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Original Article

Young men's body hemodynamics variability in different states of motor activity

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Abstract:
The state of hemodynamic parameters under the influence of dosed physical activity on the human body is an urgent problem due to insufficient knowledge of this issue. *Research aim:* is to determine the young students' hemodynamic parameters and the autonomic nervous system response to dosed physical activity. *Research materials and methods***.** The project involved 70 young students aged 18-19, studying at the Medical University of Nizhny Novgorod (Russia). In conditions of rest and dosed physical activity in the form of performing 5 standard motor tests, hemodynamics was studied according to the parameters of systolic and diastolic blood pressure, heart rate, stroke volume of the heart and cardiac output. The cardiac index, Robinson and Kerdo indices, total peripheral vascular resistance, and blood microcirculation in the young men's body were determined using the MedicalSoft sports testing system. *Research results*. The students' hemodynamics and vegetative innervation at rest and after performing dosed physical activity variability was established. At rest, the hemodynamic indicators were within the physiological range. Performing the tests «100 meters run » and «Pulling up on the crossbar» caused the most pronounced hemodynamic and vegetative shifts. The young men's arterial pressure after all physical exertion was of the hypertensive type, which indicates the atypical response of the hemodynamic reaction and the presence of desadaptative shifts in the young men's body. *Conclusions*. It was found that the power and intensity of dosed physical activity has a significant impact on the young men's organism regulation systems tension level, which manifests itself in changes in hemodynamic parameters with a tendency to desadaptative shifts.
Key Words*:* **physical loads, hemodynamic, autonomic nervous system, motor activity**

Introduction

The comprehensive use of means and methods of young people's physical education during vocational training is the basis for strengthening their health (Paliichuk et al., 2018), especially students with different levels of their body fitness (Gryaznykh et al., 2021; Martusevich et al., 2021). The adaptive reserves of the body are directly related to the peculiarities of the functional systems response to different levels of physical activity. A significant part of applicants at the time of admission to the university has deviations in health status (Paliichuk et al., 2018) and a low level of motor skills development.

Therefore, during PE classes, it is important to carry out current and prospective medical and pedagogical monitoring of students' physical activity and physical condition using various monitoring methods and make adjustments to the educational and training process (Budzyn et al., 2018). When a person performs physical loadings, an important role is assigned to constant monitoring of the cardiovascular system activity, which is a limiting system in physical education and sports.

The leading criterion for assessing the body's tolerance to exercise is the degree of the cardiovascular and autonomic nervous system reaction (Nascimento et al., 2015; Zharska et al., 2021). An important indicator of the reserve capabilities of the human body is the Robinson index, which characterizes the systolic work of the heart. The Kerdo index provides information about the role of the autonomic nervous system in the regulation of the heart. The results of determining these indices at the beginning and after the end of physical activity inform

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the researcher about the adaptive abilities of the cardiovascular system to physical exertion and the level of a person's fitness (Shved, Levitska, 2018), signal a possible overstrain of the body caused by physical exertion (Grassler et al., 2021; Bellenger & Buckley, 2021) and show the nature of the course of recovery processes (Dupuy & Dugué, 2018). The leading role of the autonomic nervous system in the body overstrains development is reported by I. Alchinova, M. Karganov (2021). In individuals performing physical activity with the development of sympathetic and parasympathetic types of overstrain, the variability of systolic and diastolic blood pressure and heart rate differ significantly (Guzii et al., 2018).

Insufficient myocardial tolerance to exercise is the basis for reducing a person's physical performance. In this situation, the tone of the sympathetic nervous system increases, lung ventilation increases and the lumen of arterial vessels narrows (Zharska et al., 2021), which significantly worsens the physical condition. Various testing methods are used to monitor the adaptive reserves of the human cardiovascular system, the degree of the body tolerance to perform dosed standard physical activity (Ponomareva, 2019). To monitor the state of the cardiovascular system in individuals performing physical activity, testing methods are used on diagnostic complexes. The instrumental methods include the system of sports testing «MedicalSoft» (Bocharin& Guryanov, 2021), which allows obtaining an informative hemodynamic protocol of human research.

There are enough research works in the scientific literature on hemodynamic and vegetative changes in the athlete's body when exposed to physical exertion at various stages of the training macrocycle (Nuuttila et al., 2017; Ivanyshyn et al., 2021) and in clinical practice (Romanchuk et al., 2019). It seems relevant to study the state of hemodynamic parameters and the autonomic nervous system under the influence of various standard dosed physical loads on the students', engaged only in physical culture in an educational institution body.

Research aim is to determine the young students' (men) hemodynamic parameters and the autonomic nervous system response to dosed physical activity.

Material & methods

The experiment involved 70 students of the Medical University aged 18-19 (Nizhny Novgorod, Russia). All the young men gave their written consent to the study, which corresponded to the directive of the Helsinki Declaration of 2008. According to the results of the medical examination, the main medical group was established for all students, without restrictions of PE classes at the university.

Testing of hemodynamic parameters at rest and reactions to dosed physical activity was carried out in the middle of the studying day. Blood pressure was measured with an automatic tonometer «Omron M2 Basic», hemodynamic parameters were determined by the hardware complex of sports testing «MedicalSoft» (variant MS FIT - 01, Russia).

The complex of dosed physical activity consisted of five test exercises. This is a standing long jump (three jumps in a row), trunk flexion and extension («Trunk lift») (the number of repetitions in one minute), shuttle running at maximum speed (3x10 meters), running 100 meters at maximum speed and pulling up on the crossbar (15 repetitions). There was a short rest of 90 seconds between each exercise.

Physiometric measurements of systolic blood pressure (SBP), mmHg; diastolic blood pressure, (DBP), mm Hg; heart rate (HRV), beats/min; stroke volume of the heart (SV), ml; cardiac output (MVB), l/min; cardiac index (SI), l/min/m^2; total peripheral vascular resistance (TPVR), conventional units were performed. The integral criterion of the microcirculation index of blood in capillary vessels was determined in points. When evaluating 0 - 5 points, the result was considered unsatisfactory, 6-7 - satisfactory, 8-10 points – a good result.

To characterize the systolic work of the heart at rest and after performing dosed physical activity, the Robinson index was calculated: IR = HRV = SBP / 100, conventional units (Robinson, 1967). The role of the sympathetic and parasympathetic nervous system in the innervation of the cardiovascular system at rest and after performing dosed physical activity was evaluated by the Kerdo index: IC = (1 - DBP / HRV) = 100, conventional units (Kérdö, 1966). According to N.Zharska et al. (2021), the value of the Kerdo index in the range from -10 to +10% was considered the norm.

With the values of the Kerdo index > 0.1, the predominance of sympathetic influence (sympathicotonia) was noted in students. At values of the Kerdo index from – 0.1 to + 0.1, a balanced vegetative effect (etonia) was recorded. The predominance of parasympathetic heart innervation in students was recorded if the Kerdo index < - 0.1. The results of the hemodynamic response of the young men's body to dosed physical activity were compared with hemodynamic parameters at rest.

The research project results were processed using the Statistica 6.1 software package for Windows. The arithmetic mean (X), the error of the arithmetic mean (m) and the sigma deviation (σ) were calculated for each sample. The Shapiro-Wilk test was used to test the research results for the normal distribution of indicators. The reliability of the differences in the sample values was determined by the Student's coefficient. The differences were considered significant at $p < 0.05$.

Results

To analyze the variability of young men's hemodynamics, the values of systolic (SBP) and diastolic (DBP) blood pressure were determined (Fig. 1).

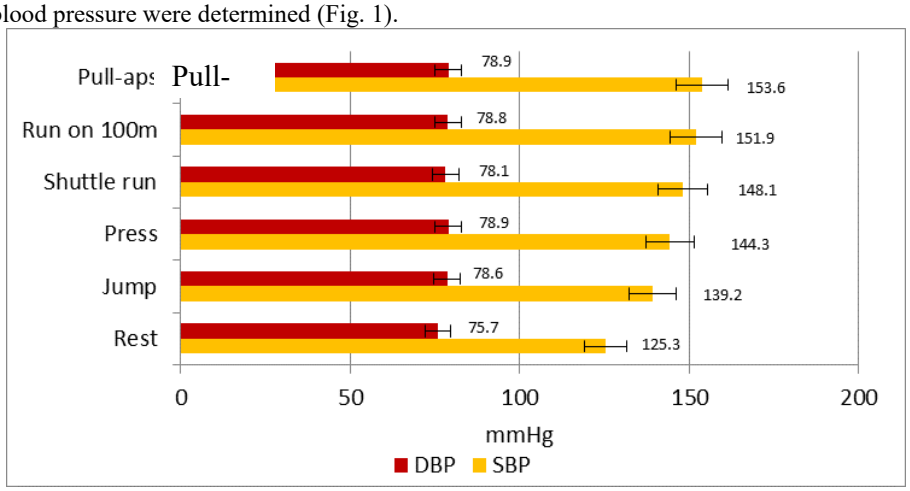

Fig.1. SBP and DBP values at rest and during physical loads

It was found that in a state of physiological rest, the value of the SBP indicator was 125.3 ± 9.7 mmHg, which corresponds to the value of the norm for young people (100-139 mmHg). The SBP value in young men increased depending on the intensity and power of physical activity. The maximum pressure on the vessel walls was noted after performing the load in the form of running 100 meters (151.9±9.1 mmHg) and pulling up on the crossbar (153.6±8.7 mmHg) and was greater than at rest by 21.2 and 22.5%, respectively, $p < 0.05$. These data indicate the intense work of the heart when performing the above motor tests. After performing physical exertion, the DBP value practically did not change and did not differ from the norm (60-89 mmHg), $p > 0.05$. Compared with the values of HRV indicators and parameters characterizing the pumping function of the heart (SV, stroke volume) at rest, the values of these indicators increased after exposure to metered physical activity ($p < 0.05$). This indicates an increase in the tension of the regulatory systems of the body of young men after performing motor tests (Fig.2).

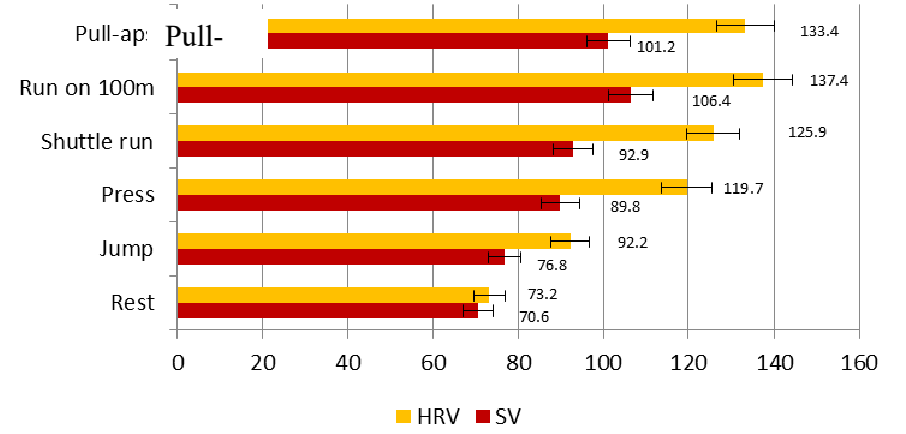

Fig.2. HRV (beats/min) and SV (ml) values at rest and during physical loads

We characterize this trend as adaptive. At rest, HRV and SV values were recorded as normal (60-84 beats/min and 60-120 ml, respectively). During physical exertion, there was no excessive increase in these indicators to values that negatively affect the young men's cardiovascular system work. The greatest increase in the values of HRV and SV indicators was noted in the 100 m run (by 84.0 and 50.7%, respectively) and the pull-up on the crossbar (by 82.2 and 43.3%, respectively) compared with the indicators recorded at rest. The performance of dosed physical exercises led to an increase in the release of blood by the heart with each contraction and an increase in the values of cardiac output (MVB) and cardiac index (SI) in the participants of the research project (Fig.3).

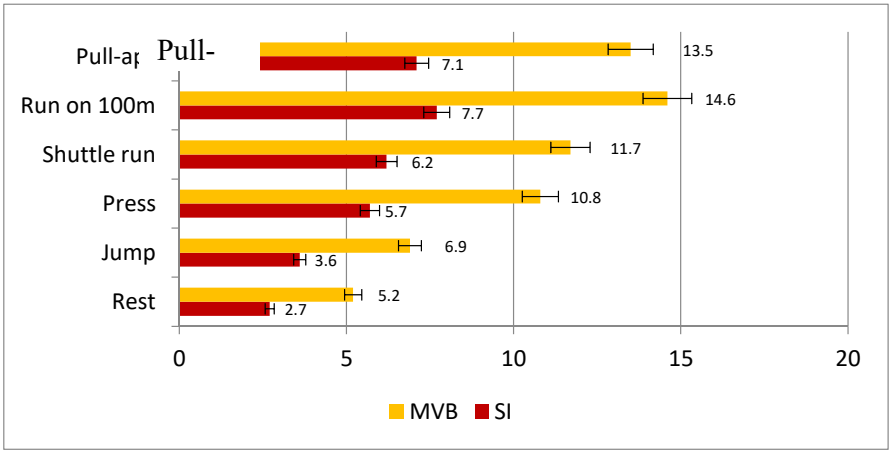

Fig.3. MVB (l/min) and и SI (l/min/m^2) values at rest and during physical loads

The values of these indicators at rest are within the normal range (MVB = 3-7 l/min and SI = 2.5-4.5 l/min/m2). After the completion of physical activity, the greatest increase in the values of cardiac output and cardiac index in young men was noted in the tests «100 m running» and «Pull-up on the crossbar». The increase in MVB and SI in the 100 m run and pull-up was 2.8 and 2.6 times greater than these indicators at rest, $p < 0.05$. Analysis of the results of hemodynamic shifts confirmed the hypothesis of a linear direction of their changes depending on the power of physical activity. To analyze the level of total peripheral vascular resistance (TPVR), the condition of the vascular component of the body of young men was monitored (Fig. 4).

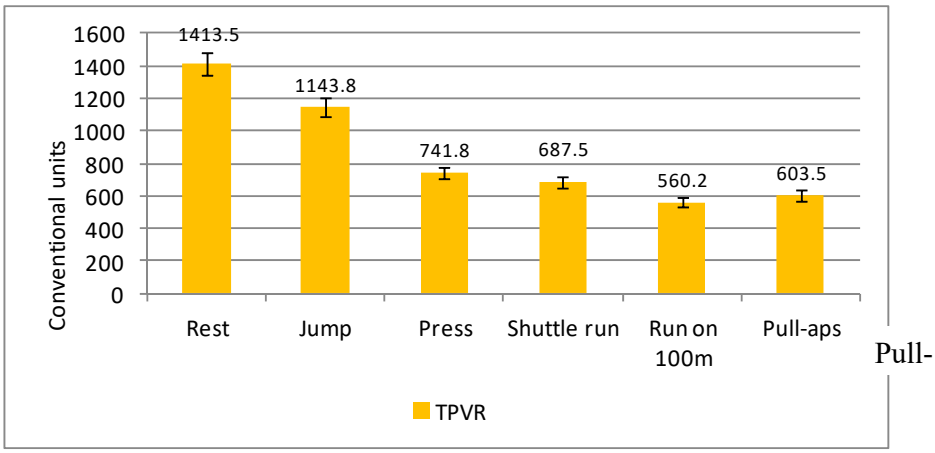

Fig.4. TPVR values at rest and during physical loads

It was found that with an increase in the power of physical activity, a proportional decrease in the value of the TPVR indicator ($p < 0.05$) is observed. The greatest decrease in the TPVR value by 2.5 times is recorded in the motor test «Running 100 m» (560.2 ±102.4 units) and 2.3 times in the test «Pull-up on the crossbar» (603±132.7 units), compared with the values of these indicators recorded at rest. The TPVR reaction to an increase in the power of physical activity can be considered as a compensatory phenomenon of the young men's body in response to sympathetic stimulation of the myocardium and increased shock volume and cardiac output, which reflexively leads to an increase in the lumen of blood vessels to ensure oxygen delivery to the working skeletal muscles. The TPVR indicator is correlated with changes in the level of blood microcirculation in young men (Fig. 5). With an increase in physical activity, the reverse variability of changes in blood microcirculation is noted.

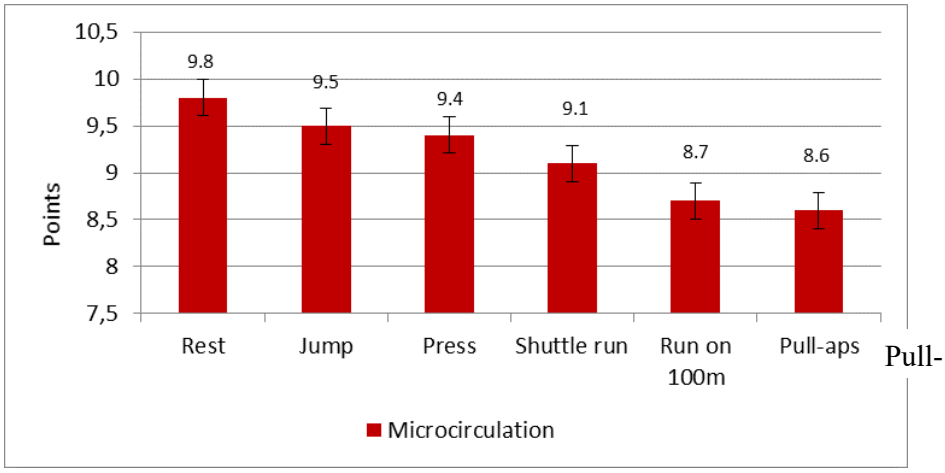

Fig. 5. Values of blood microcirculation indicators at rest and during physical loads

The highest value of the microcirculation index is recorded at rest (9.8 ± 0.2 points). With an increase in physical activity in young men, there was a decrease in the score of the blood microcirculation index. The lowest number of points is recorded in the 100 m run (8.7 ± 0.4 points) and in the «Pull-up on the crossbar» test (8.6 ± 0.3 points), which corresponds to a good assessment of blood microcirculation. The values of the Robinson index and the Kerdo index in young men are shown in Fig.6.

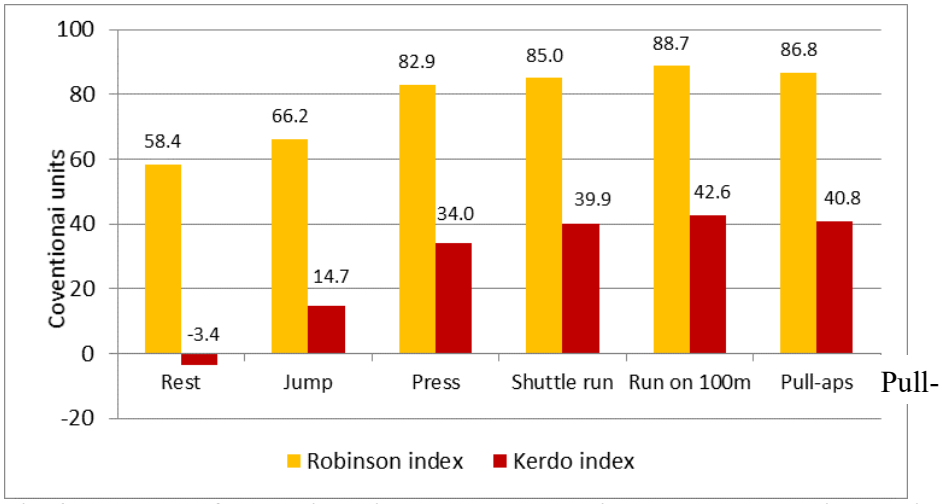

Fig. 6. The values of the Robinson index and the Kerdo index at rest and during physical loads

The highest value of the Robinson index in young men was established after performing a dosed load. For example, in the «Trunk lift» tests, the value of the Robinson index index increased by 41.9%, the «Shuttle run» by 45.5%, the «100 m run» by 51.8% and the «Pull-up on the crossbar» by 48.6% compared to the values of the Robinson index at rest. When determining the Kerdo index at rest and when performing dosed physical work (the «Standing long jump» test), normal autonomic innervation of the cardiovascular system is recorded in young men. When young men perform other motor tests, pronounced sympathicotonia is noted, which indicates the predominance of sympathetic innervation of the heart associated with heavy physical load.

As the research project result, it was found that the power and intensity of dosed physical activity has a significant impact on young men's body functional systems tension level, which manifested itself as a change in hemodynamic parameters with a tendency to desadaptative shifts.

Dicussion

The quality of life and the state of the functional reserves of the body largely depends on students' lifestyle and their motor activity level (Britton et al., 2019). This is especially important for medical university students who have a high level of psycho-emotional stress, excessive educational and practical loads, extensive clinical training and not always an optimal level of motor activity (Gryaznykh et al., 2021). These factors affect the hemodynamic indicators of the body, which characterize the functioning of the cardiovascular system and affect the processes occurring in the body (Misigoj-Durakovic et al., 2016). Therefore, timely monitoring of

adaptive reserves serves as an informative indicator in assessing the work of the body's regulatory systems (Ponomareva, 2019), helps to identify desadaptative shifts in functional parameters and allows for individual correction of the power of physical exertion on a person (Hulka, 2015). In this regard, the determination of the reactions of hemodynamic parameters and the autonomic nervous system of a young organism to dosed physical activity seems timely and relevant in the current and future planning of physical activity for students (Budzyn et al., 2018).

The systemic hemodynamics responses to dosed physical activity and maintenance of homeostasis established in this research work indicate a significant load on the heart, especially when performing motor tests «100 m run» and «Pull up on the crossbar». The pronounced response from the heart is confirmed by a 51.8% increase in the value of the Robinson index in the «100 m run» test and by 48.6% in the «Pull-up on the crossbar» test, relative to the value of this index at rest. Performing motor tests causes changes in the autonomic innervation of the young men's cardiovascular system. The results of the Kerdo index determination indicate that at rest there is a balance of sympathetic and parasympathetic innervation of the heart. According to our data, after performing each dosed physical activity, an increase in the influence of sympathetic innervation of the heart is recorded, which is consistent with the materials of the research by Guzii et al. (2018). We agree with the statement of O. Primakov (2020) that such an increase is associated with a redistribution of blood flow, an increase in stroke volume, heart rate and cardiac output caused by the muscular activity of the examined young men.

When drawing up training process programs in educational institutions, coaches and PE teachers should use knowledge about young men's vegetative innervation of the heart features (Nuuttila et al., 2017). Specialists in the field of rehabilitation of patients with cardiovascular system diseases should take into account the relationship of physical exercise with hemodynamics and autonomic innervation (Romanchuk et al., 2019).

Motor tests for assessing young men's adaptive reserves of cardiohemodynamics are widely used in testing the motor qualities of various population groups in many countries of the world (Nascimento. et al., 2015). According to the response of the human body to physical activity in the test «100 m run» and «Pull up on the crossbar» can be attributed to the most severe for the activity of the cardiovascular system. Therefore, they should be performed with caution due to the significant load and the possibility of violations of hemodynamics and regulation of the heart associated with the central nervous system (Guzii et al., 2018).

As a result of the project participants testing, we found that systolic and diastolic blood pressure at all types of physical activity has a hypertonic type of response. With this type of blood pressure, there is an increase in systolic pressure without a change in diastolic pressure. This type of blood pressure reaction to physical activity can be regarded as an atypical type of hemodynamic response, which indicates the presence of desadaptative shifts in the young men's body. It is possible that such a change in hemodynamics is associated with insufficient physical fitness of young men, which does not contradict the report of Paliichuk et al. (2018).

Other hemodynamic indicators, such as heart rate, stroke volume of the heart, systolic output and cardiac index at rest and after exercise, are predominantly linear in nature. This is consistent with the data of O. Primakov (2020), who established the same nature of hemodynamic parameters in highly qualified cyclists when performing high-power physical work. Our research of the young men's cardiovascular and autonomic nervous systems response to dosed physical activity showed a change in hemodynamics and reserve capabilities of the young body.

Conclusions

Analysis of our research project results showed that the indicators of hemodynamic indicators and the autonomic nervous system of young men at rest were within the physiological range. Dosed physical exercises significantly affect the functional state and adaptive capabilities of the young men's cardiovascular and autonomic nervous systems. The heart rate, stroke volume of the heart, systolic output and cardiac index at rest and after exercise have a predominantly linear nature depending on the physical activity power. It was noted that the motor tests «100 meters run» and «Pull up on the crossbar» caused the greatest hemodynamic and vegetative shifts in the young men's body, which manifests itself in a significant change in the performance of the cardiovascular system.

We have identified in young men an atypical type of blood pressure reaction to physical activity, which manifests itself as a combination of a significant increase in systolic pressure against the background of stable values of the diastolic pressure index. In our opinion, insufficient physical fitness of modern youth explains the presence of desadaptative shifts of autonomic innervation of the heart.

Sympathetic stimulation of the myocardium, increased shock volume and cardiac output during dosed physical exertion causes a compensatory reaction from the general peripheral vascular resistance (TPVR) and can be considered as a response phenomenon of additional oxygen delivery to young men's working skeletal muscles due to an increase in the lumen of blood vessels.

The data obtained in our research project on the young men's cardiac activity hemodynamics and autonomic innervation variability in the classroom with metered physical activity can be used in pedagogical and clinical practice, as well as for planning independent physical education and sports.

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

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