Original Article

Personalization of physical education based on the study of body composition and body vegetative support in female students

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Abstract:
The pursuit of innovative approaches to enhance physical education for youth remains a pressing concern, underscored by persistently low indicators of psychophysical and somatic health among students globally. ***Research objective:*** To personalize physical activity and investigate body composition and heart rate variability among female students with varying levels of somatic health and functional characteristics. ***Materials and methods***. The study encompassed 167 female students from Volga National Research Medical University (Russia) aged 19.2 ± 1.3 years. According to the medical examination, 105 girls had a special medical group for PE classes and 62 had a preparatory one. Body length and weight were determined using floor scales with a height meter, the indicators of body component composition were evaluated using a bioimpedance study on the hardware complex «MedicalSoft Sports Testing System». The state of the body vegetative supply was studied according to the characteristics of the heart rate variability indicators state. The Poly-Spectrum device was used the assessment was carried out taking into account the standardized protocol for recording a cardiointervalogram. For dynamic monitoring of morphofunctional status, indicators of fat and muscle mass, body mass index, phase angle, total, intra- and extracellular water content in the body, and basal metabolism were evaluated. The parameters of heart rate, temporal and spectral indicators of heart rate variability and stress index were analyzed. ***Results***. It was found that the girls in the preparatory group had higher indicators of fat and muscle mass, intracellular and extracellular water, phase angle, basal metabolism and body mass index. Among the students of the special group, there is a tendency of relative tension of regulatory systems, increased centralization of heart rhythm and sympathetic activity. The biological age parameter was recorded in a higher value among the subjects of the special health group. The correlation analysis demonstrated the presence of direct correlations of the biological age indicator with the stress index parameters and the fat mass level as well as inverse correlations with the indices of the total power of the spectrum, the RMSSD index and the phase angle. The study of other body characteristics influence over the variability of biological age may be of interest for further research. ***Conclusions***. The obtained research results of the girls' body morphofunctional parameters make it possible to identify a risk group for physical exertion among them. It individualizes female students' physical activity in PE classes at an educational institution.
Key Words: physical education, female students, health, heart rate variability, health level

Introduction

The preservation and strengthening of studying young people's health is a fundamental link in the socio-economic development in any state. It is noted that the period of study at a higher educational institution is associated with high psycho-emotional and educational workload (Tabacco, 2018), low physical activity (Chekhovska et al., 2020), the appearance of bad habits and other factors. All of these factors can lead to a violation of morphophysiological functions of the body and reduce the state of health (Baker et al., 2022; Bocharin et al., 2023, b; Sokolovskaia et al., 2022).

In addition, the recent trend shows an increase in the number of students with various health limitations and the presence of chronic diseases (Sprake et al., 2018; Diaz et al., 2020; Jha et al., 2021). At the same time, the number of students with health abnormalities can reach half of all students (Gerber et al., 2017). Higher

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requirements are imposed on the organization and methodology of physical education (PE) classes at the university for students with some health problems (Mozolev, 2020).

An important role in improving the effectiveness of the educational process of students' physical education is assigned to improving the methods of their health status comprehensive testing (Kolokoltsev, et al., 2021, a). One of the most informative and fairly accessible methods of health testing is the assessment of morphofunctional indicators (Kolokoltsev, et al., 2021, b). They include the determination of the body component composition and the vegetative tone of the student (Thomas, & Viljoen, 2020; Tripska et al., 2022; Krueger et al., 2023). The obtained digital indicators act as criteria for the adaptation of the body to the conditions of educational and professional activity (Liu et al., 2015; Rivera-Ochoa et al., 2020).

The assessment of the body component composition can be carried out using bioimpedance testing. It is based on the definition of electrical impedance or the so-called active and reactive resistance of tissues. These indicators characterize the ability of human body tissues to thermal propagation of electric current. The phase shift of the current relative to the electric voltage plays a role, which is associated with the properties of cell membranes. The electrical impedance is recorded using a low-power constant frequency sinusoidal current probing analyzer (500-800 µA). It allows determining the content of fat and muscle tissue in the body, the amount of intracellular and extracellular water, as well as other indicators.

In the process of the body adaptation to motor activity, energy costs are controlled through central and autonomous mechanisms of nervous regulation. Their derivatives are heart rate wave ranges (Min et al., 2013; Zhao et al., 2020). The method of assessing heart rate variability allows determining the indicators characterizing the state of vegetative maintenance of body functions. In the appearance of disorders in the heart work, an increase in its regulation through central mechanisms and a decrease in the autonomy of management were found (Hayano et al., 2019). The revealed deviations in the vegetative innervation of cardiac activity allow the researcher to characterize the early (prenosological) signs of deterioration in the body's adaptation to environmental factors (Li Volsi, et al., 2023). Thus, the registration of disorders of autonomic regulation contributes to the early diagnosis of pathology in the cardiovascular system (Uhlig et al., 2020). The methods of analyzing heart rate variability are time analysis, nonlinear methods, variational heart rate monitoring and assessment of the wave structure of the heart rhythm. Therefore, when analyzing a cardiointervalogram, it is advisable to use the maximum possible number of available techniques.

In the context of the educational process at universities, it is advisable to carry out dynamic control of students' morphofunctional indicators with different levels of somatic health for physical education (Aparecida Maria Catai et al., 2020; Bocharin et al., 2023, a, b). In our opinion, it is advisable to allocate students with serious deviations in morphofunctional parameters of the body to risk groups. It will allow individual monitoring of physical activity by teachers in such groups.

The available scientific literature does not fully reflect the results of the new knowledge use in physical education about the state of body component composition and heart rate variability in students with different levels of their somatic health. The use of the obtained research results will allow timely detailing the features of the body functioning for further planning of training sessions and improving their effectiveness.

Research objective: To individualize physical activity, to study the indicators of body component composition and heart rate variability in female students having different levels of somatic health and functional characteristics of the body.

Material & methods

167 girls aged 19.2±1.3 who studied at the Volga Region Research Medical University (Russia) were included into the research project. According to the results of a periodic medical examination, the subjects for physical education were divided into 2 groups: a special group (n = 105) and a preparatory group (n = 62). The girls of the special medical group had some kind of somatic disease. It limits their performance of physical activities. These students are prohibited from playing sports and participating in sports competitions. The girls of the preparatory group were practically healthy, but had minor functional disorders in the activity of body systems or insufficiently developed physical qualities.

The examination of female students was carried out between sessions, outside the days of colloquiums, tests or exams. The measurements were carried out in the middle of the school day, in a quiet room with no extraneous stimuli, at an ambient temperature of 20-22 degrees Celsius. At first, length, cm and body weight, kg were measured using floor scales with a height meter «VMEN-200-50/100- C-ST-A» («ВМЭН-200-50/100-C-CT-A») (Russia). The indicators of the component composition of the girls' body were determined in a sitting position using bioimpedance testing on the software and hardware complex «MedicalSoft Sports Testing System» (MS FIT – 01, Russia). The following parameters were determined: body mass index (BMI, kg/m^2), phase angle (FZ, cu), fat mass (FM, kg), muscle mass (MM, kg), total amount of water (O$_2$, kg), extracellular water (O$_{2ex-w}$, kg), intracellular water (O$_{2\ int-w}$, kg) and basal metabolism (BM, kcal).

To study the female students' vegetative tone in the supine position, a cardiointervalogram was recorded. For this purpose, the diagnostic complex «Poly-Spectrum» («Поли-Спектр») (Neurosoft, Russia) was

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used. According to the standard protocol, universal heart rate variability indicators (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Heart rate variability. Standarts of Measurement. Physiological interpretation and clinical application, 1996).

The heart rate (HR, bpm); the standard deviation of NN intervals (SDNN, ms); the square root of the squares of successive differences between NN intervals (RMSSD, ms); the variation range (MxDMn, ms); the power of the spectrum in the low (LF, %) and high (HF, %) of frequencies; vagosympathetic equilibrium index (LF/HF, cu); total spectrum power (TP, ms^2) and stress index (SI, cu). The value of the biological age indicator (cu) for all girls was used as an integral value.

The students attended PE classes according to the traditional curriculum 2 times a week for 90 minutes each. In both groups, physical activity in the classroom was predominantly aerobic. The examination of the girls does not violate the principles of the Helsinki Declaration of 2008, which are required for medical and biological observations.

The obtained data were processed using the Statistica 10.0 and Microsoft Excel 2016 software package. In each sample, the arithmetic mean (M) and the standard error of the mean (m) were determined. The normality of the indicators distribution was determined by the Kolmogorov-Smirnov criterion with the Lilliefors correction. To determine the statistical significance of differences in indicators between students of special and preparatory groups, the Student's t criterion was used. To identify correlations between the parameter of biological age and indicators of bioimpedance and heart rate variability, the Pearson correlation coefficient was used, and the degree of significance of the correlation was determined using the Student coefficient. The differences were considered significant at $p<0.05$.

Results

According to the bioimpedance study, it was found that the body mass index in girls in the preparatory group was 8.1% higher than the same indicator in the subjects of the special one (24.1±2.8 kg/m^2 and 22.3±2.6 kg/m^2, respectively, $p\geq0.05$), table 1. There are no significant differences in the values of the phase angle index between girls of the preparatory and special medical groups.

Table 1. Values of indicators of the body component composition of students in special and preparatory groups (M±m)

Parameter	Medical health group		p
	Special, n = 105	Preparatory, n = 62	
BMI, kg/m^2	22.3±2.6	24.1±2.8	<0.05
FZ, cu.	8.0±1.8	8.4±2.0	
FM, kg.	14.8±1.3	17.9±1.3	<0,05
MM, kg.	19.6±1.5	20.3±1.6	
O$_2$	25.1±1.7	28.9±1.8	<0.05
O$_{2ex-w}$	10.9±0.8	13.6±1.1	<0.05
O$_{2 int-w}$	13.8±1.2	16.8±1.4	<0.05
BM, kcal	1420.1±86.5	1669.3±101.5	<0.05

Note: P – the significance of the differences between the special and preparatory groups

The girls in the preparatory group had higher body fat (17.9±1.3 kg) and muscle mass (20.3±1.6 kg) relative to the students of the special group (14.8±1.3 kg of fat mass and 19.8±1.6 kg of muscle mass). For the indicator of fat and muscle mass, the difference in the values of the indicators was 20.9% and 3.6%, respectively, $p<0.05$.

The parameters of the total amount of intra- and extracellular water were significantly lower in the students of the special group (by 15.1%, 24.7% and 21.7%, respectively, $p<0.05$ for all indicators), which, in general, is consistent with a higher body mass index value of the subjects of the preparatory group compared with the girls of the special medical one.

The level of the basal metabolism index was naturally 17.5% higher in the students of the preparatory group (1669.3±101.5 kcal) relative to the girls of the special one (1420.1±86.5 kcal), $p<0.05$.

Thus, higher values of fat and muscle mass, body mass index in girls in the preparatory group characterize a higher need for energy supply for the vital organs and systems functioning, which is reflected in the indicator of basal metabolism.

An analysis of the values of heart rate variability indicators showed statistically significant differences in heart rate between girls of the special and preparatory groups 88.1±3.4 and 81.0±3.2 beats/min, respectively, $p<0.05$, Table 2.

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Table 2. Characteristics of the heart rate variability values in female students of special and preparatory groups (M±m)

Parameter	Medical health group		p
	Special, n = 105	Preparatory, n = 62	
HR, bpm	88.1±3.4	81.0±3.2	<0.05
SDNN, ms	38.5±4.6	49.4±5.7	<0.05
RMSSD, ms	46.4±5.3	57.3±5.8	<0.05
MxDMn, ms	208.1±27.4	221.3±36.4	
LF, %	39.5±3.8	32.1±3.3	<0.05
HF, %	25.7±2.2	30.9±2.4	<0.05
LF/HF, cu.	1.8±0.4	1.2±0.2	<0.05
TP, ms^2	1413.8±84.6	1686.1±105.8	<0.05
SI, cu.	189.7±38.5	130.7±20.5	<0.05

Note: P – the significance of the differences between the special and preparatory groups

At the same time, this parameter is fixed at the upper limit of the standard values among the students in the special group. These data indicate low functional reserves of the body in girls of the special medical group compared with girls of the preparatory one.

When analyzing the time parameters of heart activity variability, the SDNN index among the students of the special group (38.5±4.6 ms) was found to be 22.1% lower relative to the students of the preparatory one (49.4±5.7 ms). It indicates an increased centralization of heart rhythm control. In addition, the RMSSD parameter in the students of the preparatory group (57.3±5.8 ms) was 23.5% higher than that of the subjects of the special one (46.4±5.3ms). It indicates an intensification of the parasympathetic activity of the nervous system in girls in the preparatory group and higher recovery capabilities of their body after physical loads.

When studying the spectral analysis of the cardiac activity variability, attention is drawn to the values of the spectrum power indicators in the low and high frequencies, which indicate an increase in sympathetic innervation in students of a special group. The power of the low frequency spectrum in the students of the special group was 39.5±3.8%, in the girls of the preparatory one – 33.1± 3.3%. Among the students of the special group, the power of the parameters in the field of high frequencies was 25.7 ± 2.2%, and in the students of the preparatory group – 30.9± 2.4%. In addition, the value of the vegetative equilibrium index (LF/HF) turned out to be 33.3% lower in the students of the preparatory group relative to the students of the special medical one, $p<0.05$. This fact indicates a higher adaptive capacity of the body when performing physical activities by girls of the preparatory group compared with the special one. The assumption of higher adaptive reserves of students in the preparatory group is also confirmed by the indicators of the total power of the spectrum and the stress index. The total power of the spectrum among the subjects of the preparatory group was 19.3% higher relative to the representatives of the special group, $p<0.05$. The stress index among the girls of the special group was 189.7=38.5 units and 130.7=20.5 standard units for girls of the preparatory one, $p<0.05$. At the same time, the value of the stress index in the special group is at the upper limit of the standard and corresponds to the state of the regulation mechanisms tension. When comparing the index of the variational range of cardiac intervals (MxDMn) among both groups, the spread of cardiac intervals was almost the same (208.1±27.4 ms in the special group and 221.3±36.4 ms in the preparatory one, $p≥0.05$).

We believe that students whose values of heart rate variability indicators approach or exceed the standard values should be considered at risk when performing aerobic exercise. PE teachers should strictly individualize the loads for such students and pay attention to their condition with a study of heart rate to prevent emergencies in the body. The biological age of a person is considered by researchers as one of the markers not only of the general health state, but also of the body's tolerance to physical and mental stress. When determining the biological age on the «MedicalSoft» software and hardware complex, it turned out to be 21.6% higher among the students of the special group compared to the students of the preparatory one (20.8±2.2 and 16.2±2.0 cu., respectively, $p<0.05$), Figure 1.
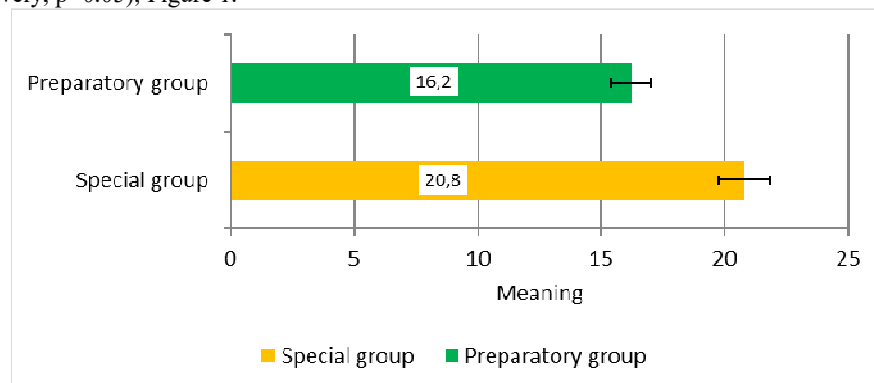

Fig. 1. Biological age of female students in special and preparatory groups

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The correlation analysis allowed establishing the relationship between the biological age of girls, indicators of body component composition and heart rate variability, Figure 2.
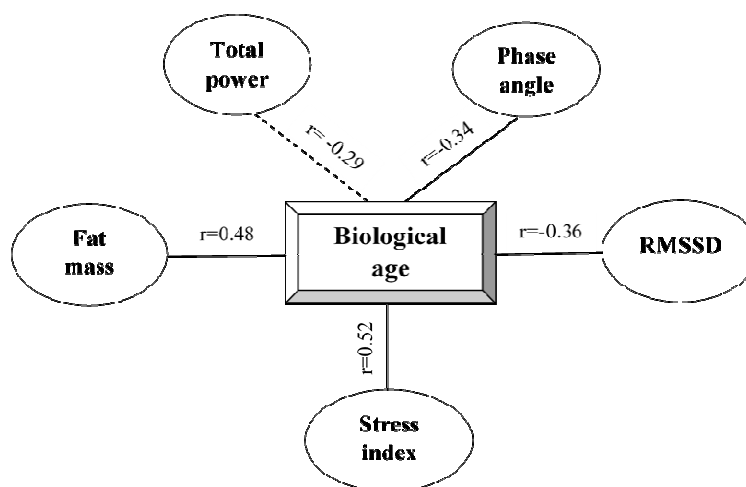

Fig. 2. Correlations between the indicator of the biological age of girls in relation to the parameters of the phase angle, body fat mass, RMSSD, total spectrum power and stress index

It was found that biological age has a positive correlation with stress index indicators (r = 0.52, p<0.05) and body fat level (r = 0.48, p<0.05). An inverse relationship was found with indicators of the total power spectrum of heart rate variability (r = - 0.29, p<0.05), RMSSD (r= - 0.36, p<0.05) and the bioimpedance analysis indicator – the phase angle (r = - 0.34, p<0.05). These dependences suggest a dynamic shift in biological age with a decrease in parasympathetic activity (according to the RMSSD indicator), a deterioration in the overall level of physical performance (according to the value of the phase angle parameter), an increase in body fat mass and a shift in the stress index towards maladaptation. These trends open up prospects for using these indicators as primary factors for diagnosing the state of the optimal level of the body functioning under the influence of the educational and training environment factors at the university.

Dicussion

Scientific literature data indicate the presence of serious deviations in the state of physical and somatic health in a significant number of studying young people (Baker et al., 2022; Bocharin et al., 2023, a; Sokolovskaia et al., 2022). The period of study at a higher educational institution is characterized by significant psycho-emotional and educational loads, which can lead to further functional disorders of the body. Insufficient physical fitness of a person plays an important role (Faílde-Garrido et al., 2022). Diseases often turn into a chronic course (Spruce et al., 2018; Diaz et al., 2020; Ja et al., 2021). Despite the existing deviations in the state of health, scientists and specialists in the field of physical culture strongly recommend that people with serious physical and somatic disorders perform regular physical activity (Budzynski-Seymour et al., 2020; Glazkova et al., 2020). When performing physical exercises by students having health abnormalities, priority attention should be given by PE teachers at an educational institution (Mozolev, 2020). An important direction in the PE classes organization with students having various somatic diseases is the further study of the issues of individualization of physical activity in the classroom (Bocharin et al., 2023, a). One of the approaches to individualization of physical education is the differentiation of physical activity from the state of morphofunctional characteristics of the student's body.

Several techniques can be used to monitor students' adaptive reserves to physical loads, one of which is bioimpedance and heart rate variability analysis (Thomas, & Viljoen, 2020; Tripska et al., 2022; Krueger et al., 2023). With their help, it is possible to assess the state of the body component composition and vegetative tone of various groups of students, which allows timely assessment of the features of the body functioning and the individual capabilities of students to minimize states of maladaptation (Bocharin et al., 2023, a).

In this research, the analysis of the state of the body's component composition was carried out and the indicators of heart rate variability among students of special and preparatory medical groups for physical education were evaluated. It is noted that the students in the preparatory group have higher indicators of fat and muscle mass, intracellular and extracellular water. It explains the higher value of body mass index and basal metabolism in girls in the preparatory group compared with the special one.

Girls studying in a special group are characterized by a relative increase in sympathetic activity and centralization of the heart rhythm according to the temporal and spectral parameters of the cardiointervalogram. These data indicate insufficient adaptive reserves of their body to physical loads. In this regard, such students

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should receive serious attention from PE teachers (Bocharin et al., 2023, b). In our opinion, it is advisable to allocate girls with low functional reserves in terms of cardiointervalogram indicators to risk groups for physical loads. It will allow a PE teacher to individualize physical exercises, which will increase the effectiveness of the wellness orientation of physical culture (Kolokoltsev et al., 2021c).

In girls of the preparatory group, the analysis of heart rate variability indicates an intensification of the parasympathetic activity of the nervous system and higher recovery capabilities of their body after physical loads. The correlation analysis demonstrated direct and inverse relationships of the biological age indicator with some parameters of bioimpedance and heart rate variability. The revealed dependencies established a dynamic shift in biological age with a decrease in parasympathetic activity (according to the RMSSD indicator), a deterioration in the overall level of physical performance (according to the value of the phase angle parameter) and a shift in the stress index towards maladaptation. A significantly greater negative shift in heart rate variability was found in girls of a special medical group. It also indicates the need for special control when performing physical activities in this group of studying girls (Kolokoltsev et al., 2021a).

Conclusions

1. According to bioimpedance analysis, the girls of the preparatory group have higher indicators of body fat and muscle mass, intracellular and extracellular water, phase angle, which affects the parameters of basal metabolism and body mass index compared with the girls of the special one.

2. Students of the special medical group have tension of regulatory systems, increased centralization of heart rhythm and sympathetic activity. It leads to an increase in heart rate, temporal (SDNN and RMSSD) and spectral (LF, HF, TP) heart rate variability, vagosympathetic balance and stress indices. It is advisable to allocate girls with functional values exceeding the normative values to the risk group for physical loads. It will allow individualizing physical education among such students.

3. Indicators of body component composition and heart rate variability can affect the parameter of biological age, which is recorded in a higher value of the indicator among girls of the special group. It may be of interest for further scientific research.

4. The use of correlation analysis demonstrated the dependence of the dynamic change in the indicator of biological age relative to the parameters of body fat mass, phase angle, total spectrum power, RMSSD index and stress index.

Conflicts of interest. The authors declare no conflict of interest.

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