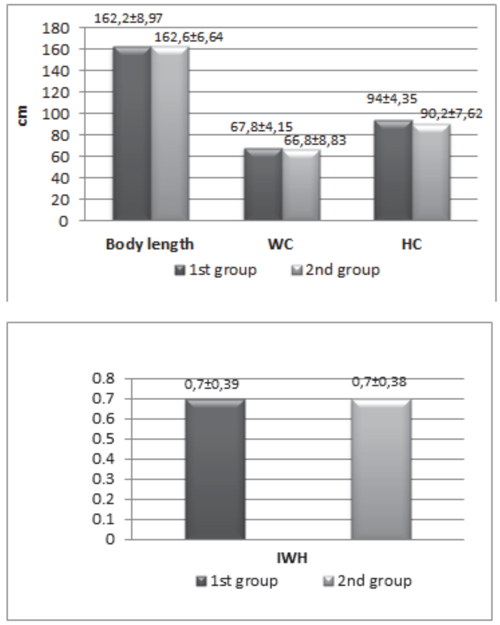


Figure 2. Average anthropometric measures (height, waist circumference (WC), hip circumference (HC), the index waist/hip (IWH)) indicators of the students of the 1st and 2nd groups.

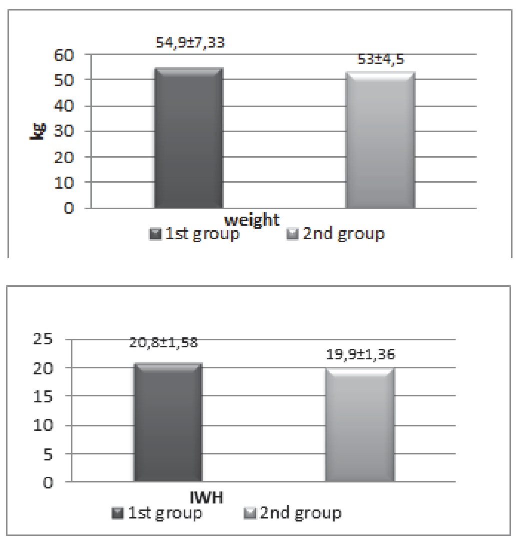


Figure 3. Average anthropometric measures: weight, body mass index (BMI) of the students of the 1st and 2nd groups.

From the Table 2 and Figure 2, 3 we can see that statistically significant differences of anthropometric indicators (height, waist circumference, hip circumference, waist / thigh index, weight, BMI) of female students of the studied groups are not found (P> 0.05). The value of IWH is the ratio of the circumference of the waist to hip circumference and it characterizes the human body type. Among these types of body there are type ("pear"), intermediate and android types ("apple"). IWH size is also used to determine the type of obesity. When abdominal obesity, the index of IWH for men exceeds 1.0, when gynoid obesity for women, it exceeds to 0.85. It should be noted that these figures of the studied female students answer the normal physiological range. It is based on the fact that the students of basic medical group without deviations in health status took part in the experiment. The index of BMI is a characteristic matching the average in population body mass values for this hight. In international practice, we use the following classification of BMI values [Nikolaev DV et al., 2009]:

BMI	*Classification*	*The risk of disease*
Less than 18,5	Deficiency of body weight	Heightened
18,5-24,9	Normal body weight	Minimal
25,0-29,9	Overweight	Heightened
30,0-34,9	Obesity of the I degree	High
35,0-39,9	Obesity of the II degree	Very high
More than 40	Obesity of the III degree	Excessively high

BMI provides only an indirect assessment of the tissue, as the increased BMI indexes can be connected with a heightened muscle mass, or the presence of edema. For individual characteristics of the degree of fat deposition and for evaluation of the risk of a disease developing, data of body weight composition is used.
Body composition analysis of the students of groups 1 and 2 are shown in Table 3 and Figure 4.

Table 3. Average indexes of body composition of female students of the groups 1 and 2.

№ п/п	Indices	1st group	2nd group
1	Fat mass (kg)	15,5±1,61	13,5±1,62
2	Lean mass (kg)	39,9±2,26	39,5±2,99
3	Skeletal muscle mass (kg)	20,6±1,71	21,4±1,60
4	Total amount of water in the organism (kg)	29,2±2,13	28,9±2,17

Note: * - statistically significant differences (P <0.05).

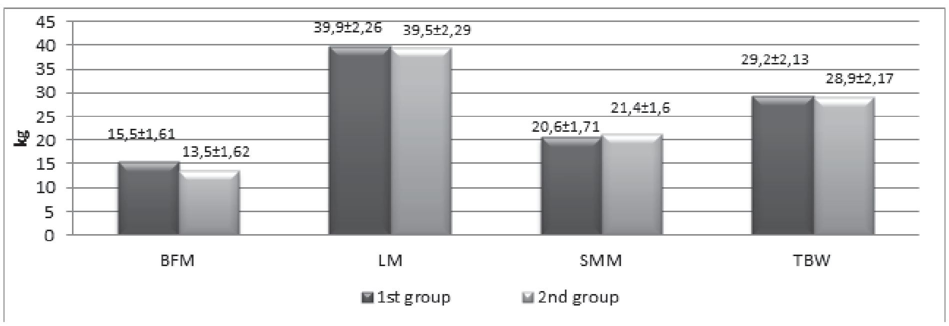


Figure 4. Average body composition: body fat mass (BFM)), lean mass (LM), skeletal muscle mass (SMM), total body water (TBW) of the female students of the 1st and 2nd groups. From the indicators in Table 3 and Figure 4 we can see that statistically there are no significant differences between the indexes of body composition students of groups 1 and 2 (P> 0.05). Mainly, indexes of the components of the body weight composition of the groups studied meet the standards of the average population of women of appropriate age.

Body fat (lipids) is an important depot of energy in the body and it is involved in the regulation of physiological and metabolic processes. Average body fat is a condition of maintaining the health, well-being and operability. An excess body fat is a risk factor for cardiovascular and other diseases. The reason for the high fat content in the body is usually lies in hypernutrition, combined with a sedentary lifestyle.

Lean mass is determined as the difference between the body weight and fat mass, comprising the metabolically active (skeletal muscle mass) as well as relatively inert tissues (connective tissue). Deviation of the indexes of the lean mass to the average indexes indicates the special features of the human constitution: reduction - closer to asthenic increase - to hypersthenic type.

The amount of SMM is used to describe the physical development of the individual, and the percentage of SMM is used to characterize the physical development and the level of fitness of the athlete.

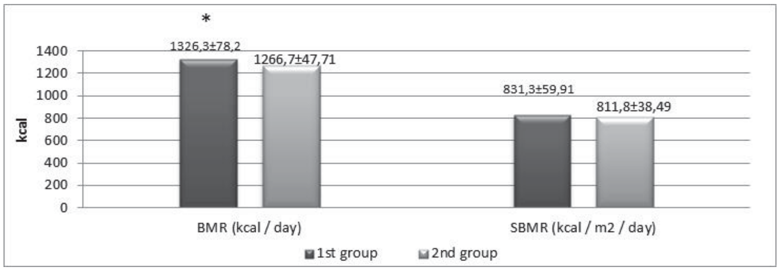
Total body water represents the largest weight component of the body weight composition and provides transport processes of the body. Normally, the TBW comprises about 73% of the lean mass. Daily consumption of water required for normal functioning of an adult is 30-40 g per 1 kg of body weight.

Indicators of active cell mass (ACM) of the female students are presented in Table 4 and in Figure 5.

Table 4. Average indices of active cell mass (ACM) and the proportion of ACM of female students of the two groups.

№ п/п	Indices	1st group	2nd group
1	Active cell mass (kg)*	22,5±2,47	20,7±1,40
2	Proportion of ACM (%)*	56,5±1,52	52,2±1,08

Note: * - statistically significant differences (P <0.05).



Note: * - statistically significant differences (P <0.05).

Picture 5. The averages indicators of active cell mass (ACM) and percentage of ACM of the lean mass (%ACM) of the students of group 1 and 2.

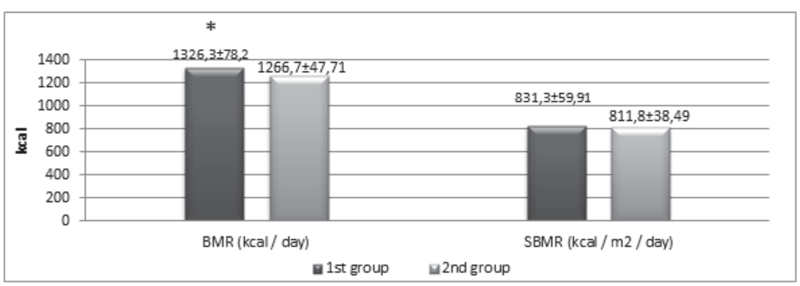
Table 5 and Figure 5 show that there are statistically significant differences between the values of parameters of ACM and %ACM (P <0.05). The average value of the index of ACM 1.8 kg more than in the 1st group of students and the average value of the index of %ACM is on 4.3% more. Active cellular mass characterizes the content of metabolically active tissues in the body. It is very important in the correction of body weight procedures to reduce fat mass in particular and to preserve the active cell mass by means of an increased physical activity and a balanced diet. ACM deviation to lower values of the average indicates insufficient supply of the protein component. In terms of training activity, an increase in ACM and %ACM can be seen. The value of the %ACM is used as a correlate of physical performance, while when the values are below the average - the severity of inactivity.

Results of the study of metabolic processes of female students are shown in Table 5 and in Figure 6.

Table 5. Average basic and specific basal metabolism of the students of groups 1 and 2

№ п/п	Indexes	1st group	2nd group
1	Basal metabolic rate (kcal / day)*	1326,3±78,20	1266,7±47,71
2	Specific basal metabolic rate (kcal / m2 / day)	831,3±59,91	811,8±38,49

Note: * - statistically significant differences (P <0.05).



Note: * - statistically significant differences (P <0.05).

Figure 6. Average indexes of basal metabolism (BMR) and specific basal metabolism (SBMR) substances of female students of the studied groups.

Based on the data of the Table 5 and Figure 6, it is found that there are statistically significant differences between the basal metabolic rates (P <0.05). In the 1st group of students, the value of this index is on 56.9 kcal / day higher than of the students of the 2nd group. Basal metabolism is characterized by minimal power consumption required to maintain the vital processes of the body at rest. Basal metabolic rate is expressed in kilocalories, allocated from the body per unit of time. The rate of basal metabolism varies because of insufficient or excess of food, increasing or decreasing of physical activity, diseases accompanied by fever, and under the influence of other factors. If a person is healthy it can fluctuate within ± 10% from the average for several days. For women of average height (160 - 170 cm) the normal range of values of basal metabolism comprises 1240 - 1480 kcal (Nikolaev V.D. et al., 2009). specific basal metabolic rate is calculated as the quotient of the dimension of basal metabolism to the body surface area and allows to compare the intensity of energy consumption of different people. (Ivanov G.G. et al., 2000).

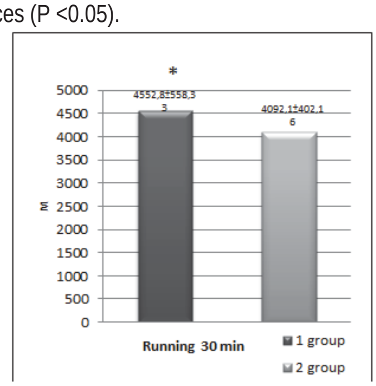
Important significance in the training process along with a functional diagnosis belongs to the determination of physical performance and physical condition of the people engaged in various motor tests. Tests applied in teaching practice to assess physical fitness should be available for the testee informatively reflect various aspects of physical fitness and development of physical qualities. In general, the tests for teaching are required demands similar to those which are defined by the test theory where reliability and valence are the most important. The complex of tests to assess the physical condition was picked up by us with the content of training sessions, which adequately reflects the dynamics of the physical qualities (stamina, strength, speed, flexibility), at the development of which the propulsion program is aimed.

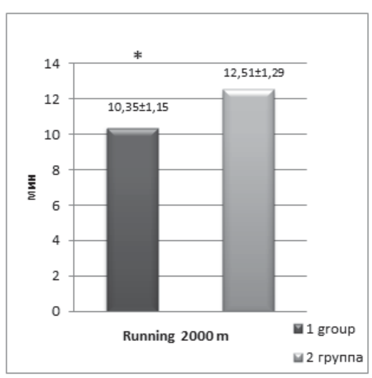
The results of moving tests of students are presented in Table 6 and Picture 7-10.

Table 6. Average indicators of physical student's preparedness of groups 1 and 2.

Indicators	Group 1	Group 2
Running 30 minutes (m) *	4552,8±558,33	4092,1±402,16
Running100 m (sec.)	17,4±1,57	18,1±1,89
Running 2000 m (min.)*	9,5±1,69	11,5±0,84
Squats on the left foot (quantity)*	15,8±6,77	9,9±4,31
Squats on the right foot (quantity)*	16,2±7,49	9,5±4,35
Bench press (quantity)	71,1±16,17	59,5±12,56
Jump broad (cm)	162,2±11,44	161,1±11,58
Flexibleness (cm)	12,2±5,62	10,1±2,88
Carpal dynamometry (kg) *	27,9±4,19	23,0±4,93
Vital lungs capacity (ml)	2863,9±327,56	2771,1±361,05

Note: * - statistically significant differences (P <0.05).





Note: * - statistically significant differences (P <0.05).

Figure 7. Average indicators of speed-strength parameters of 1 and 2 students' groups.

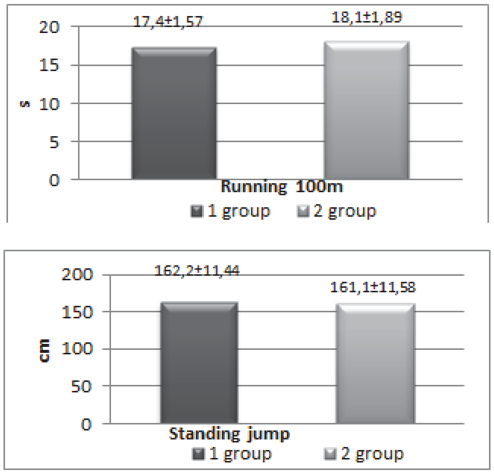
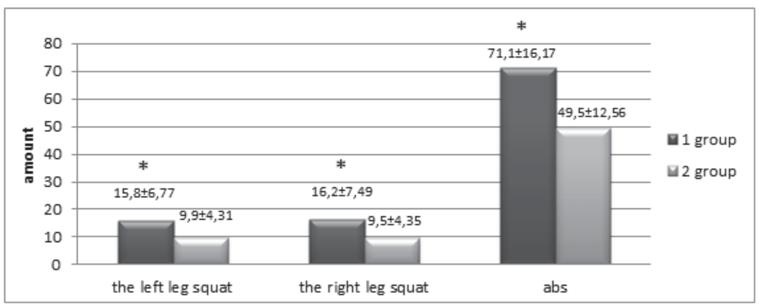
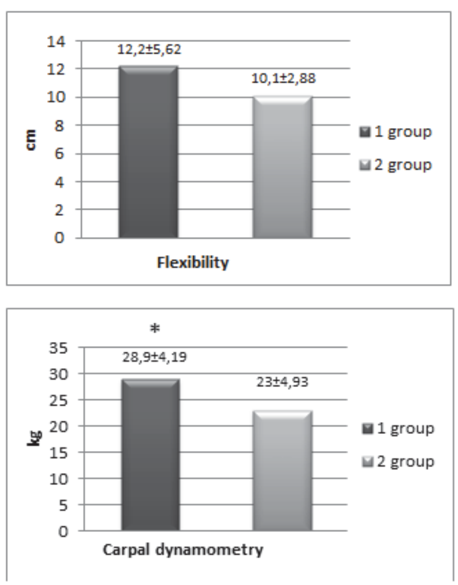


Figure 8. The average values of speed and power performance of students of 1 and 2 groups



Note: * - statistically significant differences (P <0.05).

Figure 9. Average indicators of strength endurance.



Note: * - statistically significant differences (P <0.05).

Figure 10. The average indicators of flexibility and carpal dynamometry.

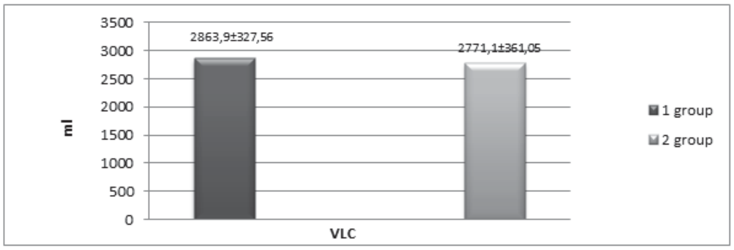


Figure 11. The average indicators of vital lungs capacity (VLC) of 1 and 2 students.groups

The data in table 6 and figures 7-10 shows that there are statistically significant differences (P <0.05) in the study groups in terms of the following tests: running for 30 minutes without switching to walking in the aerobic zone of energy supply, runing 2000м, 2000m run, sit-ups on the left and right legs, lifting of the torso from a prone position (exercise for the abdominals), carpal dynamometry. Test results show a higher physical fitness of students in group 1 (VT Nikolaev, 2011). It should be noted that the level of performance indicators of motor tests shows the physical fitness of involved ones and indirectly reflects their physical health (VT Nikolaev, 2002).

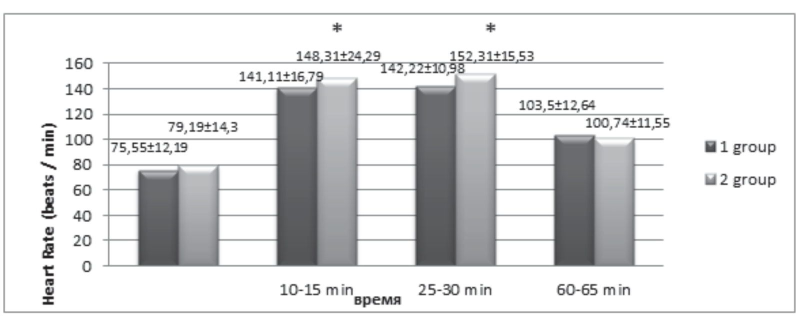
To determine the functionality of the respiratory system lung vital capacity (VC) was measured by spirometry. VC - the maximum amount of air exhaled after the deepest inspiration and one of the main indicators of the external breathing apparatus widely used in medicine and sport. Data of VC of girls from groups 1 and 2 is shown in table 6 and picture 11, which respectively amounted to 2863,9 ± 327,56i 2771,1 ± 361,05 ml (P> 0.05).

Table 7 and in Figures 12-14 show the results of the reaction of the cardiovascular system of students (HR, DT and ADD) in terms of training session at the stadium during the 30-minute run in the aerobic zone and after heaving exercises in combination with stretching exercises for 30 minutes.

Table 7. The average indicates of cardio-vascular students system on training load between groups 1 and 2.

Training load	Indicators	Group 1	Group 2
	HR initial	75,55±12,19	79,31±14,30
	SBP initial	120,2±7,41	116,63±831
	DBP initial	83,78±8,12	79, 37±5,83
Running in the aerobic mode for 30 minutes without moving to walking	HR for 10-15 min. of running*	141,11±16,79	148,31±24,29
	SBP for 10-15 min. of running	143,17±9,86	149,47±,24
	DBP for 10-15 min. of running	89,11±7,31	85,62±8,22
	HR for 25-30 min. of running *	142,22±10,98	152,31±15,53
	SBP for 25-30 min. of running	146,61±5,03	147,89±22,21
	DBP for 25-30 min. of running	84,61±8,69	78,00±12,59
Stretching exercises	HR. for 25-30 min. stretching exercise	103,50±12,64	100,74±11,55
	SBP for 25-30 min. stretching exercise	120,00±10,48	115,26±15,23
	DBP for 25-30 min. stretching exercise	81,05±7,29	79,26±8,59

Note: * - statistically significant differences (P <0.05).



Note: * - statistically significant differences (P <0.05).

Figure 12. Dynamics of average heart rate (HR) of 1 and 2 students in terms of group training sessions.

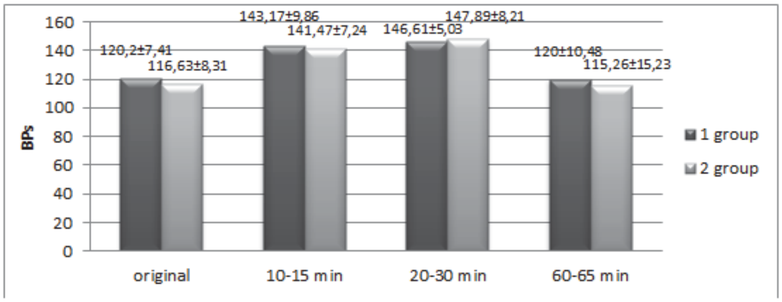


Figure 13. Dynamics of the average systolic blood pressure (BPs) at 1 and 2 students in terms of group training sessions.

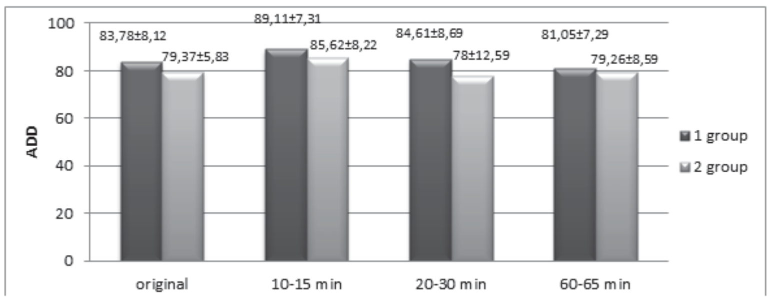


Figure 14. Dynamics of average diastolic blood pressure (ADD) of 1 and 2 students in terms of group training sessions.

The main indicators of the cardiovascular system (CVS) is the frequency serdech-tion rate (HR), systolic blood pressure (BPs) and diastolic (ADD). A statistical analysis of the response of HR, systolic blood pressure, ADD of students was conducted in terms of training sessions at the stadium in slots 10-15 and 25-30 minutes of running in the aerobic zone of energy supply and in the subsequent 25-30 minutes performing strength exercises combined with stretching exercises. This program of physical exercice simulates the fitness of exercise on the basis of aerobic exercise and stretching. Statistically significant differences in heart rate between the two groups of students are set in slots of 10-15 minutes and 25-30 minutes of running in the aerobic mode power supply ($P < 0.05$). The average values of heart rate for 10-15 minutes running of 1 and 2groups, respectively, totaled 141,11 ± 16,79 and 148,31 ± 24,29 beats per minute, 25-30 minute run 142,22 ± 10,98 and 152 31 ± 15,53 bpm. It should be noted that the average heart rate of group 1 which has higher bioelectric indicators and components of the composition of body weight were statistically lower in comparison with group 2. Later, during strength training and stretching, the average heart rate in groups 1 and 2, respectively, amounted to 103,50 ± 12,64 and 100,74 ± 11,55 beats per minute. These differences in heart rate were not statistically significant ($P > 0.05$).

During physical activity, requiring display of endurance, systolic blood pressure increases in proportion to the intensity of exercise. In the dynamics of the average of systolic and diastolic blood pressure of students of 1 and 2 groups statistically significant differences were not observed ($P > 0.05$). Averages ADF / ADD 10-15 minutes of jogging in groups 1 and 2, respectively, amounted to 143,17 ± 9,86 / 89,11 ± 7,31 and 149,47 ± 24 / 85,62 ± 8,22 bpm and a 25-30 minute run 146,61 ± 5,03 / 84,61 ± 8,69 and 147,89 ± 22,21 / 78,00 ± 12,59 beats per minute. There was an increase in average of systolic blood pressure in the groups studied by 17-18%, and diastolic blood pressure did not change significantly. The dynamics of systolic and diastolic pressure corresponded normotonic reaction. In general, the dynamics of physiological indicators of cardiovascular system indicates compliance of motor loads of individual physical and functional readiness of students (Nikolaev VT 2012).

Thus, the construction of the training process of fitness orientation with students using the monitoring components of the composition of body weight and physical condition by the motor tests contribute to their high interest to the means and methods of achievement of positive dynamics of body composition and physical fitness.

4. Conclusion

The results show that girls of the group 1 with higher values of bioelectrical indicators (phase angle, reactance) components of the composition of body weight (active cell mass and percentage of active cell mass) dominate in the physical and functional readiness of girls of group 2 who have low data (differences are statistically significant, $p < 0.05$).

Features of the body are the base of forming a basic component of formation of indicators of the general and special operability of involved in fitness and sports, therefore, serve as the main criterion of the individualization of training loads in physical exercise and sports.

During the training sessions of fitness orientation based on running in the aerobic mode power supply and power exercises combined with stretching students of studied groups identified optimal physiological response of the cardiovascular system. But the reaction of the cardiovascular system of girls of group 1 was significantly lower ($P < 0.05$) than that of girls of group 2 during the running load in the aerobic mode power supply.

Pedagogical technology of construction of training process of fitness orientation based on the monitoring of components of the composition of body weight with the provision of this information of involved contributes to the high interests in active exercise training sessions and individual sports and body correction.

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