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Original Article

Mechanism for assessing the adaptive reserves of elite wrestlers under anaerobic energy supply conditions

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Abstract
Background and study aim: Development an effective system for evaluating and enhancing the adaptive reserves of elite wrestlers is critical issue in professional sports. The challenge of optimizing the functional training of athletes with high resistance to physical loads is particularly pressing. The purpose of this study is to create a mechanism for assessing the adaptive body reserves of elite wrestlers under anaerobic energy supply conditions. *Material and Methods*: The study involved 60 elite Greco–Roman wrestlers, aged 19±0.5 years. Two test tasks were designed: executing a suplex while alternating between three partners for 15 s (targeting the creatine phosphokinase energy system) and 40 s (targeting anaerobic glycolysis). The control occurred in a state of rest before and after the specified loads. The peculiarities of adaptive and compensatory reactions of sportsmen to physical stress were researched with the help of biochemical analysis (cortisol, CPK, LDH in the blood serum) and HRV. *Results*. Based on the initial results of the spectral analysis, athletes were divided into two groups: sympathotonics (LF/HF>1.5) and parasympathotonics (LF/HF <1.5). Sympathotonics had a vagal influence on the sinus node increase after 15 seconds of exercise. At the same time, the steroid hormone, the CPK, and LDH activity in the blood increased. In parasympathotonics, the vegetative balance shifted towards sympathetic regulation due to similar loads. The level of CPK and cortisol in the blood increased, but LDH parameters did not change. Depending on the shifts in the vegetative balance in response to the load within 40 seconds, the participants of each group were divided into subgroups. Athletes with both types of regulation showed a decrease in LF/HF indicators, cortisol in the blood, and an increase in LDH in response to this stimulus. An increase in LF/HF, cortisol concentration, CPK activity, and minimal changes in the level of LDH in the blood was observed in other subgroup participants after similar loads. *Conclusions*. The study results demonstrate the practicality of simultaneously using biochemical indicators of blood and HRV as informative markers for assessing the adaptation reserves of elite wrestlers. The observed changes in cortisol, LDH, CPK in the blood, and HRV indicators of athletes with different vegetative balances will change the concept of optimizing functional training.
Keywords:**adaptive reserves, athletes, resistance, vegetative balance, biochemical indicators of blood, load.**

Introduction

In modern sports wrestling, the development of an effective system for increasing the functional capabilities of elite wrestlers is one of the principal issues. The main problem lies in the high level of resistance of athletes' bodies to loads, acquired over many years of training activity (Iellamo et al., 2019; Claiborne et al., 2021; Manolachi et al., 2023). Using a diverse combination of methods, principles, and special exercises in combination with various loads is the most common way of solving this issue (Bentley et al., 2020; DeBlauw et al., 2021; Shtefiuk et al., 2024). However, the effectiveness of the practical implementation of this mechanism of enhancing the level of organism resistance of elite wrestlers only partially solves the problem for a short period

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(Lopes-Silva et al., 2021; Finlay et al., 2023; Schoenfeld et al., 2023). The main reason is the lack of scientific substantiation of the correlation between load parameters and the adaptative reserves of the organism.

The topic of wrestlers' adaptation to different parameters of loads in sports wrestling is interesting to scientists of various directions (Chernozub et al., 2018; Korobeynikov et al., 2021; Leite et al., 2021). Although many researches are focused on the adaptive and compensatory reactions of wrestlers and are aimed at the development of endurance (aerobic energy supply) (Henríquez et al., 2013; Perrone et al., 2021). Few studies are focused on short-term adaptation to intensive loads with creatine phosphokinase or anaerobic-glycolytic modes of energy supply. The problem lies in the lack of an effective set of informative markers for evaluating the adaptive reserves of elite wrestlers under conditions of loads with anaerobic modes of energy supply.

The problem of choosing an effective set of physiological, biochemical, and morphofunctional methods for assessing the body's adaptation processes in sports fights is becoming more relevant every year. This issue is particularly acute concerning functional training of elite wrestlers' resistance to loads (Chernozub et al., 2022; Mousavi et al., 2023). In scientific practice, the heart rate variability method is actively used to assess the functional body reserves of elite wrestlers and the nature of adaptive changes (Huang et al., 2021; Brockmann, L., & Hunt, K et al., 2023). Control over the shift of the vegetative balance in the direction of parasympathetic or sympathetic regulation allows for determining the manifestation of compensatory or adaptive reactions to a stimulus (Marasingha-Arachchige et al., 2022; Kayacan et al., 2023). In the modern system of training athletes, methods of biochemical blood analysis (hormones, enzymes, macroelements) are widely used. The biochemical analysis allows for determining the physiological processes of adaptation, and disadaptation as a result of loads on the organism (Martínez et al., 2022; Manolachi et al., 2023; Chycki et al., 2024). An integral usage of HRV indicators and biochemical analysis in the medical and biological control of sportsmen will allow the development of the system for body reserve assessment.

The aim of the work. To develop a mechanism for evaluating the adaptive body reserves of elite wrestlers during training loads with creatine phosphokinase and anaerobic-glycolytic modes of energy supply.

Material & methods

Participants

60 elite athletes of Greco-Roman wrestling aged 19±0.5 years were examined. The athletes' training experience and technical and tactical training levels were the same. The research was conducted during training sessions in 2023 at the "Zaroslyak" educational and sports base, Vorokhta, Ivano-Frankivsk region, Ukraine. The study design was approved by Lesia Ukrainka Volyn National University Ethics Committee. After outlining the advantages and disadvantages of the study, participants signed an informed consent form following the ethical standards of the Declaration of Helsinki.

Measurements

Heart rate variability (HRV)

A Polar V800 heart rate monitor (Polar, Finland) was used to measure RR intervals. Heart rate and raw RR intervals were recorded using a chest strap-mounted sensor (H10, Polar, Finland). RR interval data were downloaded to a computer via the Polar Flow web service. Kubios HRV Standard 3.5.0 Software was used to calculate statical and spectral HRV parameters. The most informative statistical HRV indicator for short-term analysis is the standard deviation of RR intervals (SDNN, ms). During the analysis of the spectral characteristics of HRV power, the following ranges were distinguished: low-frequency (LF, %), very-low-frequency (VLF, %), and high-frequency (HF, %). The LF/HF ratio was determined as a measure of vegetative balance. Registration of signals of RR intervals in the subjects took place in a sitting position at rest before and after acute physical exertion. For standardization of HRV studies with short recordings, the optimal recording duration of 5 minutes was chosen. The temperature of the environment was 22–24°C.

Biochemical blood markers

The LDH and CPK activity in the blood serum of elite wrestlers was calculated by the kinetic method (High Technology Inc., USA) with a set of reagents PRESTIGE 24i LQ LDH (Poland). The concentration of the glucocorticoid hormone cortisol in the blood serum of wrestlers was determined by the enzyme immunoassay method, using a set of SteroidIFA-testosterone reagents on the equipment of the Alcor Bio company. Reference values of the studied biochemical indicators were the following: CPK (40-270 units/l), LDH (195-462 units/l), cortisol (150-660 nmol/l). Blood sampling was performed by a nurse following internationally accepted requirements for medical and biological research. Control of changes in the parameters of the studied biochemical parameters of the blood was carried out at rest (before physical exertion) and after the performance of the test task.

Experimental design

The research consisted of three steps.

First, two test tasks were developed to accomplish the study goal. During control testing, an athlete must perform a suplex of three wrestlers in turn within a certain time. The exercise was performed with maximum effort and speed. The choice of this exercise is based on the involvement of many muscle groups during performance, which requires significant energy resources. During the control tests, the anthropometric

parameters of the throwing athletes and their partners were practically identical. In the first test task, the duration of the load was 15 s, and in the second it was 40 s. Continuous performing suplexes for 15 seconds with maximum muscle effort and speed will allow you to exhaust the adaptative body reserves in CPK energy supply (CPKES) regime. The duration of the same exercise for 40 seconds will allow for estimating the short-term adaptation reserves of the study participants during the anaerobic glycolysis energy supply (AGES) regime.

The second step was to analyze the initial HRV results before exercise. The wrestlers were divided into two groups (A and B). The distribution was based on types of heart rhythm regulation. The LF/HF index, an index of autonomic balance, at rest before exercise was the main criterion for dividing the study participants into groups. Group A wrestlers whose vegetative balance shifted towards sympathetic regulation (LF/HF >1.5 y.o.) were sympathotonics. Group B included participants whose autonomic balance shifted toward parasympathetic regulation (LF/HF <1.5 y.o.), i.e. parasympathotonics (vagotonics).

Thirdly, the HRV indicators and changes in biochemical blood components of athletes were determined after acute physical exertion lasting 15 and 40 seconds. Subgroups were created under the conditions of a significant difference found in more than 40-50% of athletes in a group between HRV results before and after exercise. The variability of the division of both groups into subgroups depended on organism reactions to loads in CPKES or AGES regimes. Control tests were performed at intervals of 60 minutes. The appropriate algorithm of actions enabled the restoration of biochemical indicators of blood and HRV of athletes after the loads of the first test task to the initial level.

Statistical Analysis

Data analysis was conducted with the help of statistical methods and the IBM SPSS Statistics 26 program package (SPSS Inc, Chicago, IL, USA). Median, lower and upper quartiles, and interquartile range (IQR) were also calculated. The G-Power 3.1.96 (Dusseldorf, Germany) program was employed to compute statistical power (determining the minimum sample size for the research). With an estimated power of 0.80 and alpha of 0.05, a total sample of 20 was required to identify a meaningful effect size of 0.25. The Wilcoxon signet-rank test (one sample case), ANOVA: repeated measures, between factors, were used to assess the sample size.

Results

Table 1 presents the results of the studied HRV indicators of elite wrestlers before exercise and after the performance of the test tasks developed by us.

The HRV results obtained before the beginning of the loads were sufficiently different in the examined athletes. Based on the initial results of the spectral analysis, primarily the parameters of the LF/HF indicator, the participants were divided into groups. Group A consisted of 28 athletes with a shifted vegetative balance towards sympathetic regulation (LF/HF=3.97). Group B included 32 participants with less intense heart rhythm regulation (LF/HF=0.91).

Table 1 **Results of changes in heart rate variability indicators in elite wrestlers during different duration and energy supply of loads (median, IQR), n=60**

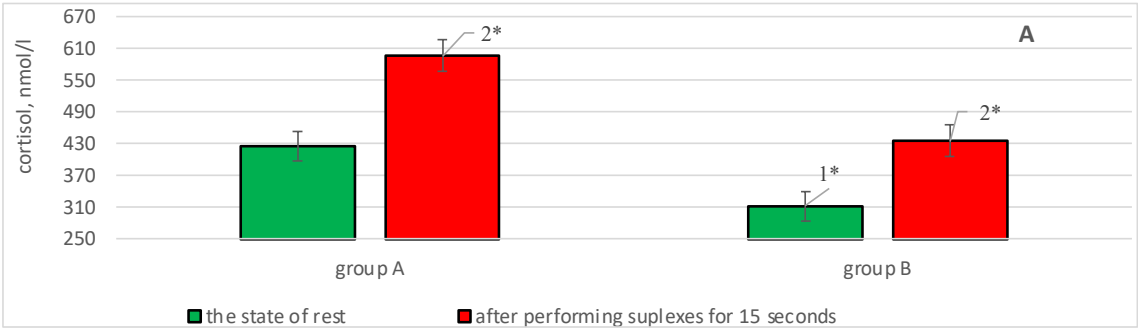
Groups of athletes		HRV parameters				
		SDNN, мс	VLF, %	LF, %	HF, %	LF/HF
Before exercise at rest						
A		1162.60 (209)	9.33 (1.47)	70.43 (3.22)	20.24 (2.23)	3.47 (0.31)
B		567.80 (101)	7.61 (1.52)	44.11 (3.25)	48.27 (3.00)	0.91 (0.13)
After performing suplexes for 15 seconds						
A		955.79 (143)*	6.67 (1.54)	64.65 (4.50)*	28.63 (2.00)*	2.25 (0.22)*
B		771.10 (123)*	8.03 (1.25)	76.41 (5.25)*	15.54 (2.20)*	4.91 (0.62)*
After performing suplexes for 40 seconds						
A	A^{1s}	577.96 (92)*	1.45 (0.21)*	68.00 (4.27)*	30.55 (3.75)*	2.22 (0.17)*
	A^{2s}	1223.5 (227)*	10.51 (1.68)	72.39 (2.75)	17.10 (2.32)	4.23 (0.29)*
Б	B^{1s}	864.70 (138)*	7.32 (1.33)	75.24 (3.79)*	17.44 (1.89)*	4.31 (0.29)*
	B^{2s}	468.52 (79)*	8.91 (2.04)	27.36 (5.00)*	63.35 (3.45)*	0.43 (0.05)*

Notes: ^{1s} – 1 subgroup; ^{2s} – 2nd subgroup; * p< .05 – comparing with the results before exercise at rest

The results of athletes performing suplex during 15 seconds demonstrated the opposite nature of the changes in HRV indicators between the groups. In athletes of group A, the SDNN indicator decreased by 17.7% after exercise. In representatives of group B, it increased by 35.8%. Group A showed an increase in HF values and an LF decrease, which indicates an increase in the vagal influence on the sinus node. Group B representatives grew a sympathetic tone (LF increased by 1.7 times) and decreased the autonomic regulation influence (HF lowered by 3 times). A significant difference between the groups was revealed regarding changes in the vegetative balance index (LF/HF).

The results obtained after the athletes performed suplexes for 40 seconds without stopping demonstrated different changes in HRV indicators within each group. Some elite wrestlers increased sympathetic activity, others - parasympathetic. Depending on the shifts in the vegetative balance in response to similar loads, the participants of each group were divided into subgroups (A^1, A^2, B^1, B^2). Athletes of subgroups A^2 and B^1, after loads, simultaneously decreased HF power and increased LF power. Changes in the components of the spectral analysis indicate a shift in the vegetative balance towards sympathetic influences (activation of the sympathoadrenal system). The HRV results of subgroups A1 and B2 representatives after 40 seconds of performing suplexes were the opposite. The SDNN parameters lowered in subgroups A^1 (-50.3%) and B^2 (-17.5%). There was a significant increase in the values of the high-frequency spectrum (HF) in athletes of subgroups A^1 (+10.3%) and B^2 (+15.1%). There was also a significant decrease in the vegetative balance index (LF/HF) in athletes of these subgroups, regardless of its initial parameters (before the load). The HRV changes indicate a possible manifestation of the body's compensatory reactions to physical stress.

Figures 1-3 show the results of changes in cortisol, CPK, and LDH in the blood of the examined wrestlers during the study. Control of the change in the studied biochemical indicators took place after the participants performed suplexes of partners for 15 and 40 seconds, compared to the initial data. The elite wrestlers were divided into groups and subgroups according to HRV results.



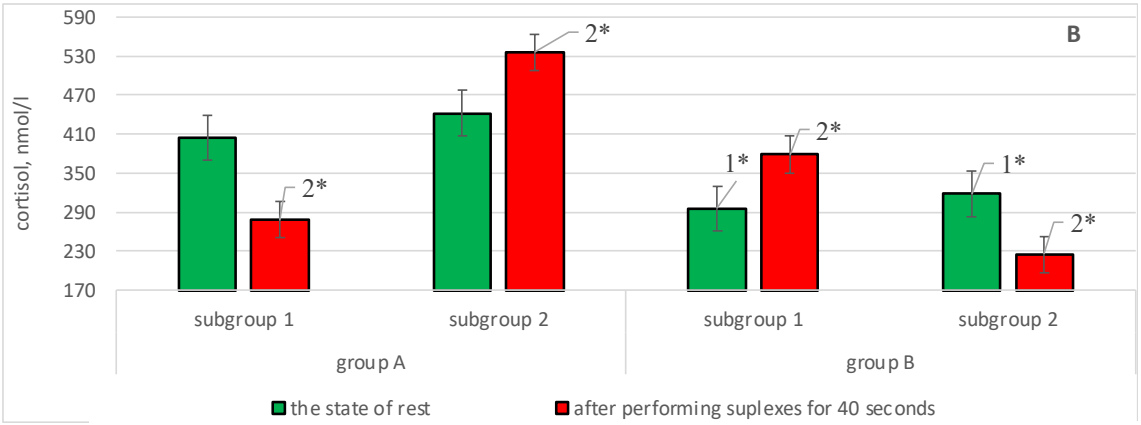


Fig. 1. Results of the cortisol changes in the blood serum of the examined wrestlers after performing control tests for 15 s (A) and 40 s (B), n=60

Note: 1* – $p<0.05$, compared to the other group (subgroup) indicators;

2* – $p<0.05$, compared to before exercise results (in a group/ subgroup)

After 15 seconds of load, the changes in cortisol in the elite wrestlers' blood enhanced by an average of 39.8% in both groups (Fig. 1). These results indicate an adequate reaction of the neurohumoral system to similar physical loads and a sufficient level of adaptive body reserves. However, the results obtained after performing exercise for 40 seconds demonstrated different changes in this biochemical indicator even among athletes within groups. Thus, after loads in anaerobic glycolysis energy supply mode, a decrease in cortisol concentration in the

blood of athletes of subgroups A^1 (-31.1%) and B^2 (-29.3%) was noted. These changes indicate the activation of gluconeogenesis processes (compensatory mechanism) due to insufficient reserves of muscle glycogen ensuring muscle activity. However, after similar loads, this glucocorticoid hormone increased in wrestlers of subgroups A^2 (+21.1%) and B^1 (+28.1%). In this case, a vivid manifestation of short-term adaptation and the adequacy of load parameters to the body's functional capabilities are shown.

The CPK activity in the blood of athletes of both groups increased by an average of 24.5% (Fig. 2) after 15 seconds of exercise. The obtained results confirm the well-known fact that creatinephosphate is the main energy source during the CPKES regime for training loads (up to 15 s). The biochemical control results after 40 seconds of exercise increased CPK in study participants.

This especially applies to athletes of subgroups A^2 (+43.3%) and B^1 (+47.6%), even in conditions of AGES regimes. The energy supply of such muscle activity occurs mainly due to muscle glycogen reserves. Therefore, the activity of the CPK enzyme should be minimal. The study results may indicate sufficient reserves of creatinephosphate in the muscles of athletes of these subgroups and optimization of the mechanism of saving energy resources.

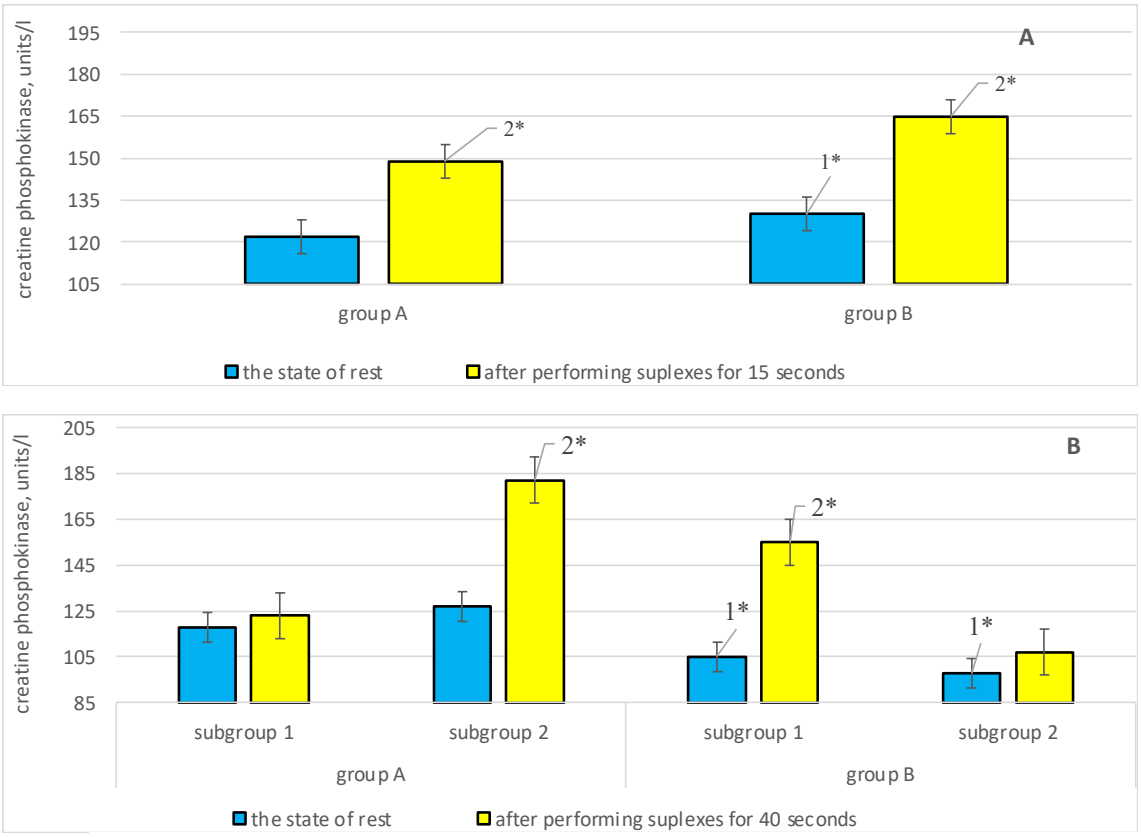


Fig. 2. Results of CPK activity in the blood serum of the examined wrestlers after performing control tests for 15 s (A) and 40 s (B), n=60

Note: 1* – $p<0.05$, compared to the other group (subgroup) indicators;

2* – $p<0.05$, compared to before exercise results (in a group/ subgroup)

Figure 3 shows that LDH activity in the blood of group A athletes (+14.8%) increased after performing the control test (suplexes for 15 seconds).

These results indicate an insufficient adaptive reserve of creatinephosphate in the muscles of this group of athletes, which requires the involvement of additional resources of the AGES regime. In group B, this enzyme activity did not change, which is a manifestation of temporary adaptation. After the 40-second control test, there was the most pronounced growth in LDH in the blood of wrestlers of subgroups A^1 (+47.1%) and B^2 (27.4%).

Representatives of the other two subgroups demonstrated 5.5 times lower dynamics of increasing the studied biochemical indicator under the same conditions. The obtained data suggest that A^2 and B^1 subgroup athletes used mainly the CPKES regime during 40 seconds of exercise.

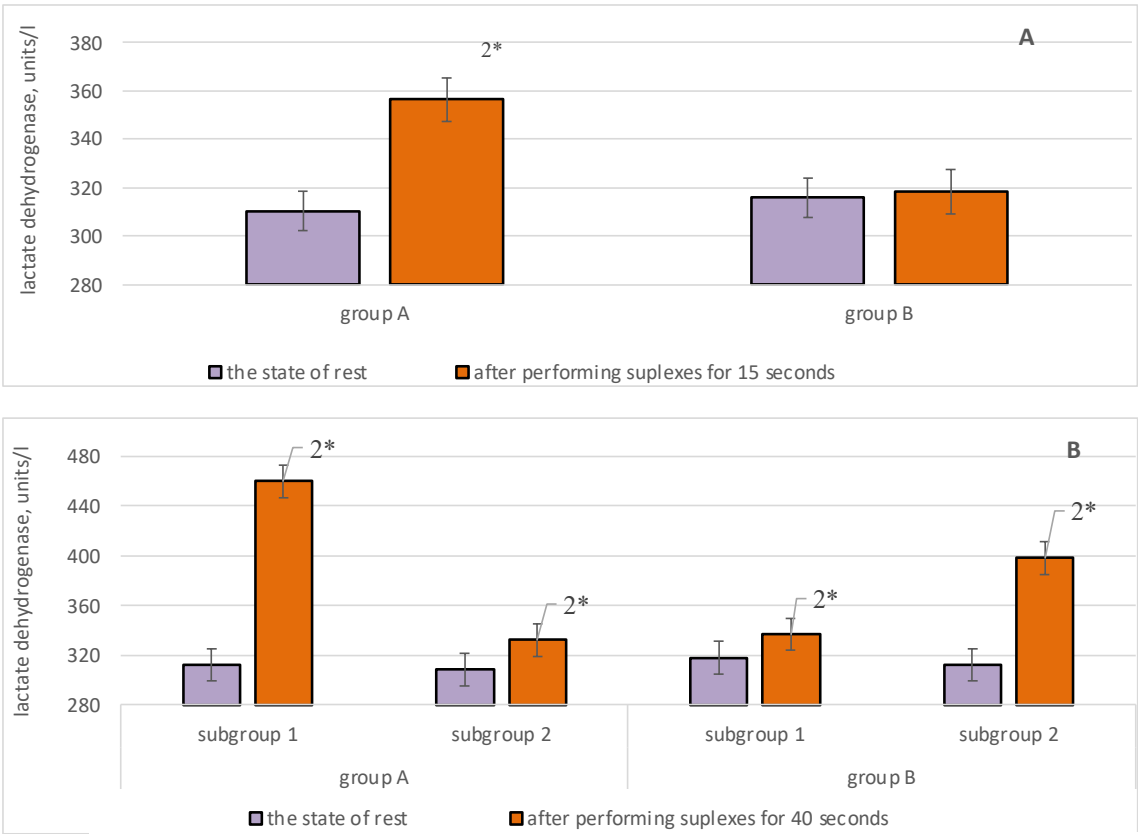


Fig. 3. Results of LDH activity in the blood serum of the examined wrestlers after performing control tests for 15 s (A) and 40 s (B), n=60

Note: 1* – $p<0.05$, compared to the other group (subgroup) indicators;

2* – $p<0.05$, compared to before exercise results (in a group/ subgroup)

Discussion

This research presents the mechanism of assessing the adaptative reserves of elite wrestlers after loads with two modes of anaerobic regimes (CPKES and AGES). Peculiarities of mobilizing processes of temporary adaptation of wrestlers' bodies to these regimes were studied. To assess the level of wrestlers' resistance to a stressful stimulus it is proved to use HVR biochemical analysis indicators. The study showed that loads with an anaerobic energy supply regime can cause both adaptive and compensatory reactions in elite wrestlers with different types of regulation. The research results will contribute to creating an effective set of scientifically grounded indicators for the control of wrestlers' adaptive body reserves. This study will help the advancement of the control system for the functional training of elite wrestlers and will affect the mechanism of its correction during high-intensity loads. In sports wrestling, the lack of a unified system for assessing the adaptative reserves of elite sportsmen is an influential factor that causes disadaptation. Determination of informative physiological and biochemical markers for assessing adaptive and compensatory reactions of elite wrestlers in conditions of high-intensity loads is one of the main research areas (Chernozub et al., 2018; Haller et al., 2023; Manolachi et al., 2023). A combination of HRV indicators and biochemical blood analysis to assess the adaptive reserves of elite wrestlers is one of the means to solve it. Modern sport physiology researchers studying the functional state of wrestlers in the pre-competition period use HRV indicators (Molins et al., 2020; Korobeynikov et al., 2021; Mishica et al., 2021). Biochemical blood analysis in sports wrestling was used for adaptive changes assessment, mainly in developing endurance (Athanasiou et al., 2021; Chycki et al., 2024). Not enough attention is paid to the problem of assessing the adaptative reserves of elite athletes during loads with CPKES and AGES regimes, using methods of HRV and biochemical analysis. The lack of norms and regularities of HRV and biochemical blood analysis of elite wrestlers during short-term intensive loads may be one of the reasons for this.

In sympathotonic athletes (LF/HF <1.5), the autonomic balance shifted towards parasympathetic regulation after exercise in the CPKES regime. At the same time, biochemical indicators (cortisol, CPK, and LDH) increased because of high-intensity load. It is caused by the start of compensatory mechanism activation due to insufficient reserves of creatinephosphate, which forces the body to use additional energy resources of muscle glycogen (Chernozub et al., 2022; Haller et al., 2023). In parasympathotonic patients (LF/HF >1.5), the autonomic balance shifted towards sympathetic regulation in response to similar loads. At the same time, the cortisol concentration in the blood and CPK activity increased but LDH parameters did not change. The athletes'

reaction to the load in the CPKES regime indicates a high level of adaptative reserves and body resistance (Finlay et al., 2023; Mousavi et al., 2023). Opposite adaptive and compensatory reactions were found in sympathotonic and parasymathonic wreslers after exercise in the AGES regime. A decrease in the parameters of LF/HF and the cortisol level in the blood was observed in representatives of both types of regulation during this regime. The LDH activity in the blood significantly increased but there were no changes in CPK level. The obtained physiological changes in wrestlers' bodies reflect compensatory reactions connected with a decrease in muscle glycogen reserves and activation of the gluconeogenesis process (Martínez et al., 2022; Shtefiuk et al., 2024). After similar loads, there was an increase in vegetative balance and cortisol levels in the blood of sympathotonics and parasympathotonics of other subgroups. The CPK activity grew by 50% compared to the state of rest but the LDH level in the blood serum changed minimally. The obtained data demonstrated the manifestation of effective mechanisms of temporary adaptation of athletes to loads in AGES regime and sufficient reserves of creatinephosphate in muscles (Manolachi et al., 2023; Schoenfeld et al., 2023).

Conclusions

The study results demonstrated the expediency of simultaneously using biochemical indicators of blood and HRV as informative markers for assessing the adaptative reserves of elite wrestlers. Control of the vegetative balance allows the regulation type determination in athletes with identical training experience and technical and tactical training levels before exercise. Based on the analysis of the studied indicators it was concluded that using special loads with different modes of anaerobic energy supply allows for determining the nature of adaptive and compensatory reactions to the stimulus. An effective algorithm for implementing short-term adaptation to anaerobic-glycolytic loads is the depletion of creatine phosphate reserves and then muscle glycogen. The lack of the required level of creatine phosphate reserves, which ensures the body's resistance to intense loads, causes the use of anaerobic glycolysis resources (compensatory reactions). Appropriate actions, especially with long-term use, will lead to adaptation disruption. The revealed changes in cortisol, LDH, CPK in the blood, and HRV indicators of athletes with different vegetative balances will change the concept of optimizing functional training.

Conflicts of interest - There is no conflict of interest.

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