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REACTIVITY OF THE OXYGEN TRANSPORT SYSTEM OF ELITE ATHLETES WITH DIFFERENT INDIVIDUAL AND TYPOLOGICAL PROPERTIES IN THEIR NERVOUS SYSTEMS

REAKTYWNOŚĆ SYSTEMU TRANSPORTU TLENU U ELITARNYCH SPORTOWCÓW Z RÓŻNYMI INDYWIDUALNYMI I TYPOLOGICZNYMI WŁAŚCIWOŚCIAMI ICH UKŁADÓW NERWOWYCH

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B. Data collection/entry
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C. Data analysis/statistics
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interpretacja danych
E. Preparation of manuscript
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F. Literature analysis/search
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Summary

Background. The mechanisms of neurovegetative interaction of the functional reactivity of the oxygen transport system (OTS) and genetically determined typological properties of the central nervous system (CNS) were studied.

Material and methods. The typological properties of the central nervous system of elite football players (32 individuals) were determined on the "Diagnost-1" neurodynamic complex. The reactivity of the OTS was investigated in a step-increasing running speed test using the Jaeger Oxycon Mobile gas analyzer.

Results. The dependence of the reactive properties of the OTS on the genetically determined functional mobility of nervous processes (FMNP) was established. Statistically significant higher indicators of blood stroke volume, carbon dioxide release rate (VCO_2) and blood lactate (HLa) were found in the athletes with a higher level of FMNP than in individuals with a low degree of typological property (p=0.033-0.045). The athletes with low FRNP were characterized by statistically significant high values of heart rate (HR) and rate of oxygen uptake (VO_2 max). The indicators of minute volumes of blood and respiration did not show statistically significant differences in groups of sportsmen with different gradations of FMNP (p=0.064-0.078).

Conclusions. The theoretical model and mechanisms of interaction of the individual-typological property of FMNP with the functional reactivity of OTS and the possibility of using the results to evaluate the playing activity of football players were discussed.

Keywords: anaerobic exercise, walk test, nervous processes, functional performance, aerobic exercise

Streszczenie

Wprowadzenie. Zbadano mechanizmy interakcji neurowegetatywnej funkcjonalnej reaktywności systemu transportu tlenu (ang. *oxygen transport system* – OTS) i określonych genetycznie właściwości typologicznych ośrodkowego układu nerwowego (OUN).

Materiał i metody. Właściwości typologiczne ośrodkowego układu nerwowego elitarnych piłkarzy (32 osoby) zostały określone na kompleksie neurodynamicznym „Diagnost-1". Reaktywność OTS została zbadana w teście stopniowego zwiększania prędkości biegu przy użyciu analizatora gazowego Jaeger Oxycon Mobile.

Wyniki. Ustalono zależność reaktywnych właściwości OTS od uwarunkowanej genetycznie funkcjonalnej mobilności procesów nerwowych (FMNP). U sportowców z wyższym poziomem FMNP stwierdzono istotne statystycznie wyższe wskaźniki objętości wyrzutowej krwi, szybkości uwalniania dwutlenku węgla (VCO_2) i mleczanu we krwi (HLa) niż u osób o niskim stopniu właściwości typologicznych (p=0,033-0,045). Sportowcy z niskim FRNP charakteryzowali się statystycznie istotnie wysokimi wartościami częstości akcji serca (HR) i szybkości poboru tlenu (VO_2 max). Wskaźniki objętości minutowej krwi i oddychania nie wykazywały istotnych statystycznie różnic w grupach sportowców o różnej gradacji FMNP (p=0,064-0,078).

Wnioski. Omówiono model teoretyczny i mechanizmy interakcji indywidualno-typologicznej właściwości FMNP z funkcjonalną reaktywnością OTS oraz możliwość wykorzystania wyników do oceny aktywności gry piłkarzy.

Słowa kluczowe: ćwiczenia anaerobowe, test chodu, procesy nerwowe, wydajność funkcjonalna, ćwiczenia aerobowe

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Introduction

The World Football Championship in Qatar witnessed the growth of complex tactical and technical methods and the personal responsibility of athletes for the decisions made; the price of making a mistake increased [1]. The requirements for preparing, controlling, and correcting the training process, selection, and competition among players have improved. Under such conditions, it has become necessary to search for such characteristics or properties of the athlete's body, which will be decisive in selection and will determine the effectiveness of game activity [2,3]. According to previous research and data, such stable characteristics can be attributed to innate highly genetically determined individual-typological properties: strength (SNP), functional mobility (FMNP), and balance (BNP) of the processes of excitation and inhibition [4,5]. At the same time, several convincing items of data were obtained, determining the patterns of physical performance, features of the functional state of various body systems, and the reactivity of the oxygen transport system (OTS) of athletes [6-8]. The problem of neurovegetative mechanisms of interaction of genetically determined typological properties of the central nervous system and reactive features of athletes' OTS under extreme physical exertion remains the most interesting and under researched.

A feature of modern sports is that it is only possible to build effective training for athletes with a fundamental understanding of the body's functional state [9-11]. Therefore, more attention is paid to studying biological patterns of the athletes' bodily adaptation to specific types of muscle activity. To this end, only some physiological issues of high-level physical performance, often in dissonance with the needs of sports practice, have been investigated. Most of the studies were conducted in the laboratory without physical exertion and using the latest technologies. A general understanding of the body's adaptation to extreme physical effort is required. In recent years, qualitatively new experimental material has been obtained regarding the functional capabilities of various systems and the mechanisms of their adaptation to strenuous muscle activity [6,7]. The main task of sports physiology is to determine the factors and properties of the body that determine and ensure a high level of physical performance. Therefore, the basis of this approach to determining the functional capabilities of athletes is based on the criteria for evaluating energy systems: creatine phosphate, glycolytic, and aerobic [10,12]. For this purpose, testing to assess energy processes' power, capacity, and efficiency is proposed [11,13]. The physiological basis of energy potential realization is its dependence on the specific integrative activity of motor and vegetative functions, the increase of activating effects of the cerebral cortex, as well as the improvement of neuro-humoral regulation and, on this basis, the optimization of the physiological reactivity of the body systems leading to the type of sports activity.

Under the condition that the issues of sports physiology and medicine are resolved, the problem of ensuring a high level of physical performance comes to the fore. It should be emphasized that in sports physiology, the dynamics of increasing exceptional physical performance are considered not only as an increase in functional reserves but also as a process of integration of various systems to a specific type of muscle activity and improvement of regulation mechanisms [11-13]. In addition, the analysis of the adaptation mechanisms of athletes with a high level of fitness can be based on both achieving high performance and adjusting the dynamic characteristics of functional systems, the speed of their deployment, reaching the peak level, and stability, which are the most effective in realizing energy potential.

To date, the scientific literature has accumulated a large amount of data that any form of adaptive response of the athlete's body to physical exertion is provided by a complex of physiological reactions that can have different variations and combinations of the athlete's morpho-functional features [14-17]. Such elements of the athlete's response to physical exertion can be represented as a physiological reactivity of the body and as a property of a living system to respond to changes in the external and internal environment [8,18].

According to some authors [6,7], the main principle of reactivity is that the nature of the body's reaction to the action of a specific stimulus is determined by both the quantitative and qualitative characteristics of the environmental factor and the functional state and adaptive capabilities of the body's systems. Therefore, reactivity is a property of the body's adaptive capabilities and its optimization to the type of sports activity. Thus, reactivity determines the effectiveness of homeostatic reactions and regulation mechanisms underlying systemic functional changes, training development, and adaptive capabilities to the type of sports activity.

It is believed in sports physiology that the expressiveness of the body's reactions to physical exertion depends on the level of training and individual characteristics of the athlete [19]. Despite the standard inclusion of physiological mechanisms of functional reactivity of the central nervous system, unique features of the development of adaptive processes will depend on the genetically determined properties of regulatory systems, which are essential for the quantitative and qualitative assessment of functional processes [20]. It can be assumed that the basis of individual reactions of adaptation to physical exertion is hereditary features of the reactivity of OTS [6], as well as unique typological properties of the central nervous system [4,5]. Therefore, it is crucial that, when diagnosing the athlete's adaptive capabilities to significant physical exertion, studies of the activity of integrating systems, which contain the parameters of the whole organism's functioning, can be particularly informative. Blood circulation, breathing, and regulatory functions of the heart rate are the main effector links. They can act as sensitive indicators of the adaptive reactions of the whole organism to physical exertion. Therefore, there is a need to investigate the individual features of the functional reactivity of the OTS to extreme physical loads.

In sports, in realizing the body's maximum physical and functional capabilities, the individual features of system reactivity are manifested in the degree of reactions to loads and the different speeds of their changes under the influence of repeated muscle loads [6]. The nature of such reactive changes depends on physical exertion and individual characteristics of the athlete's nervous system. It is known that response to physical effort involves activation and adaptation reactions in some athletes and suppression and maladaptation in others. However, the problem of the connection of the OTS reactivity with typological features of the nervous system remains open. Therefore, the issue of the role of individual-typological properties of the central nervous system in interaction with critical body systems remains the most urgent problem of physiology, medicine, and sports theory [5,11]. There are reasons to suggest that changes in the physiological reactivity of the vital systems and typological properties of the central nervous system may reflect the individual nature of the realization of physical capacity [7,21,22].

Even though long-term adaptation to physical exertion is based on changes in the functional reactivity of the body's central systems, a targeted study of the individual features of the regulation of functions and their mechanisms has yet to be conducted. The unique characteristics of the OTS's reactive capabilities in long-term sports activities have yet to be determined. In addition, it is interesting to establish correlations between individual features of the reactivity of the hemodynamic system, breathing, blood, and typological properties of the central nervous system.

Therefore, today, more than knowledge about the peculiarities of the interaction of the OTS with the individual-typological properties of the CNS of athletes under intense physical activity is required. In connection with the above, the development of criteria for optimizing the training process of elite athletes, based on considering the individual neurobiological features of the reactive capabilities of the OTS, is relevant.

Aim of the work

The purpose of the research is to determine the individual features of the functional reactivity of athletes' OTS, depending on the nervous system's typological properties.

Material and methods

Individual genetically determined typological properties of the central nervous system were studied, and the functional reactivity of the central nervous system was determined in 32 athletes of the professional team of the Premier League of the Ukrainian football championship.

The research was conducted based on data from the Mykhailo Bosy Physiology Research Institute of Cherkasy Bohdan Khmelnytsky National University and in the track and field arena. Healthy athletes participated in the experiment voluntarily. The commission approved research plans and the organization of bioethical expertise.

The genetically determined individual typological property – the functional mobility (FMNP) of nervous processes – was determined with the help of the "Diagnost-1M" computer device [4,23]. The indicator of the level of FMNP was the time of performing the task of differentiating positive and inhibitory stimuli that followed each other in the "feedback" mode in seconds. The shorter the time spent on the task, the higher the level of the investigated property was.

The reactivity of the OTS was studied under the conditions of a field test using shuttle running and walking. It was believed that under such situations, the highest level of physical performance is achieved, the necessary, specific muscle groups are involved, and the reactive capabilities of the oxygen transport system reach the highest level. Regarding functional capabilities and reactivity of the OTS, preference was given to a field test since, according to the research protocol, the load on the athlete increases due to the increase in running speed but not the angle of elevation of the treadmill track.

The reactive capabilities of the OTS of football players were determined by the functional indicators of breathing, hemodynamics, and blood lactate, in response to the performance of the test load. A shuttle test was used with a gradual increase in walking and running speed without rest intervals. During testing, athletes walked and ran between two chips at a distance of 20 m. A sound signal with a gradual rhythm increase set the movement rate. The test was stopped when the athlete did not have time to run to the chip twice. Testing lasted 15-20 minutes, depending on the individual capabilities of the examinee. The program consisted of recording indicators for 1 minute in a state of rest, 2 minutes of sitting, 2 minutes of standing, 3-4 minutes of shuttle walking at a speed of 5 km/h^{-1}, 5-20 minutes of continuous shuttle running with gradually increasing speed (every minute the rate increased by - 0.5 km/h^{-1}, initial speed - 10 km/h^{-1}1) and to "rejection". Recovery took place at a walking speed of 5 km/h^{-1} to a heart rate of 120 bpm^{-1}.

The indicators of ergometers, gas analysis, heart rate monitoring, and lactate meter determined the individual level of functional reactivity. The cardiorespiratory capabilities of the athletes were studied using a portable gas analyzer, Oxycon Mobile, manufactured by Jaeger (Germany), which provided telemetric data registration. During the research, an array of data on the activity of the respiratory system and blood circulation was formed for each athlete by 10-second averaging. At rest, during the test, and after its completion, for the 1st and 3rd minute of recovery, functional indicators were recorded: test time (T, min), minute respiratory volume (V_E, $l{\cdot}min^{-1}$), and respiratory rate (f_T, $breath{\cdot}min^{-1}$), oxygen consumption (VO_2max, $mL{\cdot}min^{-1}{\cdot}kg^{-1}$), carbon dioxide release (VCO_2, $mL{\cdot}min^{-1}{\cdot}kg^{-1}$), respiratory rate (RR), heart rate (HR, bpm^{-1}), stroke volume of cardiac output (SV, $mL{\cdot}min^{-1}$), minute blood volume (Q, $l{\cdot}min^{-1}$), lactate (HLa, $mmol{\cdot}L^{-1}$) at the 1st and 3rd minute of recovery [24,25].

Statistical material was processed using the Statistica 64 (Version 12.5.192.7) computer program. The primary analysis of data and their removal was carried out using Microsoft Excel 2019 program. Testing for the normality of the data distribution that fell under the normal distribution law was carried out using the Shapiro-Wilkie test. Since the data followed a normal distribution pattern, the statistical probability of differences between samples was determined using the students' test. The significance of probable values was taken at $p<0.05$.

Results

The functional reactivity of the oxygen transport system of football players was studied according to the parameters HR, Q, SV, V_E, VO_2max, VCO_2, and HLa in a state of relative rest and while performing the shuttle test with a gradual increase in running speed, the results of which are presented in Table 1.

Table 1. Indicators of the oxygen transport system of football players (n=32) according to the results of the shuttle test with step-increasing running speed

Statistical indicators	Investigated indicators						
	HR bpm^{-1}	Q l·min^{-1}	SV mL·min^{-1}	V_E l·mi^{n-1}	VO_2, max mL· min^{-1}·kg^{-1}	VCO_2 mL· min^{-1}·kg^{-1}	HLa, mmol· L^{-1}
Min	176.6	20	98	127.6	47	48	6.8
Max	209.3	32	171	184.6	69	68	14.5
M	188.4	28	152	153.9	59.0	60.0	10.7
σ	8.2	2.5	16.3	16.2	5.6	5.8	2.2
M	1.69	0.52	3.32	3.3	1.13	1.18	0.64
CV, %	4.3	8.9	10.7	10.5	9.4	9.3	13.3

The value of VO_2max is an indicator that distinguishes teams by the level of preparedness and characterizes the physical capacity and functional reactivity of the central nervous system of an individual football player. Teams and athletes who achieve better results are believed to have higher VO_2 max values [26]. Moreover, the value of VO_2 max is a sensitive criterion of physical performance under training loads aimed at increasing endurance. VO_2 max is also related to a player's total work on the field during a game. The study showed that, under the condition of performing the shuttle test with a gradual increase in running speed, football players absorbed VO_2 max in the range of 47-69 mL·min^{-1}·kg^{-1}, with an average value of 59.0±1.13 mL·min^{-1}·kg^{-1}, which corresponded to the work power – 218.0±3.81 W, and developed a shuttle running speed – 13.9±0.14 km·h^{-1}. In addition, the value of VO_2 max characterizes the functional capabilities of the oxygen transport system of football players. The athletes with high VO_2 max also showed high values of HR, Q, SV, and V_E, as well as power and duration in their work.

The results given in Table 1 showed that the high values of VO_2 max in football players were consistent with other high indicators of the oxygen transport system, namely: HR (188.0±1.69, bpm^{-1}), Q (28.0±0.52, l·min^{-1}), SV (153.9±3.32 mL·min^{-1}) and V_E (154±3.32 l·min^{-1}), which were registered during the shuttle test. Specialists in physiology believe that to perform effectively at the international level; football players should have a VO_2 max value at the level of 60 mL·min^{-1}·kg^{-1} [11,13]. Qualified football players have a high level of aerobic capacity. The level of maximum oxygen consumption in football players of the Premier League is, on average - 61.27 mL·min^{-1}·kg^{-1}; it is 67.05 mL·min^{-1}·kg^{-1} in leading foreign teams which corresponds to the level of athletes specializing in cycling, rowing, cross-country skiing, and middle- and long-distance running [26,27].

Previous studies [5,21] established that soccer players performed up to 30% of their work in the anaerobic energy supply mode. Therefore, it was vital to investigate the state of the athletes' physical capacity and functional reactivity according to VCO_2 and HLa indicators. It is necessary to consider that VCO_2 and HLa characterize the performance and functional capabilities of the anaerobic metabolism. Therefore, we analyzed the results of VCO_2 and HLa during the shuttle test. It was established that the examined football players were characterized by high VCO_2 values: 48-68 $mL \cdot min^{-1} \cdot kg^{-1}$. The average value of this indicator was 60.0±1.18 $mL \cdot min^{-1} \cdot kg^{-1}$. The lactate indicator (HLa) at the 3rd minute of recovery after the test with a gradual increase in running speed ranged from 6.8 to 14.5 $mmol^{-1} \cdot L$ in the subjects, and the average value of this indicator for the group was 10.7±0 .67 $mmol^{-1} \cdot L$.

To establish the connection between the functional reactivity of football players and the characteristics of individual-typological properties of the central nervous system, the calculations and comparison of quantitative and qualitative results of the OTS reactivity in the groups of athletes with different gradations of FMNP were conducted (Table 2). First, the average level of FMNP was established. For the group of football players under examination, the FMNP was 62.6±0.56 sec. The highest indicator of FMNP was 55 sec, and the lowest was 68 sec. According to the method of sigmoid deviations, the examinees were divided into three groups according to the FMNP indicator: below average ($<M-0.5\sigma$), average ($M-0.5\sigma$ – $M+0.5\sigma$), and above average ($>M+0.5\sigma$) level of FMNP. It was found that among highly qualified football players, 30.2% of the examinees were assigned to the group with a higher-than-average level of FMNP and performed the task of processing 120 signals in 55-58 sec. 42.0% joined the group with an average level of FMNP. The FMNP indicator for this group ranged from 59 to 63 sec, and the average was 60.4±0.3 sec. While 27.8% of people performed the test task of differentiating 120 signals in 64-68 seconds, they were assigned to the group with a lower-than-average gradation of FMNP. In the groups with different gradations of the FMNP, we received information about the state of functional reactivity of the OTS of athletes in connection with the individual typological features of the central nervous system at the level of achieving maximum oxygen consumption (MOC).

Table 2. Results of oxygen transport reactivity at the level of maximum oxygen consumption in athletes (n=32) with different levels of functional mobility of nervous processes

Investigated indicators	Levels of functional mobility of nervous processes, s		
	High (57.1±0.4)	Middle (60.4±0.3)	Low (65.6±0.7)
HR, bpm^{-1}	187.0±1.3	186.2±1.4	197.5±1.5*&
SV, $mL \cdot min^{-1}$	163.5±3.5*#	151.6±3.3&	151.2±3.5
Q, $l \cdot min^{-1}$	29.5±0.3	28.3±0.5	29.3±0.5
V_E $l \cdot min^{-1}$	153.5±3.4	154.1±3.6	161.5±3.6*
VO_2max, $mL \cdot min^{-1} \cdot kg^{-1}$	58.1±1.3	57.3±1.4	64.4±0.9*&
VCO_2, $mL \cdot min^{-1} \cdot kg^{-1}$	62.1±1.4*	59.1±1.4	54.3±1.4
HLa, $mmol \cdot L^{-1}$	12.3±0.5*#	10.5±0.6	9.4±0.3

Notes: Statistical significance of differences at the $p<0.05$ level between groups; * – high and low, # – high and middle; & – middle and low.

A comparison of the research results of the OTS characteristics during the test with a gradual increase in speed in groups of football players with different gradations of FMNP at the level of maximum oxygen consumption (MOC) revealed the following. A higher level of FMNP corresponded to statistically significantly higher indicators of SV and HLa than in the subjects with a low gradation of the studied typological property (p=0.033-0.045). Conversely, athletes with a low level of FMNP were characterized by statistically significantly higher indicators of HR and VO_2 max than the examined athletes with a high level of FMNP (p=0.027-0.043). The Q and V_E indicators did not show statistically significant differences in the groups of the subjects with different gradations of FMNP (p=0.078-0.064). The obtained results indicate that the athletes with a high FMNP achieved a high level of physical performance and OTS reactivity in the test with a gradual increase in running speed through a more pronounced involvement of the functional capabilities of anaerobic metabolism. At the same time, the athletes with a low gradation of the studied typological property were characterized by the advantages of aerobic functional capabilities in ensuring physical performance.

Thus, the results of Table 2 show that the oxygen transport reactivity, under the condition of performing shuttle running at the level of maximum oxygen consumption, is dependent on the FMNP. Football players with a high and medium level of FMNP were characterized by a higher functional reactivity of the oxygen transport, aerobic-anaerobic, and lactate energy systems (SV, VCO_2, and HLa) than the athletes with a low gradation of the studied typological property. In the latter, indicators of the cardiorespiratory system had advantages of aerobic metabolism (HR and VO_2 max).

The identified differences in the OTS of the athletes with different typological properties of the central nervous system indicate their use of different strategies of response to physical exertion, which are related to the peculiarities of the individual reactivity of the system of non-specific activation and FMNP.

Thus, the research results make it possible to generalize that the reactivity of the OTS of athletes under the condition of performing step-increasing load at the level of reaching the maximum oxygen consumption depends on the individual typological properties of their nervous systems.

Discussion

For now, convincing data has been obtained that neurodynamic variants of typological features in elite athletes are genetically determined properties of the central nervous system and do not change during training and competition [4,23]. Although these directions are still far from the final study, they open broad prospects for forming new approaches to the solution of theoretical and applied research. At the same time, an analysis of research data regarding the nature and individual features of the interaction of the functional reactivity of the oxygen transport system of elite athletes, depending on the highly genetically determined typological properties of their nervous systems, showed that such studies have not been conducted either in individual athletes or in groups of elite athletes. In the presented article, we tried to find the features of the neurovegetative mechanisms of the functional interaction of highly genetically determined typological features of the nervous system, namely the FMNP in the character of the functional reactivity of the oxygen transport system of elite athletes during step-increasing physical exertion. We proceeded from an understanding of the natural origin of the neurobiological rhythms of the brain, heart, and breathing and their relative constancy. Such an approach to the study of neurovegetative mechanisms of the functional interaction of typological features of the nervous system, with the nature of the functional reactivity of the oxygen transport system, makes it possible, on the one hand, to consider them as a variant of vegetative modulation of the reactive properties of the OTS, and, on the other hand, as a means of integrative influences of the higher departments of the brain on the activity of the heart, breathing, and blood within the intersystem integration of the body.

So far, convincing data has been obtained that OTS and VO_2 max are essential indicators of an athlete's aerobic capabilities and physical performance [6-8]. The value of VO_2 max characterizes the greatest amount of oxygen an athlete can utilize during breathing. It has already been proven that, during an official match, football players maintain most of the game activity in the mode of aerobic metabolism. Therefore, the value of VO_2max is not only a powerful indicator of aerobic metabolism but also characterizes the functional reactivity of the OTS and is an important indicator that determines the ability of a football player to perform game tasks [2,21].

The article demonstrates that the neurovegetative mechanisms of functional reactivity of the OTS, under conditions of physical exertion, depend on the typological features of the central nervous system in various combinations. The analysis of the dynamics of adaptive adjustments of the OTS revealed that football players with a high and medium level of FMNP were characterized by statistically significant higher indicators of SV, VCO_2, and HLa than football players with a low gradation of the studied typological property and demonstrated higher results of physical performance and reactive capabilities of the OTS. Thus, athletes with a high level of FMNP achieved a high level of OTS reactivity in the field test, with a gradual increase in running speed to a more pronounced involvement of the anaerobic metabolism. The athletes with a low gradation of the investigated typological property had advantages of aerobic metabolism, which was confirmed by statistically significant higher HR and VO_2max values. The obtained data indicate that the athletes with a low gradation of the typological property of the FRNP had less pronounced changes in OTS, a narrower range, and lower values. The identified differences indicate the activation of various regulatory mechanisms.

Reactivity and functionality of the OTS is an intersystem phenomenon and manifests itself in the activation of various parts and structures of the brain [28], changes in the rhythmic activity of the heart [7,19,21], and breathing [6-8], which induces performance of physical exercise [21] and a range of psychophysiological changes [29], variability, hemodynamic and metabolic mobility [30]. Genetically determined individual typological properties of the central nervous system, namely the FMNP in athletes, are in complex interdependent relationships with the reactive capabilities of the oxygen transport systems. The level of the FMNP determines and makes specific corrections in the degree of development of vegetative reactions, energetic aerobic/anaerobic metabolism, and physical performance of an athlete.

There are no theoretical options in the literature that can explain and form the neurovegetative mechanisms of the reactive properties of the OTS in their connection with the typological features of the central nervous system. The following considerations include the theoretical basis of the formation of individual reactivity of the OTS and its functional interaction with the typological properties of the central nervous system under conditions of extreme physical exertion. First, it is necessary to distinguish several levels of neurovegetative regulation that underlie the biological individuality of the reactive properties of the OTS. Second, during physical exertion, intersystem mechanisms of regulation of the reactive functions of the heart, breathing, and blood are aimed at ensuring the metabolism of the working muscles. Third, when the load on the athlete's body increases and reaches the limit level, their internal and intersystem integration processes must be improved. Then, other, higher neurovegetative mechanisms are additionally involved. It should be considered that the task of individual typological properties of the central nervous system can be to create conditions for subordinating the reactive capabilities of the OTS to a higher level of neurovegetative regulation and providing them with individual orientation. The higher neurovegetative level of individuality is fundamental and is based on the central nervous system's genetically determined unique typological properties. Its task is to create optimal opportunities for the interaction of various organs, systems, and mechanisms to achieve a high individual level of functional and physical activity. The availability of connections between the individual-typological properties of the nervous system and indicators of the reactive capabilities of the OTS expand and complement the idea we have formulated regarding a dynamic multi-circuit neurodynamic system, with a multi-level hierarchical organization of the mechanisms of regulation of the cardiovascular, respiratory systems and blood in athletes [5].

Thus, we have proven that individual-typological properties are decisive in forming and deploying appropriate strategies for physical performance, energy metabolism, and reactive and reserve capabilities of the OTS. Based on the obtained results, the role of individual-typological properties of the central nervous system in the intersystem interaction of the OTS has been determined, and its neurovegetative mechanisms have been tested under the conditions of actual sports activity.

Conclusions

1. Extreme physical exertion, at the level of maximum oxygen consumption in elite athletes, causes a multidirectional reaction of the OTS according to the individual typological properties of the athletes' CNS.
2. Genetically determined typological features of the nervous system, under the condition of gradually increasing physical load, assess the degree of reactivity of the OTS and the participation of anaerobic and aerobic metabolism.
3. Athletes with a high and medium level of FMNP in a field test, with a gradual increase in running speed, were characterized by a higher reactivity of the OTS and anaerobic metabolism, confirmed by statistically significant higher indicators of SV, VCO_2, and Hla, than individuals with low gradation of the investigated typological property.
4. In the athletes with a low gradation of the typological property of FMNP, indicators of the OTS reactivity had advantages of aerobic metabolism confirmed by statistically significant higher indicators of HR and VO_2 max.

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