

Results of using a plant adaptogen to improve the functional state of athletes

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Abstract:

Modern sports require adaptogens to mitigate the functional changes associated with intense training loads. Investigating the effects of plant adaptogens on physiological function and autonomic regulation in athletes is a prominent area in sports medicine. **Purpose:** This study explored the impact of a course of Eleutherococcus on cardiovascular function, autonomic balance, and aerobic capacity in highly qualified athletes. **Material and methods:** A group of elite swimmers, trained according to personalized standard techniques, received Eleutherococcus supplementation for 10 days. Standard heart rate variability parameters were used to monitor physiological changes. During the experiment, an analysis of the vegetative balance among athletes was carried out. Also, the maximum oxygen consumption among the study groups was estimated using the Astrand method. VO₂max was measured during physical work of athletes in the control and experimental groups at maximum power using a bicycle ergometer under submaximal work conditions. **Results.** In both experimental groups, reliably significant changes in the values of heart rate variability indicators were established. Relative tension of the regulatory systems is noted, which is a normal physiological response of the body to physical activity in the submaximal power zone. It is noted that in athletes who took Eleutherococcus, the body's response reflected stabilization of the cardiointervalogram indicators. This contributes to the strengthening of the adaptive reserves of the body due to the corrective effect of Eleutherococcus on the vagosympathetic balance and the effect on the parasympathetic and sympathetic links of heart rate regulation. A course of adaptogen intake demonstrated an increase in the aerobic capabilities of the body and higher physical performance, which is associated with an increase in VO₂max among athletes in the experimental group. **Conclusions.** The course use of Eleutherococcus helps to increase the physical capabilities of the body by optimizing physiological functions under the influence of physical activity. It is possible to use this plant adaptogen at the training stage of athletes in cyclic sports.

Key Words: physical activity, training loads, heart rate variability, autonomic reactivity, plant adaptogen, Eleutherococcus

Introduction

In high-performance sports, when exposed to high and ultra-high intensity physical loads that are inadequate to the functional state of the body, they can trigger the development of fatigue, acute or chronic overexertion and overtraining of the athlete's body (Losnegard et al., 2021; Lichti et al., 2023). These conditions entail a decrease in the functional reserves of the athlete's body and a decrease in the effectiveness of the training process (Flatt et al., 2020; Bocharin I. et al., 2023). Often, overexertion and overtraining are the main cause of sports injuries in athletes (Mardiana et al., 2021; Vorozheikin et al., 2021).

It is known that high-performance sports use an excessively high level of power and intensity of physical work, which is accompanied by the mobilization of the structural and functional characteristics of various body systems (Fullagar et al., 2017; Mejia-Mejia, et al., 2020; Vorozheikin et al., 2021). As a result,

over-adaptation can occur, which manifests itself in the depletion of the body's functional systems and leads to physical overtraining (Litvin, Krotova., 2023; Romanova et al., 2024).

The human body has an autonomic nervous system that regulates various organs and systems. This allows you to redistribute external influences on the structural characteristics of the body and minimize their impact. As a result of this redistribution, adaptive resistance to stress increases (Cid et al., 2019; Kamandulis et al., 2020).

In this process, the activity of the cardiovascular system comes to the fore, which acts as a compensatory mechanism for ensuring muscle activity, and a violation of the autonomic regulation of this system entails a breakdown in adaptation and leads to unsatisfactory sports results (Vitale, Getzin, 2019; Marasingha-Arachchige et al., 2020).

One of the most reliable and widespread methods for studying the adaptive potential of the cardiovascular system and the nature of the autonomic nervous system's response to physical activity is cardiointervalography (Mejia-Mejia, et al., 2020; Guzii et al., 2020; Christiani et al., 2021; Gryaznykh et al., 2021) or heart rate variability (HRV) analysis. The HRV characteristic reflects the state of the autonomic innervation of the human body. Therefore, the assessment of the vegetative status can be described through the HRV parameters. There are many factors that influence the human autonomic nervous system, including through herbal preparations, in particular the adaptogen, Eleutherococcus .

There is some experience in the use of adaptogens that are able to model the physiological functions of the body and carry out autonomic regulation. Thus, they stabilize regulatory mechanisms under the influence of test stressors (Govorukhina, Vetkalova, 2017; Romanova et al. 2023). Preparations obtained from Panax ginseng, Eleutherococcus senticosus, Rhaponticum carthamoides, Rhodiola rosea and Schisandra chinensis are considered highly active adaptogens of natural origin. Their use improves physical performance (Todorova et al., 2021; Zhang et al., 2024) and human cognitive abilities (Malik, Tlustoš, 2023). Natural adaptogens are used to treat a number of neurodegenerative diseases in humans (Lim et al., 2024) and as immunostimulatory drugs (Graczyk et al., 2024).

According to Kuo et al. (2010), 8 weeks of Eleutherococcus senticosus supplementation increased endurance by 23%, maxVO₂ by 12%, and improved cardiovascular performance in recreationally trained men. According to Li et al. (2023), an experiment on mice showed an improvement in motor coordination after a course of Eleutherococcus supplementation. It should be noted that in the search for the optimal drug to optimize the physiological functions of the body during high-intensity physical activity, it is advisable to use adaptogens of natural origin. This meets the requirements of WADA (Peeling et al., 2019; Vitale et al., 2019). However, the use of Eleutherococcus among highly qualified athletes has not yet been fully studied. There is no information in the literature on the effect of this adaptogen on the autonomic innervation of the body of athletes who perform maximum and submaximal physical activity using the HRV method. Studying this issue will allow us to assess the effect of taking Eleutherococcus on the activity of the cardiovascular system, autonomic innervation and aerobic capabilities of the body of these athletes, which will allow us to make adjustments to their training process.

Purpose. To study the effect of a course of Eleutherococcus on the state of the cardiovascular system, autonomic balance and aerobic capabilities of the body in highly qualified athletes.

Material & Methods

The experiment involved 43 athletes who were engaged in swimming at sports facilities in the Volga Federal District (Russia). The men had extensive experience in sports, had sports titles or sports categories. The average age of the examined athletes was 21.4 ± 2.3 years. Before the experiment, all athletes signed an informed voluntary consent to participate in the study and could refuse to continue participating in the experiment at any time, which is fully consistent with the Helsinki Declaration of 2008.

The criteria for exclusion from the study were the presence of pathological changes in the cardiovascular system, athletes with low sports qualifications, and female gender. The subjects were divided into two groups: athletes of the control group (CG, n = 21), who used the standard training method for their sport; the second group (22 people) consisted of athletes of the experimental group (EG, n = 22), also using a standardized training method, taking the herbal adaptogen "Eleutherococcus " daily for 10 days. Athletes took a single dose of 5 ml of the drug extract orally, in the morning and 1 hour before the start of the training process.

To record the cardiointervalogram, the software and hardware complexes "Poly-Spectrum-Rhythm" ("Neurosoft", Russia) and "MedicalSoft Sports Testing System" (MS FIT-01, Russia) were used. The cardiointervalogram was recorded before and after physical activity as part of the training process of these athletes. The subjects were in a supine position on a couch with a raised headboard, the room was maintained at a constant temperature of 20-22 degrees Celsius. Constant silence and the absence of extraneous irritants, including the presence of third parties, were ensured near each subject. The ECG signal was recorded in the second standard lead, RR intervals were determined using the Pan-Tomkins algorithm (Navaneethakrishna,

Manuskandan, 2021). The following parameters were used for monitoring: duration of cardiointervals (RRNN, ms), values of NN interval deviation spread (SDNN, ms), square root of mean squares of average difference of NN intervals (RMSSD, ms), pNN50 parameter (%), absolute values of spectrum power in the range of low (LF, ms²), high (HF, ms²) and very low frequencies (VLF, ms²).

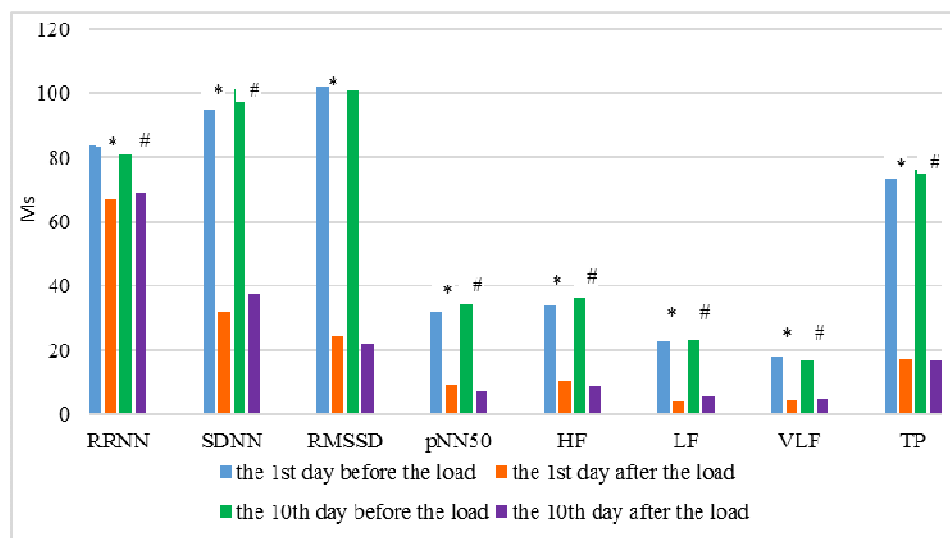
The following parameters were calculated: autonomic balance index (IVB), conventional units), centralization index (CI, conventional units), mode and amplitude parameters of cardiointervals (Mo, s and Amo, %), adequacy indicator of regulation processes (IARP, conventional units), tension index (VI, conventional units), variation range (MxDMn, ms), and autonomic rhythm indicator (ARI, conventional units). Also, the maximum oxygen consumption (VO₂max) was estimated among the experimental groups using the Astrand method.

For this purpose, the linear relationship between the heart rate and the value of oxygen consumption was estimated. VO₂max was measured during the physical work of the body at maximum power using a bicycle ergometer under submaximal work conditions lasting 6 minutes with a pedaling frequency of 50 rpm. Before the submaximal load, the subject performed a 3-minute warm-up on a bicycle ergometer, during which the load power was gradually increased to 250 W.

The obtained data were processed using the Statistica 10.0 and Microsoft Excel 2016 statistical software package. In each sample, the arithmetic mean (M) and standard error of the mean (m) were determined. The Shapiro-Wilk criterion was used to check for normal distribution. To determine the statistical significance of differences in the indicators between CG and EG athletes, the Wilcoxon criterion was used, taking into account the presence of dependent groups of subjects and the lack of normality in the distribution of the data obtained. Differences were considered significant at $p < 0.05$.

Results

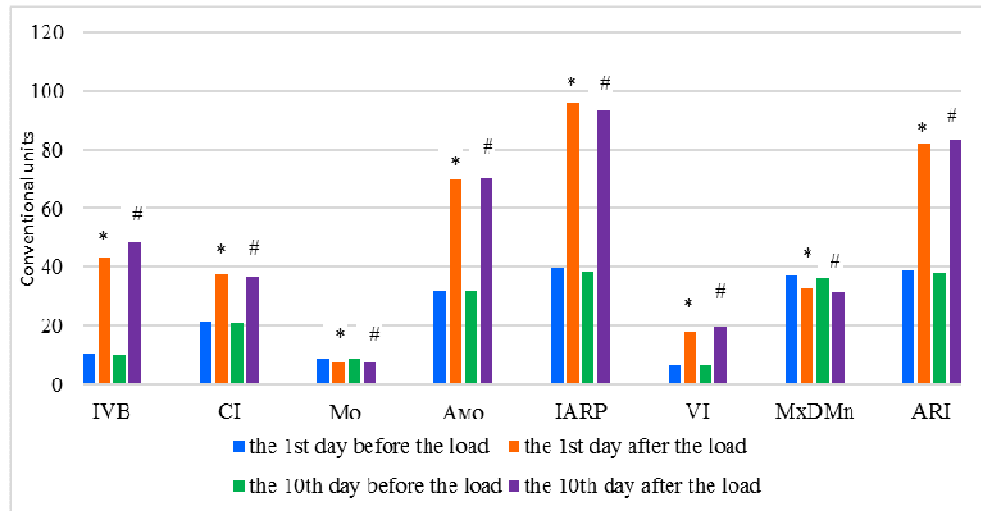
The values of the heart rate indicators among CG athletes for 10 days of the study are presented in Figures 1, 2.



Note: * - differences in indicators before and after physical activity on the first day are statistically significant, $p < 0.05$; # - differences in the indicators before and after physical activity on the tenth day are statistically significant, $p < 0.05$

Fig 1. Values of heart rate variability indicators in athletes in the control group before and after physical activity

A reliable significant decrease in the variation range and mode by 17.8% and 55.4% on the first day, as well as by 22.7% and 50.4% on the tenth day, was established, Figure 1. Temporal heart rate indicators (RRNN, SDNN, RMSSD, pNN50) statistically significantly decreased by 18.4%/66.3%/73.6%/74.1% on the first day of exercise testing, and on the tenth day of the post-exercise period - by 16.6%/66.3%/75.9%/74.6%, respectively, $p < 0.05$. It is known that a sharp increase in SDNN in response to physical activity may indicate a high risk of cardiovascular complications. Among the athletes in the control group, the standard deviation of NN intervals is displayed at a lower limit than the normative range for untrained people, which characterizes the physiological interaction of the sympathoadrenal system and parasympathetic reactivity during regular physical work.



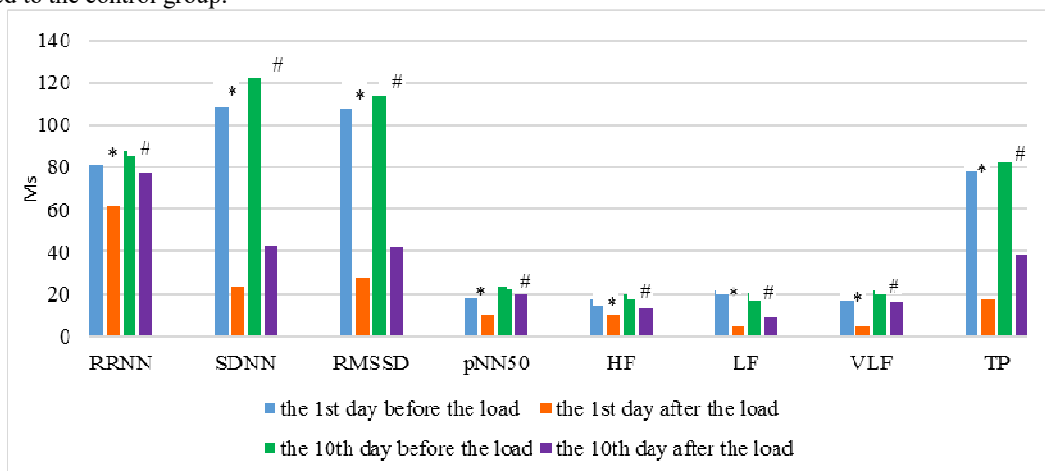
Note. * - differences in the indicators before and after physical activity on the first day are statistically significant, $p < 0.05$;

- differences in the indicators before and after physical activity on the tenth day are statistically significant, $p < 0.05$

Fig 2. Heart rate variability values in athletes in the control group before and after physical activity

The studied indicators in CG athletes changed as a standard response to physical activity, while the reaction of the autonomic nervous system remained at the same level. Some dominance of the central heart rate regulation circuit was recorded in the subjects of this group. This is reflected in the increase of geometric indices of heart rate variability, Figure 2. The mode amplitude and stress index showed the growth by 114.0% and 479.6% on the first day of training and by 119.0% and 527.0% on the tenth day of the experiment, respectively, $p < 0.05$. The dominance of the VLF component is observed in the structure of the spectral analysis, the total spectrum power decreased by 76.0% after the first day, and by 73.0% after 10 days of training. The same trend is observed for the spectrum power indicators of low, very low and high frequencies, where their decrease was recorded by 65.4%/86.9%/80.1% after the first day, and by 77.4%/83.5%/79.8% after the tenth day, respectively. The above changes are characteristic of the body's adaptation to physical activity. The absence of an increase in the total spectrum power indirectly indicates a minimal contribution of the parasympathetic nervous system to the adaptation of the body.

Among the EG studied, a course of Eleutherococcus treatment contributed to shifts in vegetative reactivity and provided more adaptive reactions of regulatory mechanisms to physical activity, Figures 3, 4, compared to the control group.

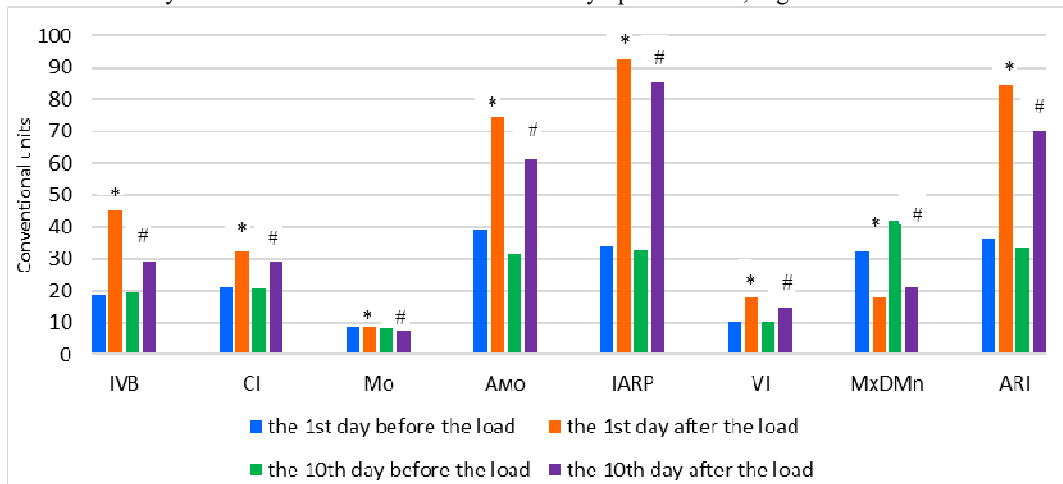


Note. * - differences in the indicators before and after physical activity on the first day are statistically significant, $p < 0.05$;

- differences in the indicators before and after physical activity on the tenth day are statistically significant, $p < 0.05$

Fig 3. Values of heart rate variability indicators in athletes of the experimental group before and after physical activity

In addition, on the tenth day after the course of treatment, stabilization of the time series of cardiointervals (SDNN, pNN50, MxDMn) was recorded in the athletes of this group in the post-load period (Figure 3). This significantly differed from similar values in the control group by 33.0% / 169.0% / 29.0%, respectively, $p < 0.05$. Also, a decrease in the stress index by 43.0% was noted relative to athletes of the control group. Consequently, the course intake of Eleutherococcus contributed to a decrease in the tension of the regulatory systems due to the modulating effect on the activation of the parasympathetic link of the autonomic regulation simultaneously with a decrease in the activation of the sympathetic link, Figure 4.



Note. * - differences in the indicators before and after physical activity on the first day are statistically significant, $p < 0.05$;

- differences in the indicators before and after physical activity on the tenth day are statistically significant, $p < 0.05$

Fig 4. Heart rate variability values in athletes of the experimental group before and after physical activity

For example, an increase in the mode amplitude indicator by 136.7% before physical activity on the first day reflected the activation of the sympathetic division of the autonomic nervous system during stress testing. At the same time, after the tenth day of taking the dietary supplement, less pronounced changes in this indicator were recorded. Thus, an increase in this parameter was established by only 79.6% relative to the resting state, which suggests the activation of parasympathetic regulatory mechanisms and an increased reserve of adaptation reserves to the effects of stress testing in the form of physical activity.

It is known that a significant level of VO_{2max} indicates high endurance and aerobic capabilities of the athlete's body. At the end of the experiment, it was found that the CG athletes had a 1.8% increase in VO_{2max} . At the same time, in EG, the increase in the indicator was significantly greater than in CG and was 18.9% compared to the first females. This indicates that the course use of the dietary supplement contributes to an increase in the value of this indicator in EG athletes, Table 1.

Table 1. VO_{2max} values in athletes of both experimental groups ($M \pm m$)

Observation time	CG (n=21)	EG (n=22)
First day	4.77±0.31	5.02±0.24
Tenth day	4.86±0.24	5.97±0.33*#

Note: * - differences in VO_{2max} among athletes on the first and tenth days are statistically significant, $p < 0.05$;

- differences in VO_{2max} among athletes in the control and experimental groups on the tenth day are statistically significant, $p < 0.05$

Thus, a course of Eleutherococcus affects the functional systems of the body, which is manifested in a decrease in the stress of regulatory systems and an increase in aerobic capacity during physical activity in qualified swimmers.

Discussion

The impact of various external extreme factors, including physical activity on the body, can be studied at the physiological level. At the same time, a set of necessary corrections of physiological functions in response to the influence of various factors has been developed (Klawitter et al., 2023).

It is known that physical activity that does not correspond to the functional reserves of the body can cause disturbances in the activity of the cardiovascular, respiratory, nervous, hormonal and other systems. This can lead to an imbalance in the activity of organs and tissues (Mejia-Mejia et al., 2020). This results in the

development of not only fatigue, as a normal physiological response to stress, but also the occurrence of acute or chronic overexertion and overtraining of the athlete's body (Losnegard et al., 2021; Lichti et al., 2023). Such conditions sharply worsen the athlete's health and reduce not only the effectiveness of performance in competitions, but can lead to the cessation of sports activities.

One of the most informative criteria for the readiness of an athlete's body to perform training or competitive loads is his physical performance. It is achieved through the complex interaction of body systems not only at the cellular, but also at the systemic level (Marasingha-Arachchige et al., 2020). The state of physical performance is largely determined by the activity of the cardiovascular system, which is the leading system in the performance of muscle activity and the formation of the motor quality "endurance" (Vitale, Getzin, 2019; Marasingha-Arachchige et al., 2020; Pronin et al., 2023). There is a close relationship between the cardiovascular system and the autonomic nervous system of the human body. By the nature and magnitude of the HRV parameters, it is possible to assess the activity of not only the heart, but also the autonomic innervation of the body (Guzii et al., 2020; Christiani et al., 2021). It is known from scientific data that external influences can be redistributed to the structural characteristics of the body and minimize their impact. As a result, adaptation to stress increases (Cid et al., 2019; Kamandulis et al., 2020). Therefore, the possibility of a course of use of various adaptogens that can optimize the reactivity of the body during physical work is relevant. A special role is given to adaptogens of plant origin, a significant number of which are not prohibited for use by WADA (Peeling et al., 2019; Vitale et al., 2019), which allows their use in sports practice. Such an adaptogen as Eleutherococcus, well-known in clinical medicine (Lim et al., 2024; Graczyk et al., 2024) and sports activities, has been used for over 50 years (Kuo et al., 2010; Todorova et al., 2021; Zhang et al., 2024). However, some issues of its effect on the autonomic nervous system in high-level athletes based on the results of the analysis of HRV parameters are not sufficiently covered in the literature.

In the present study, the autonomic balance and maximum oxygen consumption were analyzed during the experiment among qualified athletes in the control and experimental groups. In both groups, statistically significant changes in HRV parameters were found, showing the relative stress of the regulatory systems, which is the physiological response of the body to physical work in the submaximal power zone. These data are consistent with the results of studies by other authors who investigated HRV (Guzii et al., 2020; Christiani et al., 2021). According to our data, the athletes who took Eleutherococcus had a response that reflected stabilization of the cardiointervalogram parameters. These data indicate an increase in the body's adaptive reserves due to the adaptogen's corrective effect on the vagosympathetic balance. We believe that the effect of Eleutherococcus on parasympathetic and sympathetic regulation of the heart rate plays a role. In addition, a course of adaptogen administration demonstrated an increase in the body's aerobic capabilities and higher physical performance due to an increase in the maximum oxygen consumption among the athletes in the experimental group. High aerobic capabilities allow for faster oxygen uptake and more efficient resynthesis of ATP molecules to meet the energy needs of working muscle fibers. These data explain the mechanism of increased physical performance in athletes after using Eleutherococcus. A decrease in fatigue during physical work after taking Eleutherococcus was recorded by other researchers (Kuo et al., 2010; Todorova et al., 2021; Li et al. 2023; Zhang et al., 2024).

Thus, the course use of the studied adaptogen helps to increase the physical capabilities of the athletes' body as a result of optimizing physiological functions under the influence of physical activity.

Conclusions

The adaptive response of the body as an autonomic reactivity to physical activity among athletes in the control and experimental groups demonstrated a statistically significant decrease in SDNN, RMSSD, pNN50, TP, HF, LF, VLF, IIVV, IC, Mo, VR, with a simultaneous increase in the stress index, which characterizes the tension of the regulatory system and the mobilization of the body's functional reserves.

The course use of Eleutherococcus helps to stabilize the functional state of the body among the subjects of the experimental group, due to the corrective effect on the vagosympathetic balance and activation of the parasympathetic, as well as a decrease in the sympathetic reactivity of the heart rhythm.

Taking the studied adaptogen helps to increase the VO₂max indicator by 22.8% in athletes of the experimental group relative to the control group, which indicates higher aerobic capabilities of qualified athletes after taking Eleutherococcus.

To improve the physical performance of athletes at the training stage of training athletes in cyclic sports, it is possible to use the herbal adaptogen Eleutherococcus.

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

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