

## Instrumental pedagogical technology of sports testing of students

MAXIM GURYANOV<sup>1</sup>, ANNA POZDEEVA<sup>2</sup>, SOLOMON APOYAN<sup>3</sup>, MIKHAIL KOLOKOLTSEV<sup>4</sup>,  
ELENA ROMANOVA<sup>5</sup>, MARGARITA DUNAEVA<sup>6</sup>, NATALYA MANSUROVA<sup>7</sup>, ANDREI TARASOV<sup>8</sup>,  
ANDREW MARTUSEVICH<sup>9</sup>

<sup>1,2,9</sup> Privolzhsky Research Medical University, Nizhny Novgorod, RUSSIA

<sup>3</sup> Chief Physician, Nizhny Novgorod Regional Center for Prevention and Control of AIDS and Infectious Diseases, RUSSIA

<sup>4</sup> Department of Physical Culture, Irkutsk National Research Technical University, RUSSIA

<sup>5</sup> Department of Physical Education, Altai State University, Barnaul, RUSSIA

<sup>6</sup> Department of Physical Culture, Siberian Federal University, Krasnoyarsk, RUSSIA

<sup>7</sup> Department of Physical Culture and Health, Reshetnev Siberian State University of Science and Technology, RUSSIA

<sup>8</sup> Department of Pediatrics and Preventive Medicine, Immanuel Kant Baltic Federal University, RUSSIA

<sup>9</sup> Head of the laboratory of translational free radical biomedicine, First Moscow State Medical University named after I.M. Sechenov (Sechenov University), RUSSIA

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### Abstract:

At the present stage of development of physical training, it is relevant to use instrumental methods of control and monitoring heart rate variability (HRV) in people involved in physical culture and sports. *Purpose.* To investigate and study the features of the manifestation of the parameters of heart rate variability (HRV) in students in response to the impact of physical activity of various volumes and directions. *Research materials and methods.* Using the system of sports testing "MedicalSoft", we analyzed the heart rate variability (HRV) in 70 young men aged 18.7±1.1 of the Medical University (Russia). We conducted the initial HRV study of students according to the standard protocol in a state of physiological rest (control indicators pNN50, SDNN, HF and LF, autonomic balance index LF / HF, VLF, TP (total spectrum power), SI (stress index). Then, we studied the HRV parameters after performing each motor test of various directions and load volume (test indicators). To assess the effect of the dynamic strength of the muscles of the lower extremities on HRV, we used the "long jump" test. To assess the effect of power loads, we used the "flexion and extension of the trunk" test in the supine position" and the test "pulling up from the hang on the bar". We assessed the motor qualities "dexterity" and "speed-strength endurance" using the "shuttle run 3x10 meters" test. We evaluated the motor quality "quickness" according to the results test "100 m run. *Research results.* The test values of all indicators of students according to the HRV protocol significantly differ from the role. In the motor tests "running 100 meters" and "pulling up from the hang on the crossbar" in young men, the predominance of sympathetic innervation and the central mechanisms of regulation of the cardiovascular system over the autonomous one, a decrease in the body's tolerance to physical activity and the development of a state of disadaptation were established. *Conclusions.* The instrumental method of sports testing of the state of vegetative regulation of the heart rate can be used in the pedagogical practice of physical education of students to reduce the risk of overstrain, disadaptation and the occurrence of a critical state of the body.

**Key Words:** physical training, students, heart rate variability (HRV), test physical activity

### Introduction

In physical culture and sports practice, the use of modern instrumental control methods, which have high information content, reliability and validity of the studies, is becoming increasingly important (Adams et al., 2018; Aparecida Maria Catai et al., 2020). One of these methods is the determination of heart rate variability (HRV) parameters, which allows a fairly objective assessment of the degree of tolerance and reserve capabilities of the human body to physical activity (Guzii et al., 2020; Christiani et al., 2021).

The human autonomic nervous system responds to any physical activity. There is a change in the balance between the sympathetic and parasympathetic nervous systems. HRV - the method shows the state of the heart rate at rest and after exercise, measures the time intervals between the R-waves of the electrocardiogram.

HRV indicators are associated with the activation of central or autonomous parts of heart rate regulation RMSSD, IAB, IAPR, and VLF (Guzii et al., 2020). In cases of disturbances in the activity of the heart, there is an increase in its regulation through the central mechanisms of its control and a decrease in autonomy to return to normal (Steven E. Perkins et al., 2016; Hayano et al., 2019). The greater the centralization of the mechanism

for managing cardiac activity, the more difficult it is for a person to adapt to various amounts of physical activity. A similar condition can occur in an athlete performing physical activity of various directions and volumes in case of overstrain or overtraining of the body (Sergio Jiménez Morgan, & José Arturo Molina Mora, 2017).

There is a sufficient amount of information in the scientific literature about the use of the method for assessing heart rate variability in sports activities. Scientific works concerning the use of this control method among students involved in physical education are limited (Misigoj Durakovic et al., 2016). Low physical activity of modern youth (WHO. Physical activity Fact sheet, 2018) and their poor physical health Chekhovska et al. (2020) and Setiakarnawijaya et al. (2021) can lead to negative physiological changes in the body of young people and cause serious deviations in their health (Flatt et al., 2020). In the physical education classes of students, there is a different level of development of their motor qualities, due to different tolerance of the myocardium to physical stress, which creates difficulties in managing the educational process. Therefore, the timely use of effective methods of monitoring the state of the adaptive systems of the body of students allows us to determine the reserve characteristics of the body for physical exertion and offer individual educational routes. To achieve these goals, you can use the system of sports testing "MedicalSoft" as a pedagogical technology for monitoring students' heart rate variability and preventing overwork in physical education classes. Such a testing system allowed us to earlier assess the hemodynamic parameters of students (Bocharin et al., 2022) and draw up a comparative protocol for differences in heart rate depending on the student's sports profile (Bocharin et al., 2021).

The search for methods for assessing adequate urgent and long-term adaptation of the students' body to dosed physical activity of various volumes and directions is becoming relevant (Drezner et al., 2019). The proposed by us scheme of testing students in physical education classes at the university allows us to carry out a planned correction of the curriculum of physical education, to individualize physical loads that correspond to the tolerance and adaptation of the students' organism. Work in this direction seems to be a timely and relevant pedagogical technology.

*Purpose.* To investigate and study the features of the manifestation of the parameters of heart rate variability in students in response to the impact of physical activity of various volumes and directions.

#### **Material & methods**

The participants of the research project were 70 boys of 18-19-year-old ( $18.7 \pm 1.1$ ), who are students of the Privolzhsky Research Medical University in Nizhny Novgorod (Russia). All young men had the main medical group for physical education. Written consent from the boys and their parents to participate in the study was obtained. The legal basis for scientific research has been respected, in accordance with the directive of the Declaration of Helsinki (2008).

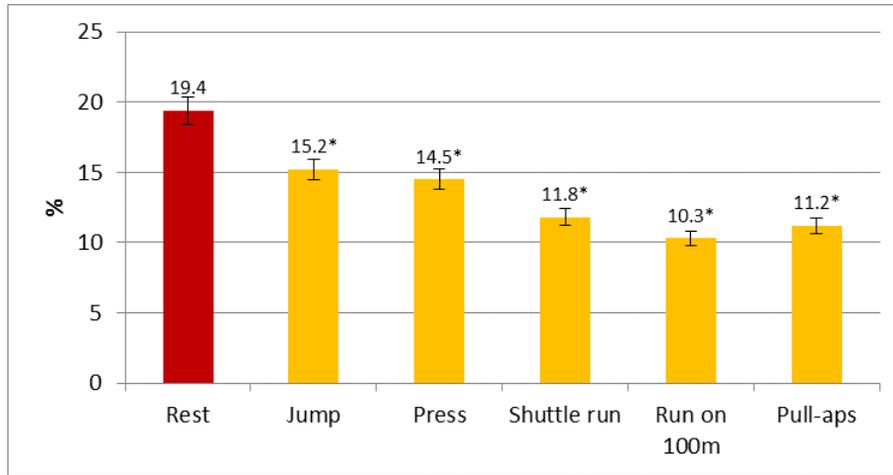
To assess the development of the main motor qualities of young men, we used motor tests (PCFSN. The president's challenge: Physical fitness test, 2011). To assess the influence of the dynamic strength of the muscles of the lower extremities on heart rate variability, we used the long jump test (3 repetitions in a row). To assess the effect of power loads on HRV, we used the "flexion and extension of the body in the supine position" test (number of times per minute) and the "pull-up from the hang on the bar" test (number of times). We assessed the motor qualities "dexterity" and "speed-strength endurance" using the test "shuttle run 3x10 meters" at maximum speed. We evaluated the motor quality "quickness" according to the results of the test "running 100 meters" at maximum speed.

In the project, we used the instrumental research method. We conducted the initial study of HRV of each student in a state of physiological rest (control indicators), then after each motor test (experimental indicators). Between physical exercises, a short rest of 90 seconds was allowed. To record a cardiointervalogram with a volume of 256 cardiocycles, we used the MedicalSoft system for sports testing of heart rate variability (HRV) parameters (version MS FIT - 01, Russia). We studied the adaptive response of the cardiovascular system of young men according to the protocol indicators: pNN50 (the number of NN intervals that differ from the previous one by 50 ms and > for the entire recording period, %), SDNN (standard deviation of the mean NN intervals), HF and LF (spectrum power in the region of high frequencies and low frequencies, respectively), vegetative balance index LF/HF (ratio of low-wave and high-wave powers of the spectrum), VLF, (value of the power of the spectrum in the region of very low frequencies in %), TP (total power of the spectrum), SI (stress index R.M. Baevsky). The results of the obtained data were analyzed in accordance with the standard protocol for the study of heart rate variability (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

We processed the data obtained during the study using the Statistica 6.1 software package for Windows. For each sample, the arithmetic mean ( $M$ ), its error ( $m$ ), and standard deviation ( $\sigma$ ) were calculated. We tested the normality of the distribution using the nonparametric Kolmogorov-Smirnov test with the Lilliefors correction. Comparison of the average values of indicators in the samples relative to the control (the state of physiological rest) we performed in pairs using Student's t test. Differences were considered significant at  $p < 0.05$ .

## Results

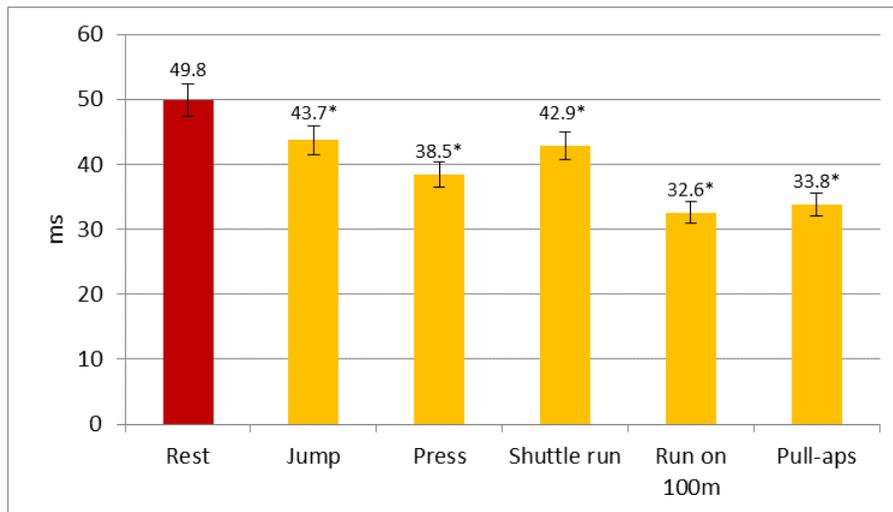
At the beginning of the research project, it was found that in young men at rest (control), the values of statistical indicators pNN50 significantly differ from the values of indicators after performing all motor tests of various directions, Figure 1.



Note. \* significant difference,  $p < 0.05$

**Fig. 1. Values of pNN50 indicators in young men at rest and after exercise**

In young men, in response to all test physical loads of different power, the number of NN-intervals, which differ from the previous one by 50 ms and  $>$  for the entire recording period, significantly decreased. This indicates an increase in the stationarity of the heart rhythm. The greatest decrease in pNN50 values was recorded after performing the 100-meter run and pull-up tests (by 46.9% and 42.3%, respectively) compared with the control indicator. Analysis of the results of the study of autonomic innervation showed a significant decrease in the values of statistical indicators of the standard deviation of the mean NN intervals (SDNN) after performing all types of motor tests,  $p < 0.05$ , Figure 2.

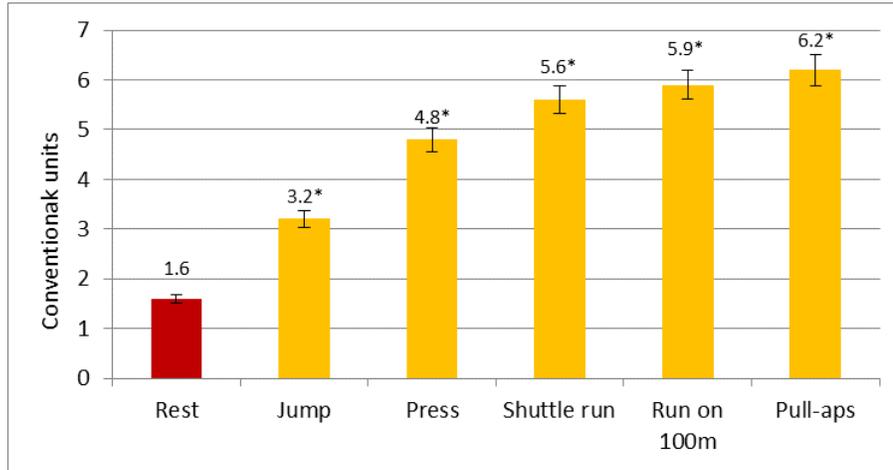


Note. \* significant difference,  $p < 0.05$

**Fig. 2. SDNN values for students at rest and after exercise**

The greatest decrease in the values of pNN50 and SDNN was found after performing the tests "100 m run" and "pull-up from the hang on the bar" (34.5% and 32.1%, respectively) compared with the control indicator,  $p < 0.05$ . Such a decrease indicates an increase in the tendency of the body of young men to centralize the control of the heart rhythm and indicates a decrease in the adaptive properties of the cardiovascular system to this type of physical activity. Significant components in the study of the adaptive reactions of the organism of young men were the spectral indices of HRV on the cardiorythmogram. The mutual ratio of the total strength of the spectra of low and high frequencies (LF/HF) can be considered as the main parameter of the vegetative

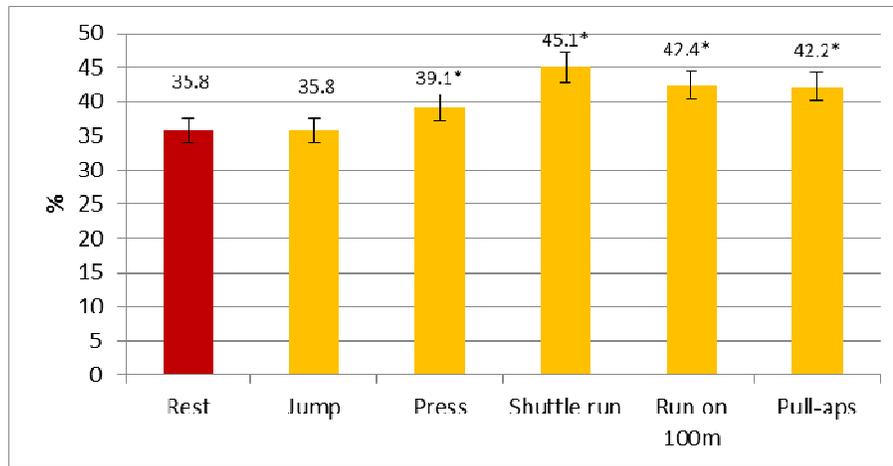
provision of the human heart rhythm. This indicator increases as the intensity of physical exercises increases and reaches its maximum value after performing the tests "running for 100" and "pulling up on the bar", Figure 3.



Note. \* significant difference,  $p < 0.05$

**Fig. 3. The indicator of the ratio of the power of the spectrum in the region of low and high frequencies (LF / HF) in students at rest and after physical exertion**

In our project, an increase in sympathetic stimulation of the myocardium of young men by 3.7 times after running 100 meters and an increase by 3.8 times after pulling up on the bar, compared with control values,  $p < 0.05$ , was established. The shift in the balance of the autonomic regulation of the heart towards the predominance of sympathetic innervation leads to a sharp increase and acceleration of heart contractions, which can be considered as a low level of tolerance of the students' body to physical activity. After performing motor tests, the predominance of the spectrum power in the very low frequency region (VLF) was noted, Figure 4.

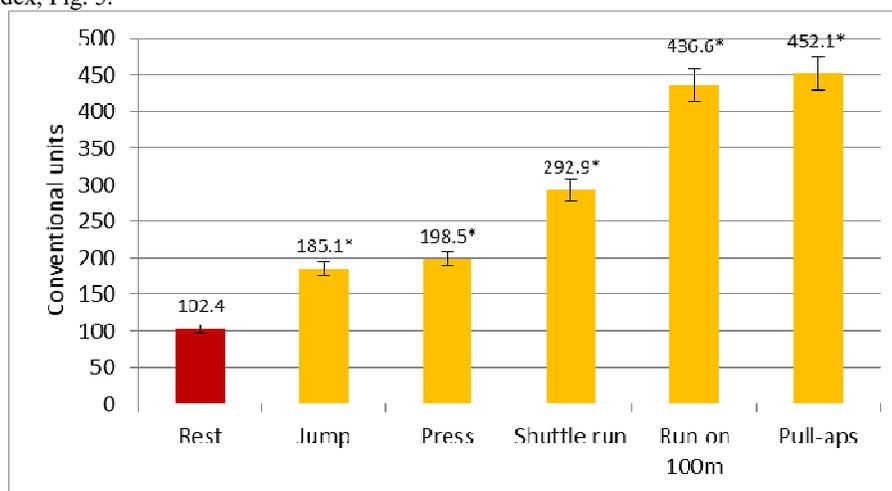


Note. \* significant difference,  $p < 0.05$

**Fig. 4. The value of the spectral power index in the region of very low frequencies (VLF) in students at rest and after exercise**

There is a relative preservation of the autonomic circuit of the regulation of the heart rhythm of young men after the first two tests. However, after the next three tests, there was an increase in the influence of the central mechanisms of regulation of the activity of the heart. The increase in VLF values after the shuttle run test was 25.9%, after the 100m run test by 18.4% and after the pull-up test by 17.8%, compared with the control values. This indicates the emergence of an energy-deficient state of the body of young men, and also indicates the predominance of the sympathetic division of the autonomic nervous system in the regulation of the heart and the presence of a complex influence from the cerebral cortex. With this in mind, it can be assumed that in the body of young men there was a connection of the humoral system of regulation of the mechanism of adaptation to physical activity. Baevsky's stress index (SI) characterizes the state of activity of the body's regulatory

systems. After performing all the motor tests, the young men recorded a significant increase in the value of the stress index, Fig. 5.



Note. \* significant difference,  $p < 0.05$

**Fig. 5. The value of the stress index (SI) for students at rest and after exercise**

The greatest predominance of the central mechanisms of regulation of the cardiovascular system over autonomous mechanisms was registered after exposure to physical activity in the 100-meter run test and in the pull-ups test,  $p < 0.05$ . Compared with the control indicators, the SI increase was 4.3 times in the 100-meter run test, and 4.4 times in the pull-up test and amounted to 436.6 and 452.1 conventional units, respectively. This indicates that young men have a state of the body close to maladaptation.

An analysis of the data obtained from the research project shows that after performing test tasks of various powers, 73.9% of the young men showed HRV values within the normal physiological range. Every fourth student has an imbalance in the regulatory mechanisms of influence on the heart rhythm, which is also determined by the dynamics of changes in the parameters of heart rate variability.

## Dicussion

The processes of adaptation of the human body to physical loads while maintaining the constancy of the internal environment of the body are closely interconnected with the work of regulatory mechanisms (Bocharin et al., 2022). A significant activity of regulatory mechanisms is the creation of optimal conditions for the body's resistance to ever-increasing physical stress (Hayano et al., 2019; Catai et al., 2020). For the successful fulfillment of physical activity in training sessions or trainings, one should take into account the individual characteristics of adaptive reserves and autonomous regulation of the students' organism, which are the main causes of overstrain and maladaptation at the initial stage of physical culture and sports. Young et al. (2018) and Tiwari et al. (2021) report on the difficulties of organizing and conducting an in-depth medical examination of applicants and students to identify the level of tolerance of the body and the adaptation of the cardiovascular system to physical activity.

The results of our research project confirmed the opinions of other authors (Mozolev et al., 2020; Tomás Reyes-Amigo et al., 2021) about the leading role of the cardiovascular system in the performance of physical work and the development of tolerance of the human body to motor activity. According to our early observations, it was found that physically inactive university students had diseases of the cardiovascular system. They recorded the lowest weekly physical activity score and metabolic equivalent level, compared with the results of students with other types of diseases. Such results confirm the importance of the cardiovascular system for the physical activity of young people and emphasize the need to improve the methods of pedagogical and medical control at the training sessions for the physical education of students (Kolokoltsev et al., 2021).

Analysis of the results of testing students, conducted in our study, showed that test physical exercises have different effects on heart rate variability and functional readiness of students. For example, the motor tests "running 100 meters" and "pulling up from the hang on the crossbar" were the most difficult for the body of young men to tolerate. After performing this type of physical activity, students noted the predominance of sympathetic stimulation of the myocardium and higher control centers. Their implementation led to a decrease in the autonomic regulation of the heart rhythm and the appearance of a state of disadaptation and overstrain in the body of young men. Therefore, it is necessary to perform them with caution, with a preliminary examination of the state of the cardiovascular system and current control in the training session (Guzii et al., 2020). Our data confirm the need for regular monitoring of the functional reserves of students studying at the university in the

discipline "physical culture and sports" (Ustselemova, & Ustselemov, 2020). We believe that the sequence of tests, taking into account their severity, has an important adaptive role for the body.

Instrumental pedagogical technology for assessing heart rate variability using the HRV method is used by us to personalize the level of functioning of the regulatory systems of the body of students and determine the individual volume and direction of physical activity in the classroom at the university.

### Conclusions

According to the results of the research project, we found that the exercises from the set of motor tests cause significant changes in the response of the cardiovascular system, compared with control indicators, with reliable results. The most significant shifts in the parameters of heart rate variability were observed in young men after performing the tests "running 100 meters" and "pulling up from the hang on the bar". After performing these tests, the number of NN intervals (pNN50) significantly decreased in young men by 34.5%, the value of the standard deviation of the mean NN intervals (SDNN) decreased by 32.1%, compared with the indicators at rest. In addition, the level of students' body tolerance to physical activity decreased due to a 3.7-fold increase in the effect of sympathetic stimulation of the young men's myocardium after the "100-meter run" test and decreased by 3.8 times after the "pull-up on the bar" test, compared with control values. The increase in very low frequency (VLF) values after the Shuttle test was 25.9%, after the 100m run test was 18.4%, and after the Hanging Pull-up test was 17.8%, compared to the control values. These results indicate the emergence of an energy-deficient state of the body of young men. The stress index increased 4.3 times after the 100m run test and increased 4.4 times after the pull up test.

The study showed that the instrumental method of sports testing on the apparatus "MedicalSoft" can be used in the pedagogical practice of physical education of students to assess the state of autonomic regulation of the heart rate in the classroom, which allows to prevent the risk of critical moments in the activity of the cardiac and vascular system. We propose to expand the arsenal of exercises for the development of speed and strength of the muscles of the upper limbs in the curriculum of physical education in order to increase the tolerance of the body of students to loads. For students with violation of the regulatory mechanisms of the heart rhythm, it is important to provide individual educational routes.

The results of the study showed that the instrumental pedagogical technology for determining heart rate variability for analyzing the tolerance and adaptive capabilities of the young men's heart and vascular system to the impact of physical activity in a training session is highly informative, versatile and relatively easy to use.

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

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