ADAPTIVE-COMPENSATORY REACTIONS OF THE ORGANISM OF UNTRAINED ADOLESCENTS WITH DIFFERENT TYPES OF HEART RATE REGULATION TO POWER FITNESS LOAD

АДАПТАЦІЙНО-КОМПЕНСАТОРНІ РЕАКЦІЇ ОРГАНІЗМУ НЕТРЕНОВАНИХ ПІДЛІТКІВ З РІЗНИМ ТИПОМ РЕГУЛЯЦІЇ РИТМУ СЕРЦЯ НА НАВАНТАЖЕННЯ СИЛОВОГО ФІТНЕСУ

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Abstracts

The work **aims** to study adaptive and compensatory reactions of untrained adolescents with different types of heart rate regulation to various power fitness class models.

Material and methods. 75 physically healthy untrained adolescents (boys aged 15–16) with identical morphometric body parameters were examined. According to the heart rate variability (HRV) results, they were divided into three groups by type of heart rate regulation: A – normotonic, B – sympathotonic, and C – vagotonic. Methods: an integral method for assessing the quantitative assessment of fitness loads, heart rate variability (HRV), and statistical analysis. The changes in the heart rate spectral analysis in study participants were determined using each of the developed models of power fitness classes. Control measurements were taken during rest and in response to a stressful stimulus sequentially applying each of the developed power fitness class models for study participants.

Results. Three modes of power load regimes were developed with a clear gradation in terms of volume and intensity using different energy supply systems. On their basis, three experimental models of power fitness classes for untrained adolescents with various types of heart rhythm regulation were created. The study showed that in response to high-volume power loads in aerobic glycolysis energy supply mode (model 1), sympathetic tone (LF) increased in groups A (+14.2%) and C (+9.7%). In Group B, the influence of autonomic regulation (HF) rose by 6.9%. Using model 2, parasympathetic activity in group A adolescents decreased by 17.8% and C – by 11.5% due to a reduction in the vegetative balance index. Group B participants increased their vegetative balance by 11.9% and the central circuit of sinus rhythm regulation (VLF) by 6.9%. After using model 3, group A representatives had the most pronounced increase in sympathetic tone (LF +14.3%), and a decrease in the influence of autonomic regulation (HF -25.6%). In group C, the vegetative balance shifted towards parasympathetic regulation (LF/HF -26.4%) in response to a stressful stimulus, indicating the activation of short-term adaptation mechanisms.

Conclusions. Determining the appropriate type of heart rate regulation based on spectral HRV characteristics allows for developing an effective model of power fitness classes in the shortest possible time. In adolescents with different types of heart rate regulation, depending on the variability of load mode combination and the energy supply mechanism while performing different sets of exercises, the manifestation of adaptive and compensatory reactions to the stimulus will vary.

Key words: untrained adolescents, vegetative balance, load modes, autonomous regulation, energy supply.

Мета – вивчити особливості адаптаційно-компенсаторних реакцій організму нетренованих підлітків з різним типом регуляції ритму серця в умовах використання різних моделей занять із силового фітнесу.

Матеріал і методи. Обстежено 75 фізично здорових нетренованих підлітків (юнаків 15–16 років) з ідентичними морфометричними параметрами тіла. За результатами варіабельності серцевого ритму (ВСР) були розділені на три групи за типом регуляції ритму серця: А – норматоніки, В – симпатотоніки, С – ваготоніки. Методи: інтегральний метод оцінки кількісної оцінки навантажень у фітнесі, ВСР, статистичний аналіз. Визначали особливості зміни показників спектрального аналізу ритму серця у представників обстежених груп в умовах використання кожної з розроблених моделей занять із силового фітнесу. Контроль відбувався у стані спокою та у відповідь на стресовий подразник, використовуючи почергово кожну з розроблених моделей занять із силового фітнесу для такого контингенту.

Результати. Розроблені три режими силових режимів навантаження з чіткою градацією за параметрами обсягу та інтенсивністю різних систем енергозабезпечення. На їх базі були створені три експериментальні моделі занять із силового фітнесу для нетренованих підлітків з різним типом регуляції ритму серця. Встановлено, що у відповідь на силові навантаження великого обсягу в умовах аеробного гліколізу (модель № 1) відбулось посилення симпатичного тонусу в групі А (LF +14,2%) та С (LF +9,7%). У групі В, навпаки, відбувається посилення впливу автономної регуляції (HF +6,9%). Після використання моделі занять № 2 спостерігаємо посилення парасимпатичної активності за рахунок зниження показника вегетативного балансу в групах А (-17,8%) та С (-11,5%). У групі В, навпаки, спостерігаємо підвищення вегетативного балансу на 11,9% та посилення центрального контуру регуляції синусового ритму (VLF +6,9%). Після використання моделі занять № 3 спостерігаємо в групі А найбільш виражене посилення симпатичного тонусу (LF +14,3%) та зниження впливу автономної регуляції (HF -25,6%). При цьому в групі С відбувається зміщення вегетативного балансу у обстежених групи С у бік парасимпатичної регуляції (LF/HF -26.4%) у відповідь на стресовий подразник, що свідчить про активацію механізмів короткочасної адаптації.

Висновки. Визначення відповідного типу регуляції ритму серця на основі спектральних характеристик потужності ВСР дозволяє в найкоротший термін часу розробити ефективну модель занять із силового фітнесу. У підлітків з різним типом регуляції ритму серця залежно від варіативності поєднання режимів навантаження та механізму енергозабезпечення під час виконання певного комплексу вправ прояв адаптаційно-компенсаторних реакцій на подразник буде відрізнятись.

Ключові слова: нетреновані підлітки, вегетативний баланс, режими навантажень, автономна регуляція, енергозабезпечення.

Introduction. Despite the growing popularity of various types of fitness worldwide, the problems associated with hypodynamia and hypokinesia among the younger generation remain unresolved [3; 8; 11]. The scientific literature presents a sufficient number of works devoted to studying the influence of various areas of fitness on the functional capabilities of the body of adolescents [4; 14; 17]. However, the main problem of these studies is that most scientists do not study the body's resistance level to such stress stimuli using modern physiological and biochemical markers [1; 2; 12]. This factor negatively affects the system of control over the adaptation of this age category to loads of various natures. The absence of a balanced system of management of load parameters considering the age-related characteristics of physiological processes of adaptation to such stimuli will in most cases lead to maladaptation [6; 7; 15]. First, this concerns the category of untrained adolescents, whose body resistance level usually does not correspond to the standard volume and intensity parameters. The same problem concerns the use of classical fitness programs, the development of which does not take into account the possible imbalance between load regimes, exercise complexes, and the energy supply system [8; 13].

The study of the scientific problem of assessing the nature of adaptive and compensatory reactions of the human body in the conditions of various types of fitness has been actively paid attention by many scientists in recent years [4; 6; 13]. The urgency of this issue is associated not only with the growth of the number of people who prefer fitness classes but also with the growth of cases of maladaptation [7; 12]. In their works, most scientists [2; 8; 15] emphasize the lack of a clear gradation of variability using informative physiological and biochemical criteria for assessing the adequacy of loads to the body's reserves. Several researchers on power fitness demonstrate the effectiveness of combining heart rate variability methods, biochemical blood parameters, bioimpedancemetry, and other parameters for assessing adaptation processes [6; 11; 16]. However, these studies have mainly involved professional athletes from various sports or mature and elderly people [2; 13]. At the same time, the available scientific literature lacks information on studying the adaptive changes in untrained adolescents using different load regimes in power fitness in anaerobic and aerobic energy supply modes.

The work aims to study adaptive and compensatory reactions of untrained adolescents with different types of heart rate regulation to various power fitness class models.

Material and methods. The study involved 75 physically healthy untrained adolescents (boys of 15–16 years old), who, according to the preliminary results of a medical examination and laboratory tests, had no contraindications for strength fitness classes. At the same time, the study participants had practically identical morphometric body parameters. The study was conducted in 2024 with the Research Center of Modern Kinesiology "KINEZUS" and its branches (Mykolaiv, Odesa, Chernivtsi, Rivne, Ukraine). The study design was approved by the ethics committee of the Lesya Ukrainka Volyn National University, Ukraine. The risks and benefits of the study were explained to the study participants and their parents who signed informed consent forms prepared following the ethical standards of the Declaration of Helsinki.

Power load parameters. Using the integral method of quantitative assessment of loads for fitness, and bodybuilding [5] allowed us to develop training regimes for power fitness with different volume and intensity parameters in the conditions of anaerobic and aerobic energy supply modes. Using the initial results of the maximum strength development (1 RM) of the main muscle groups of the study participants in control power exercises, and the key load components (number of repetitions in a set, duration of movement in each phase, movement amplitude, duration of muscle tension in a set, etc.), helped to calculate the load factor (R_a) value. The obtained results were used to determine the projectile working mass (m) parameters and load volume (Wn) in a set for each load regime.

Heart rate variability. A Polar V800 heart rate monitor (Finland) was used to measure RR intervals. Heart rate and raw RR intervals were recorded using a sensor mounted on a chest strap (H10, Finland). The Polar Flow web service downloaded RR interval data to a computer. HRV parameters were calculated with the help of Kubios HRV Standard 3.5.0 software. Fast Fourier transform was selected for spectral analysis in the frequency domain. During the HRV spectral characteristics analysis, the following ranges were distinguished: low-frequency (LF, %), very-low-frequency (VLF, %), and high-frequency (HF, %). The LF/HF ratio was determined as an indicator of the measure of vegetative balance. The registration of RR interval signals in the subjects was performed in a seated position at rest before and after the training session. To standardize HRV studies with short recordings, an optimal recording duration of 5 minutes was chosen.

Organization of research. The research was conducted in several stages during 2024.

In the first stage, using the HRV method, primarily spectral analysis indicators, the study participants were divided into three groups according to the type of heart rhythm regulation. Using the spectral indicator LF/HF (vegetative balance index) results assessed at rest before a stressful stimulus application, the division into groups was carried out according to the following parameters. Group A (normatotonics) included adolescents whose vegetative balance indicators were within the optimal range for this age (LF/HF=1.09±0.4). Group B consisted of participants whose vegetative balance was biased towards sympathetic regulation (LF/HF >1.5) – sympathotonics. Group C representatives were adolescents whose autonomic balance was shifted towards parasympathetic regulation (LF/HF <1.0) – parasympathotonics (vagotonics).

In the second stage, control testing of the study participants was carried out to determine the level of maximum strength development (1 RM) of the main muscle groups. Hammer simulators were used to prevent injuries and accommodate the surveyed adolescents with limited proficiency in performing power exercises. Using the initial data and the integral method of quantitative assessment of loads for fitness, load regimes in power fitness for untrained adolescents were developed. At this stage, models of power fitness classes for untrained adolescents with different types of heart rhythm regulation were developed taking into account the load regimes, the features of the proposed exercise complexes, and the age-related characteristics of adaptation processes.

In the third stage, the peculiarities of changes in the HRV spectral analysis in study participants were determined using each developed model of power fitness classes for untrained adolescents. The control was carried out in a state of rest and response to a stressful stimulus, sequentially applying each of the developed models of power fitness classes. A comparative analysis of the obtained data was carried out and the study results were processed.

Statistical analysis. The statistical analysis of the study results was performed using the IBM *SPSS*Statistics 27 software package (StatSoft-Inc., USA). The G-Power 3.1.96 program allows for determining the smallest sample size for the study (calculation of statistical power). Nonparametric methods of statistical analysis were used. The median (Me) and interquartile range (IQR) were calculated. The Kruskal-Wallis test was used to compare the initial parameters between the three groups of study participants. The Wilcoxon t-test was used to compare two dependent samples with each other.

Research results. Figure 1 presents the structure and content of the main load regimes in power fitness for untrained adolescents. The presented training load regimes are developed based on the practical implementation of the integral method of quantitative assessment of loads, known among fitness and bodybuilding specialists [5; 6; 14]. One of the characteristic features of these load regimes is their gradation by volume and intensity parameters. It gives additional ability to determine the projectile working mass parameters when performing power exercises in a given mode. The presented scheme reflects the variability of the key load components and their influence on the volume and intensity levels ratio. The simplification of the calculation of the main load parameters taking into account the individual level of development of the maximum muscle strength of the study participants is one of the effective mechanisms for optimizing the magnitude of the external stimulus for untrained adolescents.

Figure 2 presents experimental models of power fitness classes for untrained adolescents with different types of heart rate regulation. One of the key features of the developed models is the scientifically substantiated combination of the most effective load regimes in power fitness with quite different energy sources for muscle energy supply modes.

Developing experimental models of power fitness classes for untrained adolescents, using special training exercises in combination with load regimes and energy supply modes, caused many controversial issues. In most cases, this was associated with the age-related characteristics of the short- and long-term adaptation and with the ability of the energy system of untrained adolescents to provide the necessary activity of working muscles in given load modes. This is true especially when different numbers of simultaneously active muscle groups of agonists, synergists, and stabilizers work, depending on the variability of using free-weight or machine exercises.

Tables 1–3 show the values of the HRV spectral analysis of the examined untrained adolescents in response to the load using different power fitness class models. At each study stage, the controlled indicators were recorded at rest and after strength training under the conditions of the specified training models.

The baseline (at rest, before training) HRV spectral analysis results presented at each study stage showed the following results (Table 1–3). The study participants were divided into three groups (A, B, C) considering baseline parameters of the spectral analysis indicators. In untrained adolescents of group B, the vegetative balance shifted towards sympathetic regulation (LF/HF=3.26), which allowed us to attribute them to

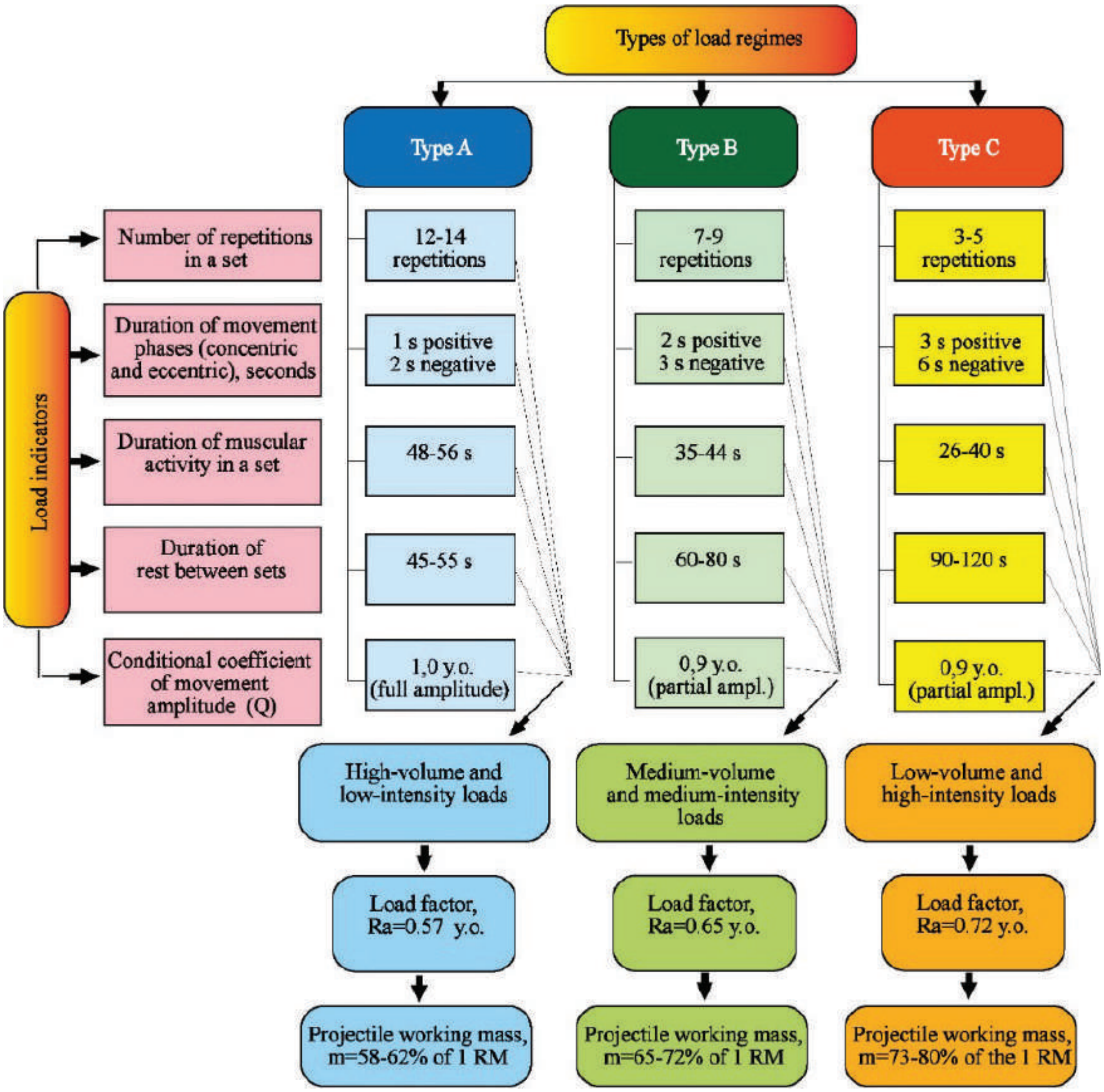

Fig. 1. The structure and content of the main load regimes in power fitness for untrained adolescents

sympathotonics by the type of heart rhythm regulation. In representatives of group C, the vegetative balance shifted towards parasympathetic regulation (LF/HF=0.87), which indicated that they were parasympathotonics (vagotonics) by the type of heart rhythm regulation. The spectral analysis results for group A (LF/HF = 1.12) indicated a balanced vagus-sympathetic tone mechanism, which classified them as normotonics in terms of heart rhythm regulation.

Analysis of HRV results (Table 1) observed after power loads of model 1 showed that the sympathetic tone increased against the background of growing LF in groups A (+14.2%) and C (+9.7%) in response to power loads of high volume and low intensity in aerobic glycolysis energy supply mode. A reduction in autonomic regulation influence was also observed, accompanied by an HF decrease in groups A (-15.8%) and C (-20.8%). Simultaneously, there was an increase in the central mechanism of sinus rhythm regulation (VLF), particularly notable in group C adolescents, where it rose by 11.1%. However, the HRV results of group B representatives exhibited entirely different patterns of change. An increase in autonomic regulation influence (HF) by 6.9% and a decrease in sympathetic tone (LF) by 10.2% were observed, indicating an enhanced vagal influence on the sinus node.

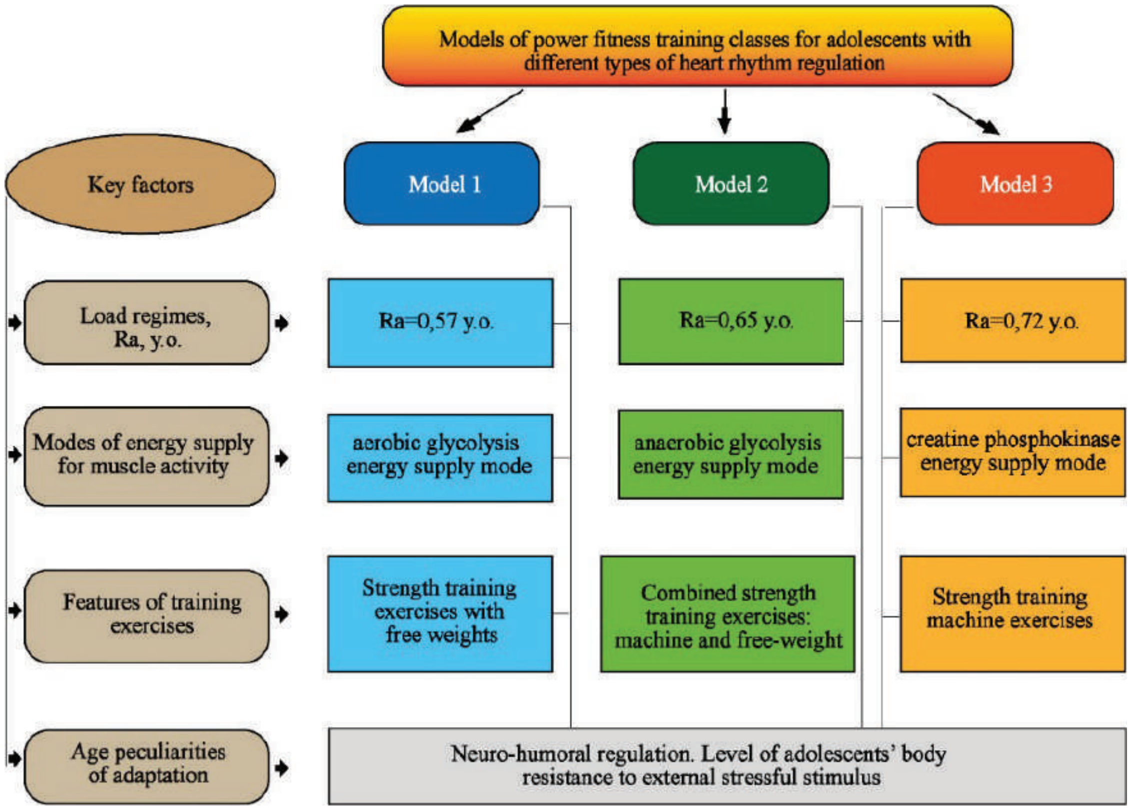

Fig. 2. The structure of experimental models of power fitness classes for untrained adolescents with different types of heart rate regulation

Table 1

Indicators of HRV spectral analysis of untrained adolescents in response to power fitness training load of model 1 (Me, IQR), n=75

Study participants	**HRV spectral analysis indicators**			
	VLF, %	**LF, %**	**HF, %**	**LF/HF**
Before exercise, at rest				
group A (normatonics)	6.95 (2.25)	49.16 (2.83)	43.89 (2.44)	1.12 (0.09)
group B (sympathotonics)	12.81 (3.14)	66.73 (3.49)	20.46 (2.03)	3.26 (0.28)
group C (vagotonics)	9.36 (1.82)	42.17 (3.02)	48.47 (3.31)	0.87 (0.11)
After exercise (R_a=0.57; aerobic glycolysis; free-weight exercises)				
group A (normatonics)	8.59 (1.85)*	63.39 (2.77)*	28.02 (2.28)*	2.26 (0.23)*
group B (sympathotonics)	16.13 (1.45)*	56.51 (3.11)*	27.36 (1.58)*	2.06 (0.42)*
group C (vagotonics)	20.45 (2.41)*	51.93 (2.66)*	27.62 (1.98)*	1.88 (0.14)*

Note: * p< .05 – compared to before-exercise results at rest

Table 2 presents changes in HRV indicators of untrained adolescents with different types of heart rate regulation in response to stress using training model 2.

The changes in spectral analysis indicators for a medium volume and intensity stressful stimulus in the study participants differ from the results shown in Table 1. There was an increase in parasympathetic activity due to a decrease in the autonomic balance indicator in groups A (-17.8%) and C (-11.5%). There was also a significant decrease in the values of the low-frequency spectrum (LF) in representatives of groups A (-6.0%) and C (-3.2%). Meanwhile,

Table 2

Indicators of HRV spectral analysis of untrained adolescents in response to power fitness training load of model 2 (Me, IQR), n=75

Study participants	HRV spectral analysis indicators			
	VLF, %	LF, %	HF, %	LF/HF
Before exercise, at rest				
group A (normatonics)	6.95 (2.25)	49.16 (2.83)	43.89 (2.44)	1.12 (0.09)
group B (sympathotonics)	12.81 (3.14)	66.73 (3.49)	20.46 (2.03)	3.26 (0.28)
group C (vagotonics)	9.36 (1.82)	42.17 (3.02)	48.47 (3.31)	0.87 (0.11)
After exercise (R_a=0.65; anaerobic glycolysis; a set of combined strength training exercises)				
group A (normatonics)	11.89 (1.89)*	43.12 (2.82)*	44.99 (2.38)	0.95 (0.06)*
group B (sympathotonics)	19.69 (1.55)*	63.07 (4.01)*	17.24 (1.78)*	3.65 (0.25)*
group C (vagotonics)	11.20 (2.31)	38.91 (2.14)*	49.89 (4.53)*	0.78 (0.06)

Note: * p< .05 – compared to before-exercise results at rest

the low-frequency spectrum parameters of heart rhythm cardio intervals in participants from groups A and C remained virtually unchanged. However, a decrease in LF (-3.6%) and HF values (-3.2%) was observed in Group B. The vegetative balance increased by 11.9%, and the central mechanism of sinus rhythm regulation (VLF) rose by 6.9%.

Table 3 displays the results of spectral analysis indicators for participants in the examined groups using model 3 of power fitness training. The study participants exhibited varying patterns of HRV changes in response to high-intensity, low-volume loads during the creatine phosphokinase energy supply mode.

The study results (Table 3) show a significant change in autonomic balance in participants from groups A (threefold increase) and B (58.9% increase) compared to the resting state. The central circuit of sinus rhythm regulation increased in groups A (VLF +11.3%) and B (VLF +16.7%). The most pronounced increase in sympathetic tone (LF +14.3%) and a decrease in the influence of autonomic regulation (HF -25.6%) were observed in representatives of group A (normatonics). In group C, there was an increase in the influence of autonomic regulation (HF +6.0%) and a decrease in sympathetic tone (LF -6.7%). The autonomic balance shifted towards parasympathetic regulation (LF/HF -26.4%) in response to a stressful stimulus indicating the activation of short-term adaptation mechanisms in adolescents from group C.

Table 3

Indicators of HRV spectral analysis of untrained adolescents in response to power fitness training load of model 3 (Me, IQR), n=75

Study participants	HRV spectral analysis indicators			
	VLF, %	LF, %	HF, %	LF/HF
Before exercise, at rest				
group A (normatonics)	6.95 (2.25)	49.16 (2.83)	43.89 (2.44)	1.12 (0.09)
group B (sympathotonics)	12.81 (3.14)	66.73 (3.49)	20.46 (2.03)	3.26 (0.28)
group C (vagotonics)	9.36 (1.82)	42.17 (3.02)	48.47 (3.31)	0.87 (0.11)
After exercise (R_a=0.72; creatine phosphokinase energy supply mode; strength training machine exercises)				
group A (normatonics)	18.22 (2.14)*	63.49 (2.68)*	18.29 (1.38)*	3.47 (0.37)*
group B (sympathotonics)	29.52 (1.69)*	59.07 (2.91)*	11.41 (1.32)*	5.18 (0.29)*
group C (vagotonics)	9.08 (2.03)	35.48 (1.42)*	55.44 (3.61)*	0.64 (0.12)*

Note: * p< .05 – compared to before-exercise results at rest

Discussion. The presented research results show one of the ways to solve the scientific problem of assessing the functional body reserves in untrained adolescents in response to physical stress stimulus [2; 12; 13]. An attempt was made to solve one of the important scientific issues related to the search for informative criteria for assessing the resistance of untrained young men of this age group to different regimes of power loads [11; 14]. The nature of the adaptive and compensatory reactions of untrained adolescents with various HRV types using different load regimes and models of power fitness classes was studied. In developing models of power fitness classes, attention was primarily paid to the age-related physiological characteristics of their adaptation to similar muscle activity [5; 6]. HRV spectral indicators of adolescents with different types of heart rhythm regulation changed differently in response to strength training exercises, even when using the same training model. Thus, in one group, there is an increase in sympathetic tone and the central mechanism of sinus rhythm regulation, suggesting possible compensatory reactions in response to a significant stressful stimulus [10; 15]. In another group, there is an increase in vagal influence on the sinus node, indicating the potential activation of short-term adaptation mechanisms [7; 13]. These results will contribute to identifying informative physiological markers that can help determine effective and simultaneously safe strength load parameters for untrained adolescents. The study results will assist in improving the system for developing and adjusting load regimes and strength fitness class models for this age group.

In power fitness, insufficient attention is given to the lack of operational criteria for assessing the level of adaptive reserves in untrained adolescents under acute load conditions [1; 17]. Most researchers [6; 13] attribute this issue to the lack of a clear gradation between load parameters and the nature of adaptive and compensatory reactions during adolescence, due to unstable neurohumoral regulation. Scientists only partially address the issue of the effectiveness of using spectral characteristics of HRV power indicators as informative markers for classifying adolescents by the type of heart rhythm regulation [4; 9]. This approach to solving the scientific problem may stem from the lack of studies demonstrating the need for this group to use different models of power fitness classes.

The research revealed that after using the developed model 1 during training, the influence of autonomic regulation increased, and sympathetic tone was reduced only in the group of sympathotonic adolescents. These changes indicate increasing vagal influence on the sinus node and the effective activation of short-term adaptation processes in response to a stressful stimulus [7; 14; 16]. In the other two groups (normatotonic and vagotonic), there was an increase in the central circuit of sinus rhythm regulation, which may indicate compensatory reactions. However, most fitness experts [3; 5] believe that such a combination of load parameters with the energy supply mode during training (model 1) is the most effective for all untrained adolescents.

The HRV results after high-intensity exercise in the creatine phosphokinase energy supply mode (model 3) increased the influence of autonomic regulation and decreased the sympathetic tone in the group of vagotonic adolescents. These changes in HRV indicators suggest a sufficient level of the body's resistance to such power loads, supported by adaptive reserves [7; 13]. However, in response to a similar stressful stimulus, the sympathotonic group exhibited an increase in the central mechanism of sinus rhythm regulation. Although several researchers addressing this scientific issue [2; 12] argue that high-intensity anaerobic power loads in untrained adolescents can lead to a breakdown of adaptation.

Conclusions. The results demonstrate the potential of using HRV indicators as informative markers for evaluating the adaptive reserves of untrained adolescents with similar morphometric parameters and strength capabilities. Determining the appropriate type of heart rate regulation through spectral HRV characteristics enables the development of an effective model for power fitness classes in the shortest time possible. In adolescents with different types of heart rate regulation, the manifestation of adaptive and compensatory reactions to the stimulus will vary depending on the combination of load regimes and energy supply modes during the performance of a specific set of exercises. In this study, only sympathotonic adolescents, when using high-volume loads during free-weight exercises in the aerobic glycolysis energy supply mode, had an increase in the influence of autonomic regulation and the activation of short-term adaptation. Similar adaptive and compensatory reactions were observed in vagotonic adolescents during high-intensity machine exercise in the creatine phosphokinase energy supply mode.

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