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FEATURES OF URGENT ADAPTATION TO HIGH-ALTITUDE CONDITIONS IN ATHLETES WITH DIFFERENT LEVEL OF PHYSICAL CONDITION

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Annotation. The aim of the work was to identify the features of physiological adaptation to hypobaric hypoxia in mountaineers with different experience of climbing 5000 m mountains. The study involved 24 mountaineers aged 24 to 46 years, regularly engaged in mountaineering. They were divided into two groups: 9 people – athletes (mountaineering for at least 5 years) and 15 people – "beginners" (mountaineering from three months to a year). We assessed the saturation level and pulse at different heights of step-by-step adaptation when climbing Mount Kazbek (5033 m). The duration of the expedition was 10 days. The differences in the adaptation strategy between mountaineers with different levels of condition for physical loads in high-altitude conditions is that the level of blood saturation in experienced athletes is maintained at an altitude of 3600 m above sea level with a lower pulse value than in athletes with less climbing experience, which indicates the presence of functional reserves formed during training.
Keywords: step-by-step adaptation to high altitude, hypoxia, alpine region, mountaineers.

Introduction. Increase of functional reserves of an athlete's body to hypoxia is significant not only for the arrangement of climbing training, but also when planning training for athletes, their better acclimatization to competitions in conditions of hypobaric hypoxia. Many international competitions take place in middle-altitude conditions. For example, the 1968 Olympics took place in Mexico City, located at an altitude of 2240 m above sea level (ASL), the ski tournament at the 2022 Olympics in Beijing took place at an altitude of 1800 m ASL. One of the prerequisites of successful performance in these conditions are the formation of adaptation's functional reserves of an athlete's body to physical loads, including conditions of lowered partial oxygen pressure at these altitudes. It was noted earlier that the respiratory (increase of respiratory volume and rapid breathing due to the stimulation of arterial chemoreceptors) and cardiovascular (rapid heartbeats) systems response to hypoxia according to the hyperbolic curve, in dependence to partial oxygen pressure in the blood (PaO_2) [1].

The aim of the study was to examine the physiological adaptation to hypobaric hypoxia in mountaineers with different climbing experience on the 5000 m mountains.

Methods and organization. The study included 24 mountaineers aged 24 to 46 years, who climb regularly. According to the study's design, we divided them into two groups: 9 people – athletes (mountaineering for at least 5 years) and 15 people – "beginners" (mountaineering from three months to a year). When climbing on Mount Kazbek – 5033 m ASL (Georgia), we conducted the saturation (blood oxygen saturation – SpO_2, %) and pulse rate analysis in seated participants with the "Armed YX302" fingertip pulse oxymeter ("Medical equipment", Russia) at 500 m ASL, 1500 m ASL, 3000 m ASL and 3600 m ASL (before and after the ascension). The expedition took 10 days: first three days – moving from Gergeti village (Georgia) to the altitude of 3000 m ASL (one night stay at 500 m, 1500 m, two stays and one acclimatization day at 3000 m); the 5th day – moving to the “Meteostation” summit camp at 3600 m ASL; the 6th day of acclimatization – ascent to 4000 m ASL, then descent to 3600 m ASL and one night stay; the 7th day – ascent to 4200 m ASL, descent and one stay at 3600 m ASL; the 8th day – ascent to the mountain’s top at 5033 m ASL, descent and one stay at 3600 m ASL; the 9th day – descent from the summit camp to Gergeti village, one stay at 500 m ASL; the 10th day – departure.

The statistical data processing was conducted with the R software package [2], using the non-parametric criterion (the Mann-Whitney U-test) for intergroup comparison. Differences between groups are deemed as statistically significant if $p<0.05$. The indicators are presented in medians (Me) and quartiles (Q25-Q75), the correlation between indicators in groups was calculated using the Spearman correlation coefficient. The imaging was made in the R programming language [2] with the ggplot2[3], aplpack[4] и GGally[5] software packages.

Results and discussion. The analysis of the degree of formed physical adaptation when climbing Kazbek in mountaineers with different physical condition revealed that at 500 m ASL the saturation level was not different in both groups. However, the saturation level in athletes with less mountaineering experience (“beginners”) was supported by an increase in pulse rate (fig. 1). Schemes below also show great distribution range of this indicator’s values in the group.

This tendency remains when climbing to 1500 m ASL (fig. 2). We have also identified an extension in range of individual responses of the cardiovascular system (the pulse rate at this altitude) in the group of experienced athletes.

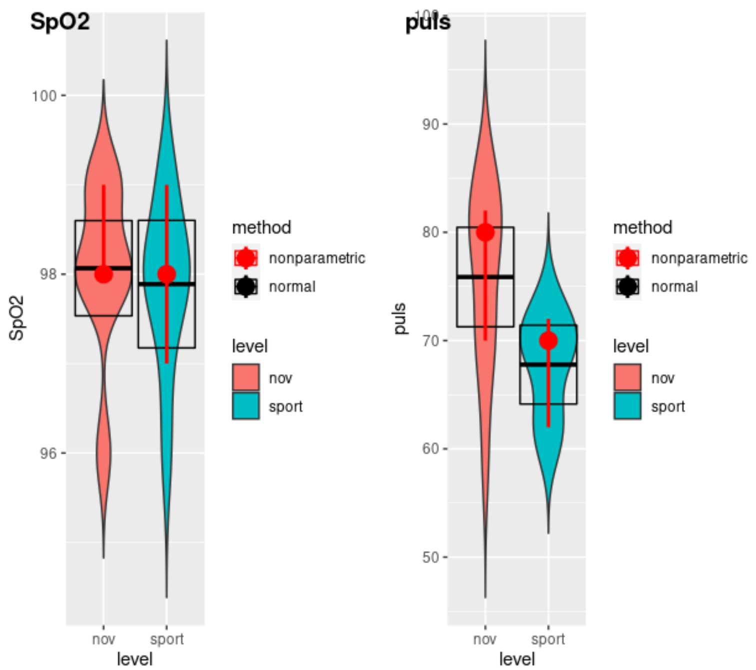

Fig. 1. Saturation level and pulse rate at different stages of the step-by-step adaptation to hypoxia – 500 m ASL

Note: nonparametric – Me(95%CI) – median (red dot), 95% – confidence interval (red lines directed towards different sides from the dot); normal – M(95%CI), mean value (black bold line), 95% – confidence interval (black fine lines)

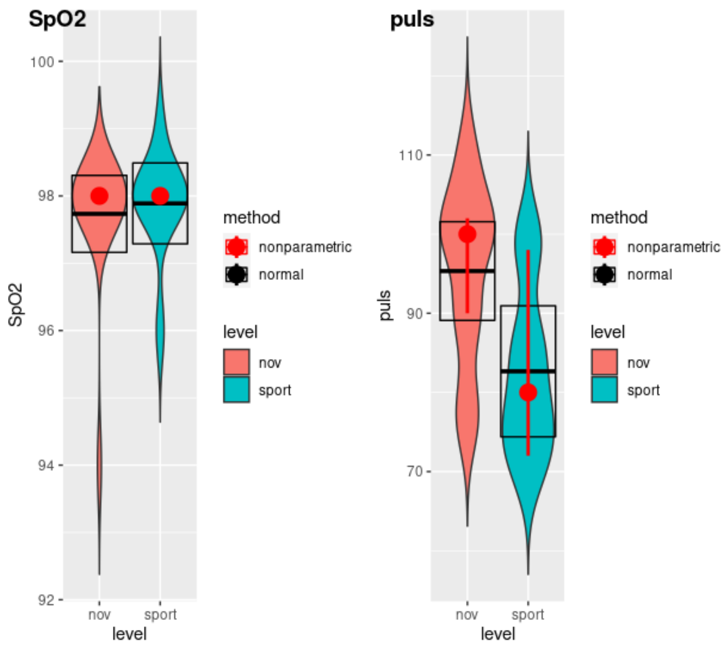

Fig. 2. Saturation level and pulse rate at different stages of the step-by-step adaptation to hypoxia – 1500 m ASL

Note: nonparametric – Me(95%CI) – median (red dot), 95% – confidence interval (red lines directed towards different sides from the dot); normal – M(95%CI), mean value (black bold line), 95% – confidence interval (black fine lines)

During the process of the step-by-step adaptation at 3000 m ASL (fig. 3), we have registered a tendency of increasing blood saturation (not significant) in experienced athletes (not significant, p=0.678) with relatively low pulse rate (p=0.011), which indicates a presence of functional reserves, formed during the training process.

The same adaptation mechanism, but in a more pronounced form, is preserved at higher altitudes (the summit camp before and after the ascension – 3600 m ASL, fig. 4, 5).

It is important to note the preservation of these physiological adaptation strategies in experienced athletes after the ascension. However, we have registered a greater variation of individual responses of physiological systems (the width of it is shown on fig. 5, blue color). It can be interpreted as individual metabolic reactions, generated during training, and the specificity of the biochemical enzymatic “profile” of each athlete. Therefore, we have learned that the hypoxic preconditioning contributes to an increase of tolerance to acute hypoxia conditions, which is shown through the less pronounced degree of hemoglobin desaturation and lowered heart rate [6].

It should be pointed out that in case of the ascension the acute (urgent) adaptation effect is implemented mainly at the expense of the cardiovascular system. Figure 6 shows that there is an inverted correlation between the saturation and pulse, and its absolute values increase when climbing under hypobaric hypoxia conditions (from r=-0.1 at 500 m ASL to r=-0.5 at 3600 m ASL). Important is the fact that after the ascension this correlation is much higher (r=-0.8), i.e. the pulse is even higher with lowered blood saturation. When analyzing values of the coefficient correlation between these indicators, we can assume the high degree of physiological connection between them in conditions of the urgent adaptation to hypoxia.

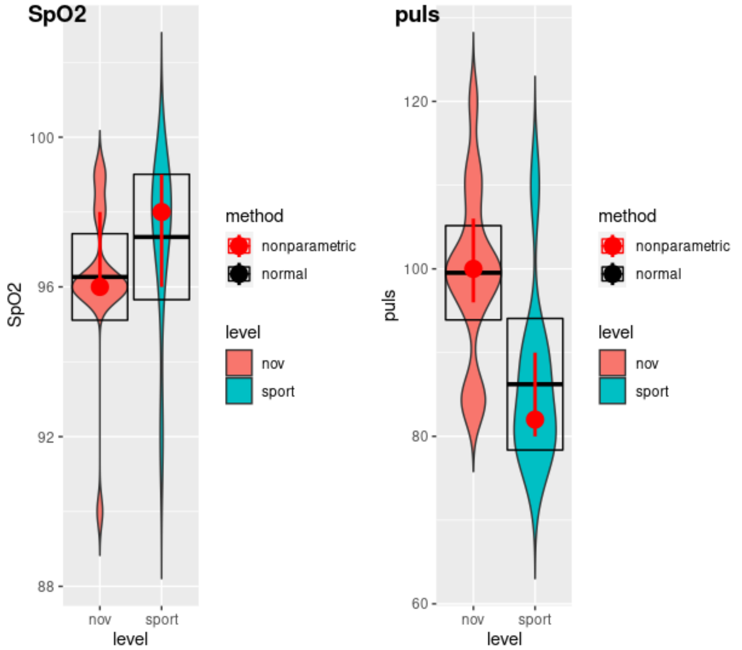

Fig. 3. Saturation level and pulse rate at different stages of the step-by-step adaptation to hypoxia – 3000 m ASL

Note: nonparametric – Me(95%CI) – median (red dot), 95% – confidence interval (red lines directed towards different sides from the dot); normal – M(95%CI), mean value (black bold line), 95% – confidence interval (black fine lines)

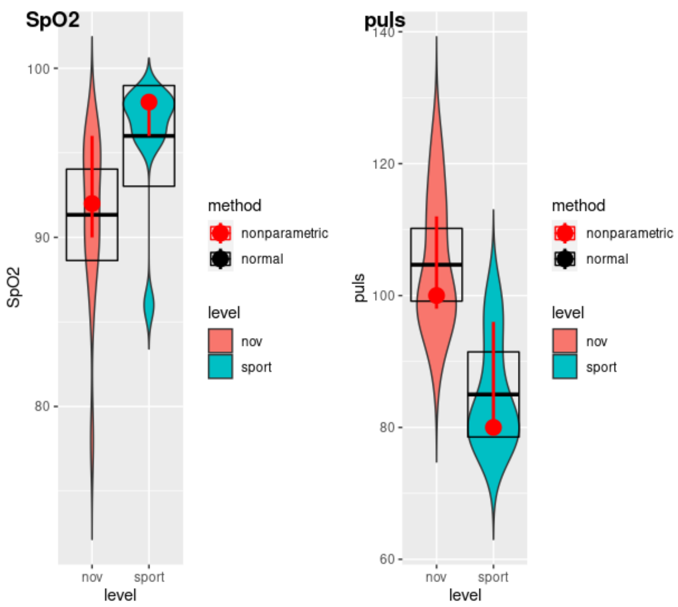

Fig. 4. Saturation level and pulse rate at different stages of the step-by-step adaptation to hypoxia – 3500 m ASL

Note: nonparametric – Me(95%CI) – median (red dot), 95% – confidence interval (red lines directed towards different sides from the dot); normal – M(95%CI), mean value (black bold line), 95% – confidence interval (black fine lines)

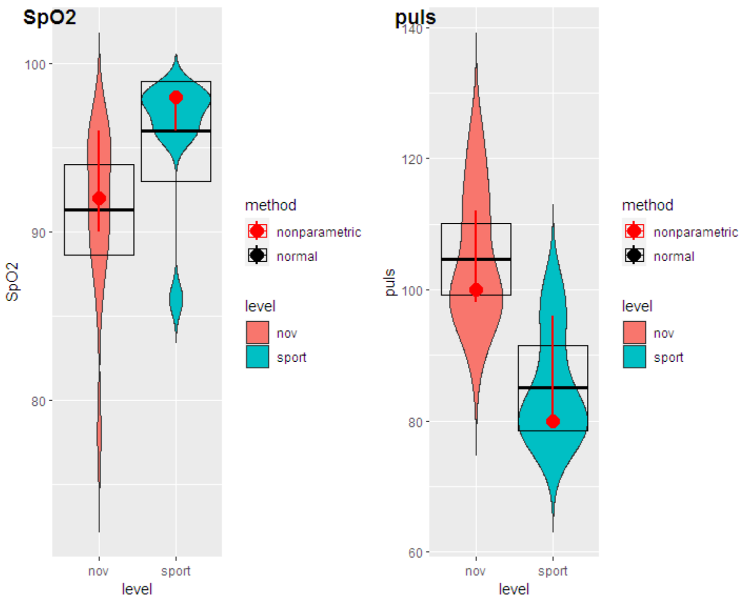

Fig. 5. Changes in saturation and pulse rate at 3600 m ASL after the ascension

Note: nonparametric – Me(95%CI) – median (red dot), 95% – confidence interval (red lines directed towards different sides from the dot); normal – M(95%CI), mean value (black bold line), 95% – confidence interval (black fine lines)

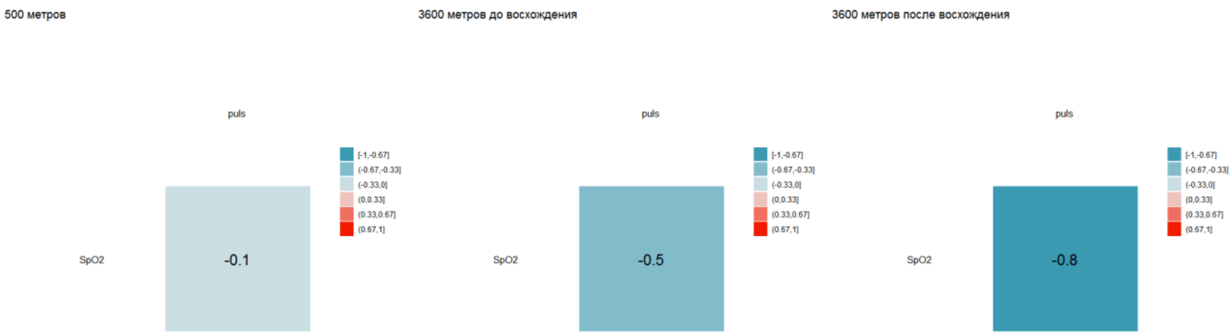

Fig. 6. The Spearman correlation coefficient between saturation indicators and pulse at different stages of the urgent adaptation to hypoxia in high-altitude conditions of 500 m ASL (S=2600.7, p=0.543), 3600 m ASL before the ascension (S=3524.4, p=0.007) and 3600 m ASL after the ascension (the summit camp) (S=4090.6, p<0.001)

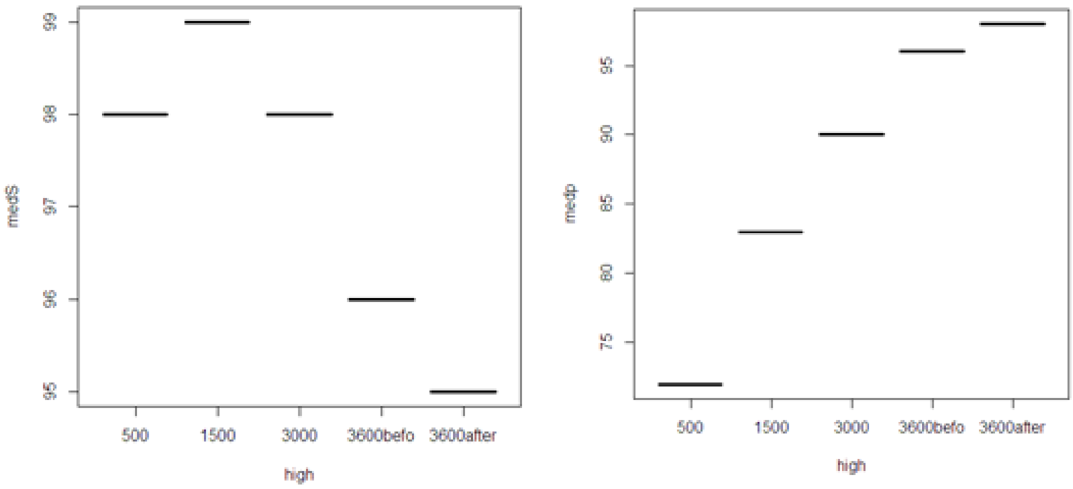

Fig. 7. Dynamics of the saturation and pulse rate (median (Me) values) during the formation of adaptation to hypoxia when ascending Mount Kazbek (5033 m ASL)

After the ascension, the blood saturation level, according to the medians of the whole group, decreases (fig. 7). It indicates an urgent adaptation phenomenon called the “oxygen debt”, where there is a need to recover oxygen in tissues (in myoglobin).

Similar changes of the cardiorespiratory system were noted in other works studying adaptation to the high-altitude hypoxia [7-8].

In the study by Yu.V. Koryagina [8], when analyzing urgent adaptation processes in conditions of the one-day expedition to the Elbrus region (2380 m ASL in the Dzhily-Su area), it was revealed that athletes without mountaineering experience also have lowered saturation with a simultaneous increase of heart rate and tone activation of the sympathetic nervous system, but to a greater extent than in the “beginner” group of our study – the athletes, mountaineering for a year and attending regular weekly training sessions according to the developed program for the interval hypoxic training when preparing to ascend in high-altitude conditions.

The experimental works have revealed that preservation of oxygen content in arterial blood in case of hypoxic submaximal loads can be done at the expense of stimulating hypoxic factors (HIF – hypoxia-inducible factor), increased erythropoietin and changes in the hemoglobin oxygen affinity [9-10].

Conclusion. Therefore, we have identified differences in a degree of forming adaptation to hypobaric hypoxia between two mountaineer groups at an altitude of 3600 m ASL. Athletes with less experience have signs of hypobaric hypoxia: lowered blood saturation, increased pulse rate. In the experienced athletes (more than 5 years), the saturation is supported by other physiological mechanisms. The suggested algorhythm of the step-by-step adaptation to hypoxia for 10 days can be used when arranging programs of active tourism, e.g. when ascending to Elbrus.

Mechanisms of forming the long-term adaptation to hypoxia in high-altitude conditions among athletes of different qualification requires further research and appropriate biomedical support.

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THE LONG-TERM TRAINING PROCESS OF YOUNG SOCCER PLAYERS FROM THE POSITION OF THE DYNAMIC FUNCTIONAL SYSTEM'S FORMATION

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Annotation. The purpose of this study was to characterize the long-term training process of young soccer players from the position of forming a dynamic functional system. Based on the study of individual parameters of physical development, the functional state of the cardiovascular system of the body, the physical fitness of young soccer players in the age range from 12 to 18 years, correlation matrices were calculated, taking into account which the indicators of the adaptation efficiency coefficient were established, allowing to judge the formation of the dynamic functional system of the player. The adaptation efficiency coefficient indicators at each stage of the specified age range can be used to assess the effectiveness of training influence in the long-term aspect.
Keywords: young soccer players, long-term training process, dynamic functional system, adaptation efficiency coefficient.

Introduction. Currently, rational training of young athletes becomes complicated due to an absence or inconsistency of information on the specificity of a developing body in formed environmental conditions. Considering this fact, we can form two groups of factors: objective and subjective. The first group includes social, economic and hygienic living conditions, conditions of the training process, in which an adolescent, engaged in sports, is growing up. The second group includes biological regulations of a developing body of a young athlete. Each trainer, who wants to achieve maximal results and preserve a high level of performance of athletes over a long period of their professional career, should know features of how a child's body grows and develops.

A group of researchers [1-4] has found that systematic soccer classes have a positive influence on natural processes of growth, physical and functional development of an adolescent's body. Meanwhile, soccer, from the point of motor skills and their energy support, is considered as the most complicated type of sports, requiring long-term versatile development, involving all main physiological systems and all physical qualities of a human. In conditions of many-years training, changes, taking place, have not only functional, but also structural nature. According to a number of studies [5-7], processes of the long-term adaptation of soccer players, as for many other types of sports requiring the development of endurance, are manifested through the formation of physiological reserve of the blood circulation and respiratory systems, efficiency of their work, increasing level of performance etc. Moreover, there are features that allow estimating an acquirement of specific traits of the long-term adaptation to the multiyear soccer training: a high degree of developing all energy support systems; high level of imaginative thinking and psychophysiological indicators (attention, perception etc.); significant hypertrophy of muscle groups in the lower extremities.

In order to understand physiological changes, taking place in a soccer player's body during the process of the multiyear muscle activity of high intensity and data interpretation, we need to give a clear description of terms "functional system" (FS) and "dynamic system" (DS). In this study, the body is described from the point of the functional system theory developed by P.K. Anokhin. The main point of this theory is that the FS is formed in each specific moment of time, satisfying the homeostasis's needs. In this case, the "urgent" connections appear, formed under the influence of an unknown or extreme condition, as well as the "long-term" ones, which occurred after the system deletes unnecessary, ineffective elements of interactions between systems. Control of these processes is conducted on the autonomic and central regulation levels [8-9].

According to K.V. Sudakov – the founder of the functional system doctrine – the body, using self-regulation mechanisms, supports vital processes in limiting conditions by including and excluding the functional system's elements in a united group – the same group, which is going to contribute to the homeostasis. Therefore, a rearrangement of appropriate functioning parameters or an adjustment to changing external or internal factors are possible not only inside one system, but also with an involvement of other interacting systems. Meanwhile, according to the I.I. Shmalhausen's opinion, the body is not a mosaic of parts, organs or signs at any stage of development. It always develops as a whole, responses specifically at each stage. New correlation mechanisms of broad meaning appear. They do not disappear and remain for a long time. Such mechanisms relieve and support processes of the body's adaptation as a whole to the changing environment and contribute to a possibility of the internal structure's rearrangement. All changes and rearrangements in the body that appear due to a prolonged effect of environmental factors are of various nature. These specific traits, formed in the body in case of multiyear training, characterize an occurrence of the "dynamic functional system" that supports these exact needs, necessary for successful competitive activity.

It is known, that performance in game sports depends substantially on the level of physical development, functional state and physical fitness of athletes [10-12]. The motor system of a young athlete is a tool, with which they learn different forms of movement in the set space. The training process of young athletes is connected to performance of different locomotions in various modes of intensity. In the age of 11-12 years, effectiveness of the competitive activity is mostly because of physical fitness of young soccer players, since they have to participate in full-size formats of competitive soccer matches [13-15]. The post-puberty, being one of the most stable periods of individual human development due to the cessation of intensive growth against the background of sufficient maturity of energy support systems, nervous and humoral regulation of the body's functions is still characterized by a weakness of functions in a number of organs and systems [5, 16, 17]. Insufficiently strong liver barrier function, activity of the immune system do not support high resistance of the body and reliability of adaptation to the influence of higher physical loads. Adequate systematic physical effect causes the long-term adaptation, accelerates formation of organs and systems of a young athlete and shortens the period of delay in the development of internal organs from the tempo of physical development. This is the reason why, in case of planning these loads, we need to consider these facts, and their distribution by volume and intensity in separate training cycles should take into account still limited adaptation capabilities of the body.

Based on the above, it becomes obvious that in the case of soccer, when assessing the body functioning level, it is necessary to take into account the age aspect, since in addition to the features of the development of the body of soccer players, there are also features of the muscular activity's specificity. For example, puberty in soccer players is noted by some experts as a stage of transitioning to sports professionalization, the duration of which can take several years [18-20]. During this period, it is extremely important to organize the process of training for young soccer players in a way, that they, on the one hand, could promptly integrate in the training process of a professional team, on the other hand – preserve health and possibility to continue regular and purposeful individual development.

The purpose of this study was to define substantial criteria of the adaptation efficiency coefficient of 12-18 year old soccer players from the point of the forming dynamic functional system.

Methods and organization. The study included 500 soccer players from sports schools of the Southern Federal District: the “Academy of Soccer” in Krasnodar, the “Rostov” school in Rostov-on-Don, the “Academy of Soccer “Alania”” in Vladikavkaz.

In order to achieve the set goal, we used methods of scientific research that allow assessing physical development, physical fitness and functional state of the cardiovascular system of young soccer players. The anthropometric methods included the measurement of body length, body mass, and chest girth. Based on the data obtained, we calculated the body mass index, the Erismann index, which characterizes the development’s proportionality and allows you to judge the physique type of an athlete. Using dynamometry, we identified muscle strength of the right and left wrists of players. We also calculated the strength index, characterizing a percent ratio of the wrist’s muscle strength to body mass. In order to identify features of the blood circulation system’s function, we assessed following hemodynamic parameters: stroke volume, cardiac output, double product, pulse pressure, mean blood pressure, blood circulation efficiency coefficient, self-regulation type. Control pedagogical tests were conducted to define indicators of physical fitness in young soccer players from seven age groups (12 years, 13 years, 14 years, 15 years, 16 years, 17 years, 18 years). A set of test tasks for assessing physical fitness was carried out considering training programs and recommendations given by experts, engaged in scientific and methodological support of the sports reserve training. To identify structural elements, as well as to reveal an amount and quality of correlations between main indicators, we used the adaptation efficiency coefficient (AEC), suggested by N.V. Bondar’ (2000) and successfully applied in works of physiological field, that characterizes ratio of a number of “strong” correlations to a total number. Low AEC values characterize satisfactory (effective) adaptation, related to a prolonged influence of external factors. In our opinion, it also shows that the body systems are ready for further, stronger stimuli, causing improvement of fitness.

Results and discussion. The analysis of the main indicators for the age groups of soccer players revealed that heterochronous changes in the structure of correlation matrices are observed with age (table). The least amount of total correlations was found at the age of 13, the most – in 18-year old soccer players. At the same time, at the age of 13 and 18, the largest number of "strong" correlations were observed, and the lowest indicators of the strength of correlation matrices were found in 15-year-old and 17-year-old soccer players. In our opinion, data presented in the table show inertia of the dynamic functional system at the age of 13, because there is no increase in a number of total correlations (306 versus 402 in 12-year-old players). However, the strength of the already present correlations slightly increases (170 versus 136 in 12-year old soccer players). This age can be characterized from the point of improving motor skills by a certain period of stabilizing the results obtained early and achieved functional changes.

Table

Adaptation efficiency in soccer players in the age range of 12 to 18 people

№	Indicators	Age of examined players						
		12 years	13 years	14 years	15 years	16 years	17 years	18 years
1	Total number of correlations	402	306	372	374	440	347	429
2	Number of “strong” correlations	136	170	148	110	120	112	168
3	AEC (c.u.)	0.32	0.55	0.39	0.29	0.27	0.32	0.39

Note: AEC – adaptation efficiency coefficient

We also discovered the highest AEC indicator (0.55 c.u.) in this age period (13 years), which confirms the aforementioned data and indicates strained adaptation of the body. When analyzing the training process and study programs for soccer training in the examined group, we have found that at this age-related stage, basic simple technical skills of movements with the ball are learned, such as receiving and passing the ball, leading the ball, curved pass, hitting the goal, taking into account the pubertal spurt. It seems that puberty, regardless of rational arrangement of the training, brings imbalance in the formation of the dynamic functional system.

Another period of inertia, from the point of expanding the search for the formation of new functional correlations in the conditions of the formation of more complex motor skills that are formed in this age range, can be considered the age of 17 years. During this period, there is a small number (347) of total correlations with a smaller number of “strong” correlations. It is notable that at the age of 17, AEC amounts to 0.32 c.u., which can be described as the satisfactory adaptation level without strain of adaptation mechanisms. Based on the above, we can assume that the age of 17 is not a stagnation period due to low efficiency of the training process in examined selections of soccer players and a necessity to expand and complicate motor skills and abilities. Possibly, irrationally lowered or forced loads in terms of magnitude and degree of complexity take place in the training process. It is suggested that the training program needs corrections at this stage, since that would contribute to the transition of the body's systems to a higher level of function.

Conclusion. Taking the results obtained into account, we can conclude that the dynamic functional system of a soccer player is formed under the influence of a wide variety of factors related to conditions of training and competitive activity. The AEC indicators reliably evidence changes in composition and quality of correlations that make the structure of the dynamic functional system, formed in constantly changing conditions of training and competitive loads of soccer players at stages of the multi-year sports training. According to the obtained values of the AEC (c.u.), we can also conclude that each age period has its own features of the body function, causing inclusion of adaptation responses of certain indicators that support homeostasis, into the group. In general, it can be noted that in the age range from 12 to 16 years, adaptive changes occur that correspond to the established general patterns of the body development, indicating a rationally constructed training process that does not make a certain imbalance in the body formation. In 13-year-old soccer players, the AEC reaches the highest values, which indicates a pronounced strain on adaptive systems. The age range from 17 to 18 years proceeds without the necessary stress of adaptation processes, which implies the stabilization of sports results, as well slowed down growth of athletic skills of soccer players due to insufficiently effective exercise stimuli.

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FUNCTIONAL ASYMMETRIES OF EMG ACTIVITY AND DYNAMIC CHARACTERISTICS IN ELITE WEIGHTLIFTERS WHEN PERFORMING A COMPETITIVE CLEAN AND JERK EXERCISE

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Annotation. The relevant issue of biomechanics and physiology of sports, as well as sports medicine, in the aspect of injury prevention, is to identify the asymmetry of sports movements. The aim of the study was to identify functional motor asymmetries manifested in the power and electromyography parameters of the leading muscles during the clean and jerk exercise in elite male and female weightlifters. In the study, using the developed method of biomechanical and electromyographic evaluation of the clean and jerk, the functional asymmetries of electromyographic activity and dynamic characteristics in elite weightlifters during the performance of the exercise were determined. Functional asymmetries of the vertical component of the effort of the right/left foot on the support were small with a predominance of right-sided asymmetry in both men and women. Men differed from women in large values of the average electromyographic amplitude of all the studied muscles, which indicates a greater strength. The laterality and magnitude of the asymmetry of the average electromyographic amplitude of the muscles during the performance of a clean and jerk also has gender characteristics. A large asymmetry is manifested in the squat and recovery phases, i.e. into phases characterized by greater dynamics of movement of the body of the athlete and the projectile. A large right-sided asymmetry of electromyographic activity indicates dominance of the body's right side in elite weightlifters. Overall, we can conclude that elite weightlifters perform the movement quite symmetrically and coordinately, which indicates a good balance and coordination of movements.

Keywords: functional asymmetries, motor asymmetries, biomechanics, electromyography, weightlifting exercises, clean and jerk.

Introduction. Research of the functional sensorimotor asymmetry are relevant from the point of determining effective strategies of adaptation and success prediction in sports [1]. In order to reveal features of biomechanics and physiology of the neuromuscular system, as well as to prevent injuries in sports, researchers apply identification of motor asymmetry during sports movements [2-3].

Currently, there are studies dedicated to manifestations of motor symmetry-asymmetry when separate and sports movements are being performed. Researchers have already studied to the fullest extent biomechanics and asymmetry of leg movements during walking [4].

Scientists from the Lesgaft National State University of Physical Culture, when researching asymmetry of the biomechanical structure of weightlifters' movements when performing the clean and jerk in the scissor or half-squat position, have found that asymmetry is typical for parameters of kinematic movements in the elbow, hip, knee and ankle joints, as well as for vertical components of the support reaction power. The revealed asymmetry is significantly manifested in case of performing the clean and jerk in the scissor position, it decreases when performing the exercise in the half-squat position. Manifestations of asymmetry decrease as the external resistance and sports qualification of weightlifters grow [5].

Our published study of functional asymmetries of the EMG activity and dynamic characteristics in elite weightlifters during performance of the competitive snatch shows a reliably symmetrical performance and work of the neuromuscular system, which serves as an evidence for a good technical fitness of examined elite weightlifters, as well as appropriate muscle balance. Both in men and in women, the study results revealed small right-sided functional asymmetries of vertical components of the support reaction power. We have also discovered an insignificant asymmetry of the average amplitude of muscle EMG: left-sided asymmetry for the trapezius muscle and right-sided asymmetry for the leg muscles (vastus lateralis, biceps femoris and gastrocnemius muscles). The greatest asymmetry manifestations were identified in the snatch phase. It is possibly related to a partially unsupported position of the body. According to EMG activity, dominating position of the right leg was revealed in weightlifters [2].

The weightlifting clean and jerk, performed in the scissors position, is a more asymmetrical exercise than the snatch. Thus, a study of functional asymmetries of power and EMG parameters that manifest in elite male and female weightlifters when performing the competitive clean and jerk is relevant.

The purpose of this study was to identify functional motor asymmetries, manifested in power and EMG parameters of leading muscles during performance the competitive clean and jerk by elite male and female weightlifters.

Methods and organization. The study was carried out in the Center for biomedical technologies of the FSBI NCFRCC FMBA of Russia in Kislovodsk on the Maloe Sedlo mountain, at an altitude of 1240 m, in conditions of training camps in the Federal State Unitary Enterprise "Yug Sport". The study involved 45 male and female weightlifters with the Master of Sports qualification, members of the Russian national team in weightlifting.

We conducted biomechanical and EMG analysis of the weightlifting exercise with identification of power, kinematic and EMG parameters and following calculation of asymmetry calculations. The study was carried out on the BTS Motion System (BTS Bioengineering, Italy), including SMART-DX – the optoelectronic system with three infrared cameras and two video cameras, two sensor floor-standing tensodynamometric platforms sized 60×40 cm. In order to analyze the technique of the weightlifting exercise, we have developed a special method and acquired a patent for an invention: "Technique of biomechanical and electromyographic express-evaluation of weightlifting exercises" № 2756567 C1 from 10/01/2021 [6]. To analyze the technique, we applied the phase structure of the clean and jerk developed by L.S. Dvorkin [8].

The coefficients of functional asymmetry of mean values in vertical components of the support reaction power, average EMG amplitude of the trapezius, vastus lateralis, biceps femoris (long head – middle part) and gastrocnemius (lateral head – middle part) muscles were calculated according to the following formula:

$$Cas = \frac{N_r - N_l}{N_r + N_l} \times 100\% ,$$

where N_r – indicator for the right side of the body, N_l – indicator for the left side of the body.

The statistical data processing was made with the Statistica 13.0 software. It's main purpose was to compare indicators of groups divided by gender with the non-parametric Mann-Whitney U-test.

Results and discussion. The weightlifting clean and jerk is a complex coordination, speed-power exercise, in which an athlete lifts great weights in a short period of time. Unlike the snatch, the clean and jerk consists of two exercises: the hang squat clean (first four phases that match those in the snatch) and the jerk.

Results of studying the power dynamic indicator, i.e. the vertical component of the force applied with two legs on the support in the boundary moment between movement phases revealed that men significantly exceed women in all phases (table 1).

Comparison of functional asymmetry coefficients of the vertical components of the force made on the support with the right/left leg when performing the exercise revealed that women have a significantly greater asymmetry in the Snatch 2.2 phase. During all phases, both in men and in women, a very insignificant right-sided asymmetry prevails, expect during the Squat 3.1 phase in women. The greatest signs of asymmetry were revealed in both groups during the Squat 3.1 phase and during the Jerk 7 and Recovery after the jerk 8 phases in women only. Overall, we can conclude about a symmetrical and coordinately precise performance of the movement by elite weightlifters, which shows good balance and movement coordination.

Table 1

Mean values of the vertical component of the force applied with two legs on the support in male and female weightlifters, M±σ, kg

№	Phases	Men	Women	p<
1	Pull 1.1	233.1±47.26	168.0±34.47	0.0002
2	Pull 1.2	186.4±47.30	125.1±26.05	0.0001
3	Snatch 2.1	256.4±58.45	206.7±35.65	0.01
4	Snatch 2.2	42.54±58.50	27.58±22.19	-
5	Squat 3.1	177.2±36.63	131.8±51.67	0.006
6	Squat 3.2	293.4±54.75	235.4±52.31	0.004
7	Recovery 4	140.2±43.15	107.5±29.89	0.03
8	Clean 6.1	330.0±66.34	259.9±50.58	0.004
9	Clean 6.2	65.92±94.84	30.02±28.32	-
10	Jerk 7	132.5±52.84	93.13±41.29	0.03
11	Recovery after the jerk 8	171.6±47.18	101.6±43.68	0.00004

Note: p – according to the Mann-Whitney U-test

Table 2

Functional asymmetry coefficients of the vertical components of the force made on the support with the right/left leg when performing the weightlifting clean and jerk by male and female weightlifters, M±σ, %

№	Phases	Men	Women	p<
1	Pull 1.1	2.55±5.04	1.02±4.56	-
2	Pull 1.2	1.17±4.58	2.80±3.17	-
3	Snatch 2.1	-2.06±7.35	5.02±10.65	-
4	Snatch 2.2	0.60±8.10	5.31±9.76	0.04
5	Squat 3.1	8.32±19.45	-9.49±26.47	-
6	Squat 3.2	2.08±6.10	1.84±5.83	-
7	Recovery 4	1.07±4.97	1.63±3.95	-
8	Clean 6.1	1.83±5.00	0.69±5.13	-
9	Clean 6.2	-0.54±5.25	3.89±5.61	-
10	Jerk 7	5.91±84.45	11.69±93.14	-
11	Recovery after the jerk 8	4.70±86.69	10.89±94.77	-

Note: p – according to the Mann-Whitney U-test

EMG recording and simultaneous registration of movement’s biomechanical parameters during the exercise allowed us to obtain characteristics of electric activity of examined muscles. We have found that average amplitude of the right trapezius muscle in male weightlifters was higher during the Pull 1.2 and Squat 3.1 phases compared to women. Indicators of the left trapezius muscle were not significantly different (table 3).

Comparison of the average EMG amplitude of the vastus lateralis muscle revealed greater values of EMG amplitude in men on the right during the Squat 3.1 phase and on the left during the 2.2 phase (table 4).

Table 3

Average EMG amplitude of the trapezius muscle in male and female weightlifters performing the clean and jerk, M±σ, mV

№	Phases	Right			Left	
		Men	Women	p<	Men	Women
1	Pull 1.1	0.16±0.11	0.10±0.06	-	0.15±0.11	0.13±0.07
2	Pull 1.2	0.48±0.21	0.34±0.16	0.03	0.46±0.19	0.38±0.17
3	Snatch 2.1	0.45±0.15	0.36±0.16	-	0.51±0.26	0.38±0.12
4	Snatch 2.2	0.47±0.19	0.40±0.17	-	0.45±0.22	0.41±0.18
5	Squat 3.1	0.31±0.13	0.21±0.09	0.03	0.30±0.11	0.23±0.12
6	Squat 3.2	0.51±0.19	0.54±0.22	-	0.57±0.26	0.55±0.21
7	Recovery 4	0.42±0.21	0.39±0.21	-	0.51±0.29	0.40±0.21
8	Clean 6.1	0.37±0.21	0.32±0.16	-	0.40±0.25	0.33±0.19
9	Clean 6.2	0.55±0.29	0.51±0.25	-	0.59±0.31	0.47±0.23
10	Jerk 7	0.68±0.27	0.64±0.21	-	0.71±0.31	0.65±0.21
11	Recovery after the jerk 8	0.64±0.33	0.66±0.30	-	0.61±0.35	0.67±0.38

Note: p – according to the Mann-Whitney U-test, indicators of the left trapezius muscle were not significantly different

Table 4

Average EMG amplitude of the vastus lateralis muscle in male and female weightlifters performing the clean and jerk, M±σ, mV

№	Phases	Right			Left		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	0.17±0.12	0.17±0.09	-	0.14±0.07	0.16±0,09	-
2	Pull 1.2	0.26±0.16	0.29±0.18	-	0.23±0.10	0.25±0.12	-
3	Snatch 2.1	0.34±0.18	0.34±0.13	-	0.33±0.15	0.30±0.18	-
4	Snatch 2.2	0.35±0.22	0.24±0.13	-	0.32±0.13	0.22±0.14	0.02
5	Squat 3.1	0.23±0.10	0.16±0.07	0.03	0.22±0.11	0.17±0.08	-
6	Squat 3.2	0.30±0.18	0.31±0.14	-	0.26±0.10	0.31±0.14	-
7	Recovery 4	0.38±0.25	0.33±0.15	-	0.29±0.17	0.30±0.19	-
8	Clean 6.1	0.23±0.15	0.22±0.10	-	0.20±0.09	0.22±0.16	-
9	Clean 6.2	0.39±0.28	0.27±0.14	-	0.35±0.15	0.28±0.14	-
10	Jerk 7	0.35±0.21	0.24±0.09	-	0.25±0.15	0.20±0.10	-
11	Recovery after the jerk 8	0.18±0.11	0.15±0.10	-	0.14±0.08	0.12±0.10	-

Note: p – according to the Mann-Whitney U-test

Functional asymmetry coefficients of the average EMG amplitude of the trapezius and vastus lateralis muscles in male and female weightlifters were not significantly different (table 5). Recording of the average EMG amplitude of the trapezius muscle revealed small right- and left-sided asymmetries (within 11%), both in men and in women. Recording of the average EMG amplitude of the vastus lateralis also revealed small right- and left-sided asymmetries. Right-sided asymmetries had greater values during the Recovery 4, Jerk 7 and Recovery after the jerk 8, i.e. phases that are characterized by greater dynamics of body and barbell movements. During these phases, the vastus lateralis muscle serves the role of the active crus extensor in the knee joint, which plays a significant role in the effectiveness of the whole exercise. The great right-sided asymmetry of EMG activity indicates the right-leg dominance in weightlifters.

The average EMG amplitude of the right biceps femoris muscle in men was higher during the Recovery 4 phase, left biceps femoris muscle – during Pull, Snatch, Squat and Recovery phases. In whole, man had higher values of average EMG amplitude in the biceps femoris muscle compared to women (table 6). During movement phases of the clean and jerk, the biceps femoris muscle serves the role of the thigh extensor and crus flexor, great average EMG value indicates greater developing effort and an ability to lift greater weights in male weightlifters compared to female ones.

Table 5

Functional asymmetry coefficients of the average EMG amplitude of muscles in male and female weightlifters, M±σ, %

№	Phase	Trapezius muscles		Vastus lateralis	
		Men	Women	Men	Women
1	Pull 1.1	-0.9±24.5	-8.1±27.3	5.6±30.8	2.5±29.3
2	Pull 1.2	1.6±26.2	-4.0±27.9	3.1±30.1	3.6±31.2
3	Snatch 2.1	-0.6±25.3	-3.4±14.1	1.3±29.6	8.0±24.6
4	Snatch 2.2	5.1±16.8	-0.3±21.8	-1.4±28.5	5.7±30.4
5	Squat 3.1	1.0±15.0	-2.9±23.7	3.7±29.7	-2.1±19.0
6	Squat 3.2	-4.3±16.6	-1.7±19.1	4.0±27.5	0.4±19.8
7	Recovery 4	-11.6±23.5	-1.5±20.0	9.9±30.7	6.2±27.2
8	Clean 6.1	-2.6±26.4	3.3±25.6	1.3±32.3	5.6±29.8
9	Clean 6.2	-2.9±17.4	7.0±29.4	-1.5±31.7	-2.7±23.8
10	Jerk 7	-1.8±14.4	-0.7±10.0	13.3±37.7	12.4±30.1
11	Recovery after the jerk 8	6.1±29.0	5.0±37.3	11.3±38.0	14.8±35.2

Table 6

Average EMG value of the biceps femoris muscle in male and female weightlifters, M±σ, mV

№	Phases	Right			Left		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	0.12±0.08	0.08±0.03	-	0.10±0.09	0.08±0.02	-
2	Pull 1.2	0.32±0.12	0.23±0.08	-	0.30±0.10	0.19±0.06	0.006
3	Snatch 2.1	0.46±0.25	0.34±0.12	-	0.39±0.14	0.29±0.14	0.02
4	Snatch 2.2	0.33±0.18	0.22±0.10	-	0.29±0.16	0.16±0.10	0.01
5	Squat 3.1	0.24±0.15	0.16±0.10	-	0.21±0.11	0.14±0.05	0.04
6	Squat 3.2	0.31±0.24	0.22±0.11	-	0.29±0.25	0.21±0.09	-
7	Recovery 4	0.29±0.13	0.18±0.08	0.04	0.23±0.10	0.16±0.07	0.04
8	Clean 6.1	0.18±0.14	0.12±0.05	-	0.13±0.09	0.12±0.06	-
9	Clean 6.2	0.37±0.19	0.26±0.13	-	0.29±0.11	0.23±0.10	-
10	Jerk 7	0.32±0.17	0.22±0.08	-	0.18±0.13	0.15±0.09	-
11	Recovery after the jerk 8	0.17±0.11	0.13±0.08	-	0.10±0.08	0.08±0.07	-

Note: p – according to the Mann-Whitney U-test

Average EMG amplitude of the gastrocnemius muscle is significantly higher in men on the right during the Pull 1.1, Pull 1.2, Snatch 2.2, Squat 3.1, Jerk 7 phases, on the left – during the Snatch 2.2 phase (table 7). The gastrocnemius muscle in the analyzed movement serves as a pelmatic sole flexor in the ankle joint, as well a sole stabilizer. High average EMG amplitude of the gastrocnemius muscle in men indicates a developing effort in sole extension, especially during Pull and Snatch phases.

Functional asymmetry coefficients of the average EMG amplitude of the biceps femoris were only right-sided during all phases of the clean and jerk, both in men and in women (table 8). The greatest asymmetries for the biceps femoris were revealed in women during the Snatch 2.2 phase and in men during the Jerk 7 and Recovery after the jerk 8 phases. Great right-sided asymmetries during the final phase may indicate an enhancement of the leading right leg domination in case of fatigue.

Table 7

Average EMG value of the quadriceps femoris muscle in male and female weightlifters, M±σ, mV

№	Phases	Right			Left		
		Men	Women	p<	Women	Men	p<
1	Pull 1.1	0.09±0.08	0.03±0.02	0.005	0.08±0.08	0.05±0.03	-
2	Pull 1.2	0.17±0.07	0.10±0.05	0.02	0.17±0.10	0.13±0.06	-
3	Snatch 2.1	0.39±0.22	0.27±0.10	-	0.32±0.22	0.33±0.09	-
4	Snatch 2.2	0.24±0.15	0.12±0.06	0.05	0.25±0.18	0.12±0.04	0.03
5	Squat 3.1	0.15±0.13	0.07±0.06	0.009	0.10±0.09	0.05±0.03	-
6	Squat 3.2	0.21±0.14	0.15±0.08	-	0.18±0.11	0.20±0.09	-
7	Recovery 4	0.13±0.09	0.09±0.04	-	0.12±0.09	0.12±0.08	-
8	Clean 6.1	0.14±0.09	0.10±0.05	-	0.13±0.11	0.13±0.06	-
9	Clean 6.2	0.33±0.18	0.23±0.05	-	0.30±0.16	0.23±0.07	-
10	Jerk 7	0.23±0.15	0.12±0.05	0.01	0.15±0.07	0.16±0.06	-
11	Recovery after the jerk 8	0.14±0.09	0.11±0.06	-	0.14±0.07	0.15±0.07	-

Note: p – according to the Mann-Whitney U-test

Table 8

Functional asymmetry coefficients of the average EMG amplitude of muscles in male and female weightlifters, M±σ, %

№	Phases	Biceps femoris muscle			Gastrocnemius muscle		
		Men	Women	p<	Men	Women	p<
1	Pull 1.1	6.4±26.6	3.1±11.4	-	14.4±29.9	-24.1±21.8	0.002
2	Pull 1.2	3.8±13.2	9.0±8.2	-	4.9±28.0	-13.5±15.5	0.03
3	Snatch 2.1	5.2±18.0	8.3±11.5	-	12.0±25.4	-8.7±20.7	0.02
4	Snatch 2.2	4.3±26.8	16.0±28.2	-	4.2±28.1	1.2±19.2	-
5	Squat 3.1	2.4±22.1	2.9±31.0	-	15.2±32.3	13.4±17.0	-
6	Squat 3.2	4.2±22.7	1.0±21.7	-	5.7±40.4	-14.5±20.0	-
7	Recovery 4	11.8±24.2	4.8±13.5	-	4.4±35.5	-14.8±17.9	0.03
8	Clean 6.1	13.6±31.9	2.5±25.3	-	9.5±29.8	-11.0±22.7	-
9	Clean 6.2	7.5±29.3	3.8±15.2	-	6.0±31.9	-0.3±11.3	-
10	Jerk 7	29.1±40.8	19.6±36.4	-	18.6±28.6	-14.0±23.2	0.007
11	Recovery after the jerk 8	26.2±37.9	24.3±53.0	-	0.3±35.7	-14.3±27.8	-

Note: p – according to the Mann-Whitney U-test

Right-sided asymmetries of the gastrocnemius muscle were revealed in men. On the contrary, left-sided asymmetries prevailed in women. In terms of the asymmetry's scope and laterality, women were different from men in the Snatch 2.1, Recovery 4 and Jerk 7 phases.

The greatest asymmetry were identified during the Pull, Squat and Recovery phases. When analyzing the asymmetry of the examined muscles, we can conclude that it has higher values in the biceps femoris and the gastrocnemius muscle. Apparently, the closer the muscles are to the core, the less pronounced their asymmetry is.

Conclusion. Therefore, we managed to identify functional asymmetries of the EMG activity and dynamic characteristics in elite weightlifters when performing the competitive clean and jerk using the developed method of biomechanical and electromyographic evaluation of the exercise.

Functional asymmetries of the vertical components of the force made on the support with the right/left leg were small with the predominance of the right-sided asymmetry in both men and women.

Men were different from women by higher values of the average EMG amplitude of all examined muscles, which serves as an evidence of greater pronounced power. Laterality and scope of the asymmetry of the average EMG amplitude of muscles also have gender-based features. Greater asymmetry is manifested during Squat and Recovery phases, i.e. phases, characterized by greater dynamics of body and barbell movement. Great right-sided asymmetry of EMG activity indicates dominance of the right side of the body in weightlifters.

Overall, we can conclude that elite weightlifters perform the movement quite symmetrically and coordinately, which indicates a good balance and coordination of movements.

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HILDEBRANDT INDEX IN SKIERS AND TAEKWONDO ATHLETES AT REST AND UNDER STANDARD BICYCLE ERGOMETRIC LOADS

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Annotation. This study included examination of 15 skiers, developing endurance, and 17 taekwondo athletes, developing speed strength, under laboratory conditions. By using the Oxycon Pro system, we registered indicators of blood parameters and respiration in athletes. Skiers revealed higher values of lung capacity and vital index, Skibinskaya index, maximum oxygen consumption, but lower values of heart rate, double product, and Hildebrandt index at rest and under loads. Taekwondo athletes differ from skiers by an increased body mass index and higher strength indicators (strength and power index), increased "pulse and pressor cost" of physical loads.

Keywords: skiers, taekwondo athletes, bicycle ergometric loads, blood circulation, respiration, Hildebrandt index.

Introduction. Cardio-respiratory synchronization and its indicator, called the Hildebrandt index (HI), are used in human physiology and medicine for a long time [1-4]. Some authors noted changes in HI in case of increasing physical activity. However, there was no comparison between athletes of different sports. It is widely known that engaging in different sports has effects on morphofunctional and physiological indicators of a human. The literature sources have data on specific features of athletes' body in different sports [5-9]. Data on comparison of physiological features of those, who develop endurance and speed strength, are scarce [10-11]. That is the reason why it is interesting to compare the functional state of skiers, developing endurance, and taekwondo athletes, developing speed strength, on a united methodological basis, including the comparison of HI values.

The purpose of the study is to compare morphofunctional and physiological data and indicators of blood circulation and respiration, as well as HI, in skiers and taekwondo athletes at rest and under physical loads.

Methods and organization. We examined 15 male skiers and 17 male taekwondo athletes, who live in the Komi Republic, in comfortable laboratory conditions during warm time of the year. Both selections included rated athletes (about 30%), candidates to master of sports (about 30%) and master of sports (about 30%) in almost equal ratio. All of them gave consent to participate. The Bioethics Local Committee in the Komi Institute of Physiology approved the studies.

We registered morphofunctional and physiometric indicators using common methods. The lung capacity (LC) was registered with a dry spirometer. The heart rate (HR) and blood pressure (systolic – sBP and diastolic – dBP) – with a UA-767 device (A&D Company Ltd., Japan). We also calculated the body mass index (BMI), power index (strength/body mass – PI), vital index (LC/body mass – VI), double product (DP) according to Robinson, the Kerdo index (KI) and the Sibirskaya cardio-respiratory index (SI).

Athletes were tested on a bicycle ergometer with registration of cardio-respiratory indicators (HR, sBP, dBP, respiration rate – RR, respiratory volume – RV, respiratory minute volume – RMV, oxygen consumption – OC, degree of blood oxygen saturation – SO_2, oxygen pulse – OP) with the Oxycon Pro system (Germany) and calculation of DP, the oxygen utilization coefficient – OUC and the Hildebrandt index – HI, obtained through dividing HR by RR. After the five-minute sitting on a bicycle ergometer at rest, we gave standard loads with a capacity of 50 W, 100 W and 150 W, 5 minute each. The maximum oxygen consumption (MOC) or aerobic threshold was calculated with the Astrand nomogram, taking into account values of HR and oxygen consumption after loads with a capacity of 150 W.

The data obtained was statistically processed with Statistics 6.0 and Biostat 4.03 software with checking on variational series for distribution type (according to the Shapiro-Wilk criteria). We applied mean arithmetic values with their errors (M±m) for indicators with normal (or close to normal) distribution. The differences were considered as statistically significant if $p<0.05$.

Results and discussion. Data from table 1 show that the compared selections of athletes are identical in age. However, skiers have a slightly greater height and lower body mass, which is why the body mass index is much lower than in taekwondo athletes. Taekwondo athletes have higher strength indicators (arm strength and power index), the difference is statistically significant. Hypoxemia resistance (data from tests on holding breathing) is almost equal in both selections.

Values of LV and VI are significantly higher in skiers than in taekwondo athletes. According to the sBP level, both groups are almost the same. However, other indicators of central hemodynamics show that these groups have substantial differences. Skiers have lower dBP, HR, DP and KI and higher Skibinskaya index.

Table 1

Comparison of morphological, physiometric and physiological indicators in athletes (M±m)

Indicators	Standard	Skiers, n=15	Taekwondo athletes, n=17	Difference level, p
Age, years		21.8±0.76	22.4±0.80	S.In
Height, cm		177.3±0.89	175.2±0.94	S.In
Body mass, kg		71.8±1.38	73.3±1.25	S.In.
BMI, kg/m²	20-25	22.8±0.33	24.1±0.37	<0.05
Right wrist strength, kg		48.8±1.17	53.5±0.92	<0.001
Left wrist strength, kg		45.7±0.99	49.8±0.89	<0.001
Power index, %	≥66	68.1±1.34	73.4±1.79	<0.01
Test of breath holding on inhale, s	≥50	77.0±3.84	79.2±2.92	S.In.
Test of breath holding on exhale, s	≥30	43.4±2.70	41.8±2.22	S.In.
LC, ml		4998±105	4580±101	<0.001
VI, ml/kg	≥56	69.9±1.34	62.5±1.49	<0.001
sBP, mm Hg	100-140	126±1.79	128±1.69	S.In.
dBP, mm Hg	60-90	69±1.60	72±1.25	<0.05
HR, beats/min	55-75	55±1.66	64±1.92	<0.001
DP, c.u.	<94	68±2.50	79±1.06	<0.001
KI, %	(-10)-(+10)	-27.8±3.94	-17.5±4.47	<0.05
SI, points	>31	72±4.60	60±4.21	<0.05

Note: here and in the next table, “S.In.” means “statistically insignificant differences”

When working with the bicycle ergometer (table 2), skiers, in comparison with taekwondo athletes, have significantly lower HR, DP, HI, RV, RMV and OP, but higher SO_2. Values of OC and OUC are almost equal in both groups. The situation is changing in case of applying

100 W and 150 W loads. Even though both groups have almost equal OP, HR in skiers is lower, while values of SO_2, OC and OUC is higher, than those in taekwondo athletes. Central hemodynamics indicators (sBP, dBP) at rest and under mild loads (50 and 1000 W) are approximately the same in both selections. However, higher level of loads (150 W) reveals difference in sBP reactions. Values of HR, DP and HI in skiers are significantly lower on each stage of the experiments. Aerobic capability indicators are also different. MOC values are higher in skiers.

Table 2

Comparison of load test indicators in athletes (M±m)

Indicators and loads	Skiers, n=15	Taekwondo athletes, n=17	Difference levels, p
HR, beats/min: at rest	50±1.38	75±1.13	<0.001
50 W	84±2.00	97±2.59	<0.01
100 W	99±2.19	119±2.84	<0.001
150 W	115±2.52	140±2.96	<0.001
sBP, mm Hg: at rest	109±1.95	108±1.88	S.In.
50 W	117±1.80	118±2.19	S.In.
100 W	129±2.02	133±2.95	S.In.
150 W	143±2.48	155±3.17	<0.01
dBP, mm Hg: at rest	73±1.53	72±1.64	S.In.
50 W	71±1.84	72±1.92	S.In.
100 W	69±1.35	72±2.29	S.In.
150 W	70±2.19	73±2.65	S.In.
DP, c.u.: at rest	55±1.88	80±1.97	<0.001
50 W	95±3.07	115±4.56	<0.01
100 W	126±3.43	156±5.88	<0.001
150 W	162±4.46	218±6.53	<0.001
RR, cycle/min: at rest	17.0±0.64	17.1±0.61	S.In.
50 W	18.8±0.68	18.3±0.62	S.In.
100 W	21.3±0.54	21.4±0.87	S.In.
150 W	24.6±0.74	24.8±0.95	S.In.
HI=HR/RR, beat/cycle:			
at rest	2.92±0.07	4.38±0.07	<0.001
50 W	4.39±0.08	5.27±0.08	<0.001
100 W	4.58±0.09	5.54±0.08	<0.001
150 W	4.61±0.08	5.62±0.09	<0.001
RV, ml: at rest	670±29	910±44	<0.001
50 W	1450±44	1470±60	S.In.
100 W	1755±44	1930±63	S.In.
150 W	2030±67	2200±60	S.In.
MRV, l: at rest	11.3±0.41	14.8±0.61	<0.001
50 W	27.1±0.57	25.7±0.55	S.In.
100 W	37.0±0.71	39.7±1.02	S.In.
150 W	59.3±1.21	53.9±1.37	S.In.
OC, ml/min: at rest	390±20	538±28	<0.001
50 W	1208±20	1125±16	<0.05
100 W	1706±19	1690±19	S.In.
150 W	2305±31	2230±35	S.In.

Table 2 (continued)

OUC, ml/l: at rest	34.8±0.97	35.5±0.84	S.In.
50 W	44.6±0.66	43.8±0.64	S.In.
100 W	46.5±0.78	43.0±0.76	<0.01
150 W	46.4±0.77	42.1±0.83	<0.001
OP, ml/beats: at rest	7±0.40	7.4±0.42	S.In.
50 W	14.9±0.39	12.0±0.39	<0.001
100 W	17.9±0.49	14.6±0.36	<0.001
150 W	20.5±0.47	16.1±0.38	<0.001
SO_2, %: at rest	98.5±0.11	98.0±0.15	<0.01
50 W	96.8±0.43	95.1±0.70	<0.05
100 W	97.1±0.48	94.6±0.70	<0.01
150 W	96.9±0.44	93.4±0.88	<0.01
MOC, l/min	5.36±0.15	3.86±0.16	<0.001
ml/min*kg	73.9±1.87	54.5±2.30	<0.001

When analyzing HI dynamics in athletes of different sports, we have found a statistically significant growth of this indicator at rest to the 50 W load (p<0.001). When increasing loads to 100 and 150 W, we registered tendency of increasing HI in taekwondo athletes between loads of 50 W to 100 W (p<0.05) and tendency to load increase from 100 to 150 W. Therefore, less enduring taekwondo athletes have a more pronounced cardio-respiratory synchronization according to HI data.

As we can see from the received data, skiers, who mainly perform aerobic loads and develop endurance, have higher LC, LI and SI that show great capabilities of the cardiorespiratory system, but lower values of HR (bradycardia), HI, dBP that characterize an increased preparedness of the cardiovascular system and body in whole. Lower level of KI in skiers demonstrated a predominant parasympathetic influence of the vegetative nervous system on blood circulation. Scientific data also have evidence on aerobic capability and more sparing work of the cardiovascular system in skiers [12-13].

Taekwondo athletes, who develop speed strength, are different in higher strength indicators, both absolute and specific (per unit of body mass). Scientific data also notes significant strength and high anaerobic capability of taekwondo athletes and other martial artists [5, 14].

As it was revealed from the data of table 2, HR values in skiers, both at rest and under loads, are much lower than in taekwondo athletes. It allows us to note not only the sparing work of the heart, but also lower “pulse cost” of standard physical loads in skiers, who perform aerobic loads and develop endurance. Central hemodynamics indicators (sBP and dBP) at rest and under mild loads (50 и 100 W) in both groups are practically the same. Nonetheless, higher loads (150 W) reveal difference in sBP reactions in the compared groups. The “pressure cost” of these loads in taekwondo athletes is higher. Such indicator as DP that shows mechanical work of the heart is lower in this group both at rest and under physical loads. It is safe to assume that the less trained heart gives “excessive response” to standard physical loads.

Lower values of respiratory functions (RV and RMV) and OC at rest show more sparing work of the skiers’ body. In case of loads, body of skiers and taekwondo athletes requires almost equal levels of RMV and OC. It means that “ventilation” and “oxygen” cost of standard physical loads within the range of 50 to 150 W is not different in both groups.

At rest, as well under all applied loads, skiers have higher blood saturation, which is typical for people, who develop aerobic capability. Higher effectiveness of the cardiorespiratory system in skiers is shown when applying loads. It is demonstrated through higher values of OP (more oxygen is transferred with each systole) and OUC (more oxygen is taken out by blood from each liter of alveolar air). At rest, there are no differences.

MOC values (absolute and specific – per unit of body mass) that characterize aerobic capability or aerobic threshold is higher in skiers. That confirms fitness of their cardiorespiratory system and stayer endurance of the body. Sources also have data on high aerobic capability in skiers [12-13], low aerobic, but high anaerobic capability in taekwondo athletes [5, 14].

The cardio-respiratory synchronization method, suggested by V.M. Pokrovskij et al. [1], can be used as a model that allows evaluating regulatory and adaptive capabilities of the body. Interaction between two main life support systems, i.e. systems of blood circulation and respiration, was always of interest for physiologists and physicians [3].

One of indicators showing synchronization of the heart and respiration in human body is HI, which is informative and is characterized by its simplicity and accessibility. A group of researchers [10] suggested to 10 athletes to perform increasing stage-dosed physical loads on a bicycle ergometer. As physical loads increased, HI increased as well. This indicator is used as an accessible criterion of the body's physiological costs.

According to other data [16], 16 test subjects also had increased HI. It was a sign for stopping intense physical loads and a criterion for rejection diagnosis, in cyclists in particular.

The received HI values in skiers and taekwondo athletes in case of increasing physical loads on a bicycle ergometer correspond with scientific data [2, 4] on assessing physiological costs on similar bicycle ergonomic tests. Nonetheless, we also discovered substantial and statistically significant differences in HI levels among skiers and taekwondo athletes.

High capabilities of skiers' cardiorespiratory system, noted above, allow them to participate in stayer many-kilometer and many-hour ski races. Strength- and speed-based advantages of taekwondo athletes allow them to participate in short-term martial arts, which require increased strength and speed of movements.

Conclusion. As a result, we revealed economization of blood circulation functions both at rest and under standard physical loads, as well as an increased efficiency of the cardiorespiratory system and high aerobic threshold in skiers, who develop endurance. Taekwondo athletes, who develop speed strength, in comparison with skiers, have higher body mass index, increased indicators (arm strength and power index), "pulse" and "pressure" cost of standard physical loads. Research of cardiorespiratory indicators in case of substantial physical loads (150 W and higher) give more information for revealing body features of athletes, who develop various athletic qualities.

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FEATURES OF FUNCTIONAL STATE OF THE NEUROMUSCULAR SYSTEM IN ELITE FEMALE ATHLETES OF DIFFERENT SPORTS

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Annotation. The purpose of this study was to examine and compare parameters of the neuromuscular system's functional state of female athletes with different direction of the training process. The study involved 41 female athletes specialized in weightlifting, track-and-field, triathlon, biathlon, rhythmic gymnastics. We have discovered higher values of the motor response (area, amplitude) in athletes, who train speed, power and endurance (track-and-field, weightlifting, biathlon, triathlon); higher values of nerve conduction velocity along the motor fibers of the peroneal nerve in athletes specialized in the speed-power direction (track-and-field, weightlifting); lower values of residual latency in athletes of complex coordination sports. Therefore, as a result of the conducted research, we revealed features of the neuromuscular system in female athletes engaged in different sports.

Keywords: neuromuscular system, stimulation electroneuromyography, female athletes, sexual dimorphism.

Introduction. Typical features of the neuromuscular system's (NMS) functioning form within the process of the long-term sports training [1-3]. It is known, that physiological processes related to the adaptation of an athlete's NS to regular physical loads contributes to high results in sports [4-6]. Moreover, direction of the training process and the specificity of loads influence the functional state of an athlete's NMS. Currently, the biggest part of conducted studies dedicated to an evaluation of the NMS work was carried out in male athletes [7-8]. This study's relevance is due to not only research of the NMS work parameters in female athletes, but also to the identification of correlations between the training process's direction and motor response indicator when conducting stimulation electroneuromyography.

The purpose of the study was to examine and compare parameters of the neuromuscular system's functional state of female athletes with different direction of the training process.

Methods and organization. The study involved 41 female athletes specialized in weightlifting (7 people), track-and-field (middle-distance sprinters, 13 people), triathlon (6 people), biathlon (6 people), rhythmic gymnastics (9 people). Average age of the athletes is 21.4±4.1 years. It was carried out with the stimulation electroneuromyography method on the 4-channel hardware and software complex Neuro-MVP (Neurosoft, Ivanovo). We registered motor response from the extensor digitorum brevis muscle, innervated by the n. Peroneus. Following parameters of the motor response were analyzed: latency, residual latency, amplitude, surface, motor response duration, nerve conduction velocity (NCV). The data statistical processing was carried out with the Mann-Whitney U-test in the Statistica 13.0 software.

Results and discussion. The latency examination in the "Tarsus" stimulation point on the right revealed a significant difference ($p \leqslant 0.04$) in parameters between track-and-field (3.7±0.5 ms) and triathlon (4.3±0.7 ms) athletes. In other stimulation points, latency values of track-and-field female athletes ("Head of fibula" – 10.8±1.0 ms, $p \leqslant 0.03$; "Popliteal fossa" – 12.4±0.9 ms, $p \leqslant 0.03$) and gymnasts ("Head of fibula" – 11.2±1.0 ms, $p \leqslant 0.008$; "Popliteal fossa" – 13.6±1.5 ms, $p \leqslant 0.01$) (fig. 1).

Latency parameters in the “Tarsus” stimulation point on the left is lower in weightlifters (3.3±0.8 ms) than in track-and-field (3.9±0.3 ms, p⩽0.04), triathlon (4.6±1.1 ms, p⩽0.02), and biathlon athletes (4.8±1.4 ms, p⩽0.01). Moreover, latency values of biathlon athletes (4.8±1.4 ms) were significantly different from parameters in gymnasts (3.6±0.5 ms, p⩽0.01) and track-and-field athletes (3.9±0.3 ms, p⩽0.04). In the “Head of fibula” stimulation point, latency parameters in track-and-field athletes (9.4±1.1 ms) were also lower compared with those in track-and-field (10.7±0.9 ms, p⩽0.03), rhythmic gymnastics (11.2±0.8 ms, p⩽0.02) and biathlon (11.4±2.0 ms, p⩽0.05) athletes. In the “Popliteal fossa” stimulation point, latency values in weightlifters (10.8±1.0 ms) were significantly different from those in track-and-field (12.1±0.7 ms, p⩽0.02), triathlon (12.9±0.8 ms, p⩽0.005), biathlon athletes (13.4±2.2 ms, p⩽0.01) and gymnasts (13.2±1.3 ms, p⩽0.01) (fig. 2).

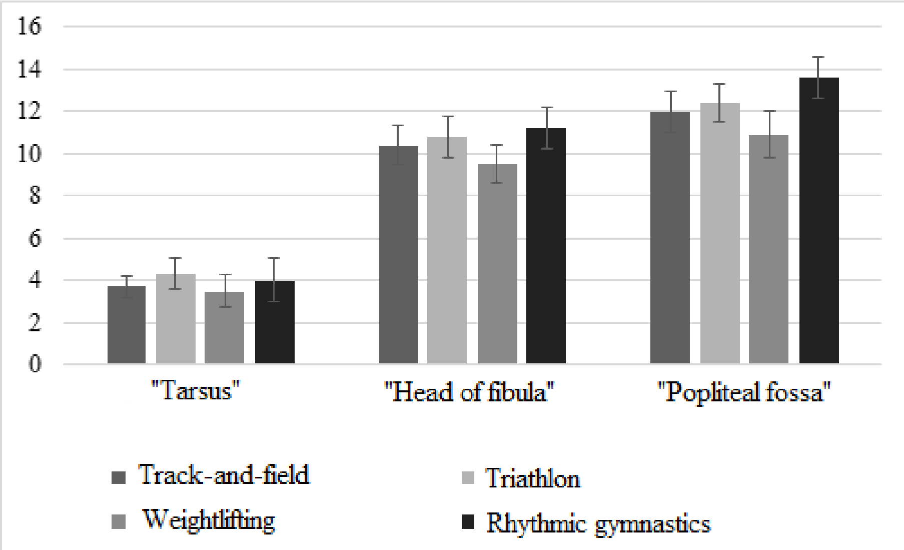

Fig. 1. Motor response latency parameters on the right in female athletes specialized in track-and-field, weightlifting, triathlon, rhythmic gymnastics

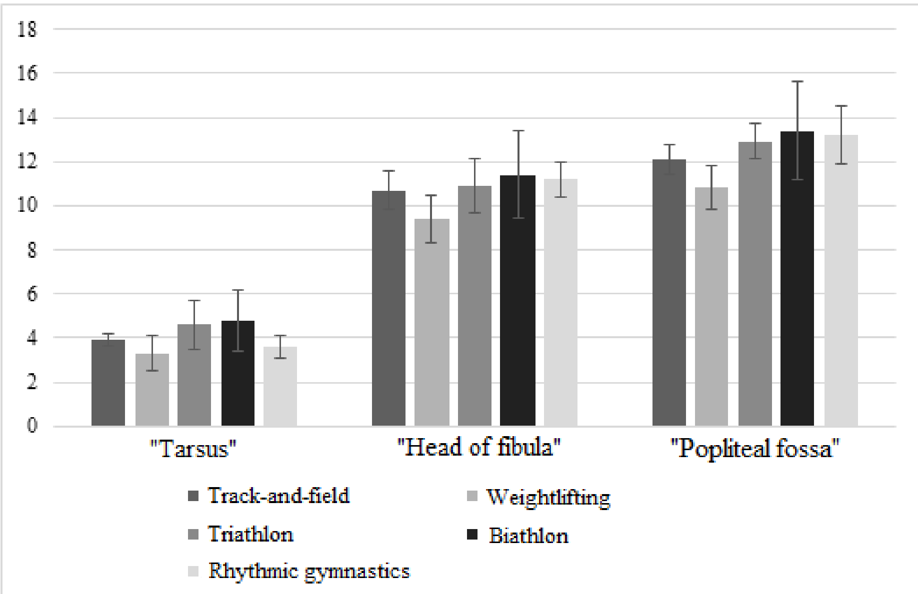

Fig. 2. Motor response latency parameters on the left in female athletes specialized in track-and-field, weightlifting, triathlon, biathlon, rhythmic gymnastic

Parameters of residual latency on the right is significantly different between athletes of track-and-field (2.3±0.4 ms) and triathlon (3.0±0.7 ms, p⩽0.03). We also revealed differences on the left side when comparing the group of triathlon athletes (3.0±0.6 ms) with groups of weightlifters (2.0±0.7 ms, p⩽0.02) and gymnasts (20±0.5 ms, p⩽0.01). Residual latency parameters were also different in track-and-field athletes (2.6±0.4 ms) and gymnasts (2.0±0.5 ms, p⩽0.02) (fig. 3).

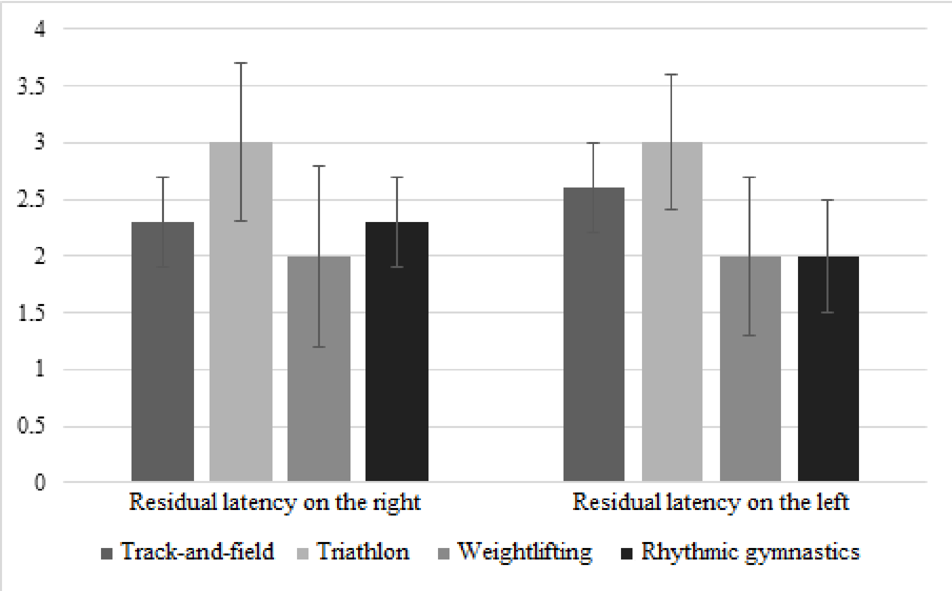

Fig. 3. Residual latency parameters in female athletes specialized in track-and-field, weightlifting, triathlon, rhythmic gymnastics

Analysis of electromyography (EMG) data has demonstrated that values of the motor response amplitude in female athletes specialized in rhythmic gymnastics are lower than in female athletes of other sports. For example, in the "Tarsus" stimulation point on the right the motor response amplitude in gymnasts amounted to 3.8±1.0 mV, in track-and-field athletes – to 6.5±2.6 mV (p⩽0.002), in weightlifters – to 6.2±1.8 mV (p⩽0.02), in biathlon athletes – to 6.4±1.6 mV (p⩽0.003). In the "Head of fibula" stimulation point on the right, amplitude parameters in gymnasts (3.1±1.1 mV) were also lower than those in track-and field athletes (6.7±2.8 mV, p⩽0.003), weightlifters (6.2±2.1 mV, p⩽0.02), triathlon (5.3±1.5 mV, p⩽0.01) and biathlon (5.3±2.6 mV, p⩽0.03) athletes. The same data were received when stimulating the peroneal nerve in the "Poplietal fossa" point on the right. The motor response amplitude in gymnasts (2.7±0.9 mV) were significantly different from the parameters in track-and-field athletes (6.7±2.8 mV, p⩽0.0002), triathlon athletes (5.4±1.9 mV, p⩽0.008), weightlifters (7.3±2.2 mV, p⩽0.003) and biathlon athletes (5.8±1.1 mV, p⩽0.002) (fig. 4).

When stimulating the peroneal nerve in the "Tarsus" point on the left, the motor response amplitude in athletes specialized in track-and-field (6.9±2.0 mV) was higher than in triathlon athletes (4.1±1.4 mV, p⩽0.01) and gymnasts (4.6±1.7 mV, p⩽0.008). In the "Head of fibula" point, amplitude parameters of track-and-field athletes (6.5±2.4 mV) are also higher than in gymnasts (4.1±1.3 mV, p⩽0.03). When stimulating the peroneal nerve in the "Popliteal fossa" point, we discovered that amplitude parameters in gymnasts (3.7±1.4 mV) are significantly different from those in track-and-field (6.7±2.1 mV, p⩽0.001) and triathlon athletes (5.0±0.5 mV, p⩽0.03) (fig. 5).

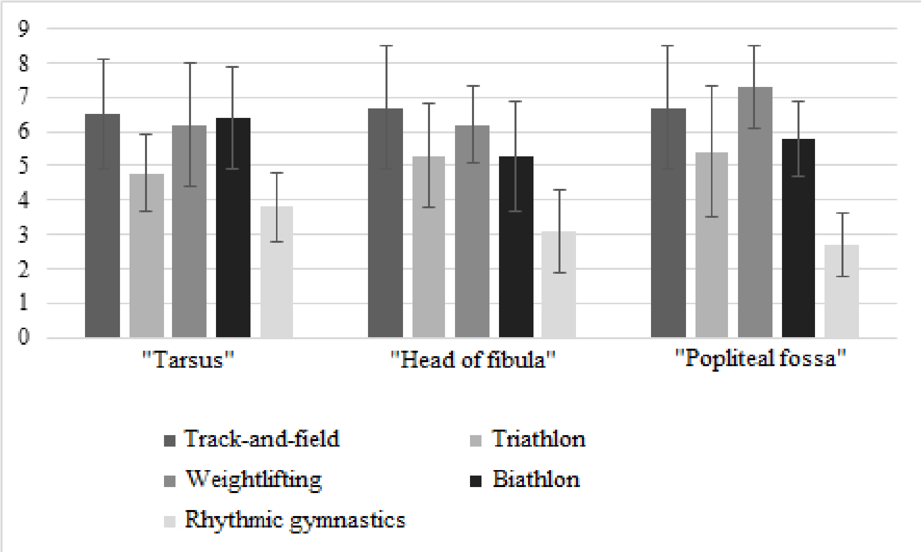

Fig. 4. Motor response amplitude parameters on the right in female athletes specialized in track-and-field, triathlon, weightlifting, biathlon, rhythmic gymnastics

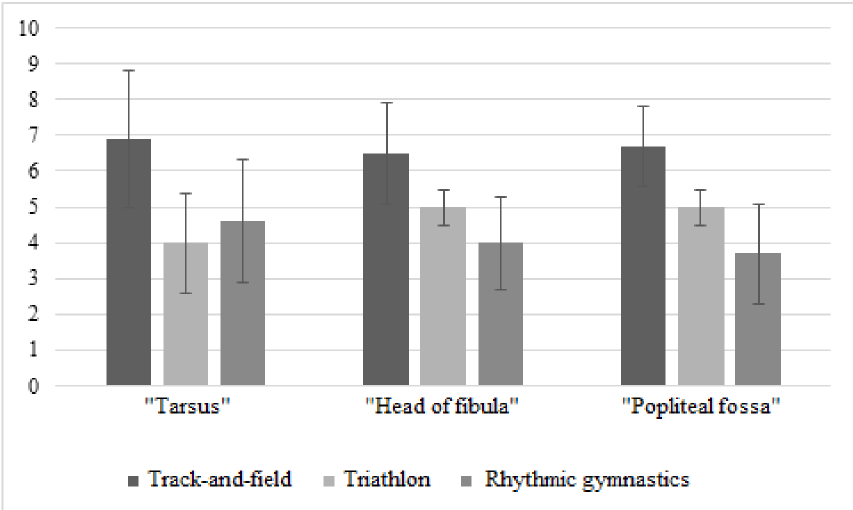

Fig. 5. Motor response amplitude parameters on the left in female athletes specialized in track-and-field, triathlon, rhythmic gymnastics

Motor response duration in gymnasts is higher than in weightlifters in the "Tarsus" point on the right (weightlifters – 5.6±1.0 ms, gymnasts – 6.7±0.8 ms, $p \leqslant 0.03$), the "Head of fibula" point on the right (weightlifters – 6.2±1.0 ms, gymnasts – 7.3±1.1 ms, $p \leqslant 0.02$), and the "Head of fibula point on the left (weightlifters – 6.3±0.8 ms, gymnasts – 7.1±0.7 ms, $p \leqslant 0.007$) (fig. 6).

In the "Tarsus" stimulation point on the right, the motor response area in track-and-field athletes (20.7±7.7 mV×ms) is higher than in gymnasts (14.0±4.1 mV×ms, $p \leqslant 0.03$). We also found significant differences between indicators of triathlon (14.3±6.5 mV×ms) and biathlon athletes (21.3±6.5 mV×ms, $p \leqslant 0.04$). In the "Head of fibula" point on the right, these parameters in track-and-field athletes (22.3±9.1 mV×ms) are higher than in gymnasts (11.8±4.9 mV×ms, $p \leqslant 0.01$). Values of the motor response area in gymnasts (7.1±3.9 mV×ms) are significantly different from the same parameters in track-and-field athletes (22.6±8.7 mV×ms, $p \leqslant 0.0002$), triathlon athletes (17.3±5.1 mV×ms, $p \leqslant 0.005$), weightlifters (21.1±6.7 mV×ms, $p \leqslant 0.003$) and biathlon athletes (19.8±4.8 mV×ms, $p \leqslant 0.003$) (fig. 7).

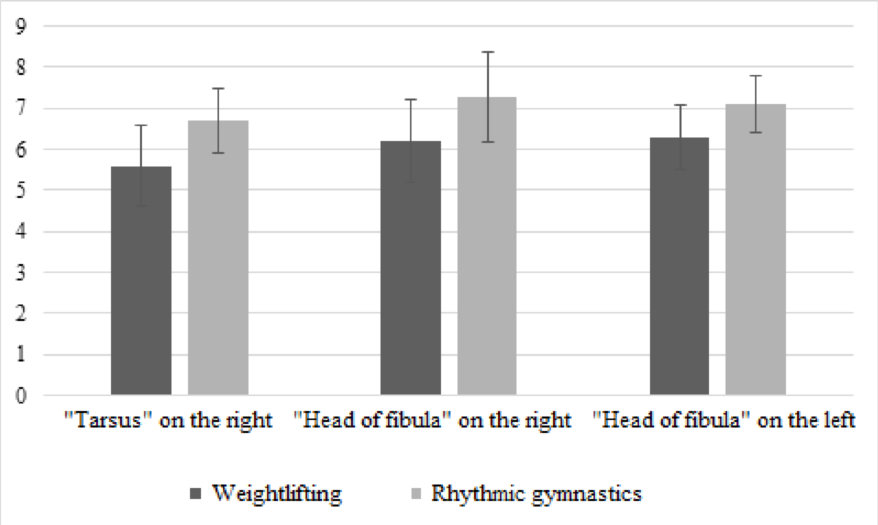

Fig. 6. Motor response duration parameters in female athletes specialized in weightlifting and rhythmic gymnastics

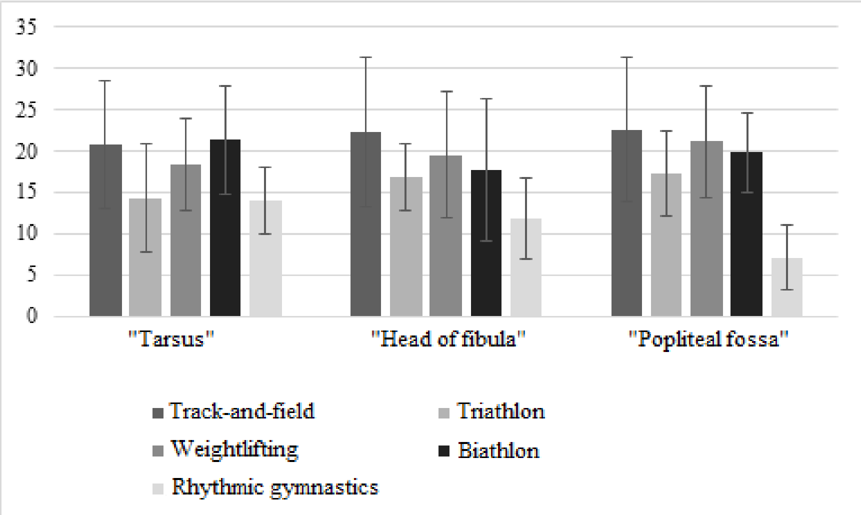

Fig. 7. Parameters of motor response area on the right in female athletes specialized in track-and-field, triathlon, weightlifting, biathlon, rhythmic gymnastics

In the "Tarsus" stimulating point on the left, parameters of motor response area in track-and-field athletes (21.6±6.5 mV×ms) are higher than in triathlon athletes (12.9±5.4 mV×ms, p⩽0.02), weightlifters (16.5±5.6 mV×ms, p⩽0.03) and gymnasts (15.9±4.1 mV×ms, p⩽0.04). In the "Popliteal fossa" point on the left, values of motor response area were also different in female athletes specialized in track-and-field (22.3±7.9 mV×ms) and rhythmic gymnastics (11.7±6.5 mV×ms, p⩽0.006) (fig. 8).

When stimulating the peroneal nerve in the "Head of fibula" point on the right, the nerve conduction velocity is higher in weightlifters (55.8±4.5 m/s) compared to track-and-field athletes (50.1±3.4 m/s, p⩽0.008) and gymnasts (47.6±2.0 m/s, p⩽0.003). We also identified lower values of the nerve conduction velocity in gymnasts (41.6±12.9 m/s) compared to track-and-field athletes (59.4±7.4 m/s, p⩽0.001), weightlifters (62.1±9.0 m/s, p⩽0.001) and biathlon athletes (61,.5±4.2 m/s, p⩽0.002) when stimulating the peroneal nerve on the "Popliteal fossa" point on the right (fig. 9).

The nerve conduction velocity when stimulating the peroneal nerve in the "Head of fibula" point on the left is lower in gymnasts (45.7±2.7 m/s) compared to track-and-field athletes (50.8±3.1 m/s, p⩽0.003), triathlon athletes (53.6±5.8 m/s, p⩽0.01) and weightlifters (53.7±5.2 m/s, p⩽0.01). We identified significantly higher values in the "Popliteal fossa" point in female athletes specialized in weightlifting (66±6.6 m/s) compared to the data from biathlon (47.8±7.6 m/s, p⩽0.003) and triathlon athletes (46.7±6.9 m/s, p⩽0.01). Velocity parameters are also higher in track-and-field athletes than in biathlon (47.8±7.6 m/s, p⩽0.01) and triathlon athletes (46.7±6.9 m/s, p⩽0.008) (fig. 10).

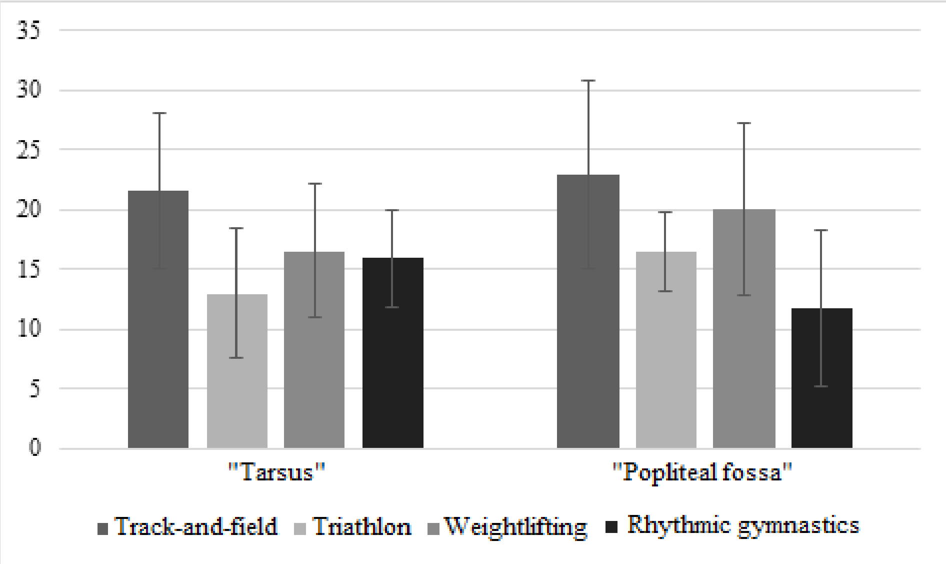

Fig. 8. Motor response area parameters in female athletes specialized in track-and-field, triathlon, weightlifting, rhythmic gymnastics

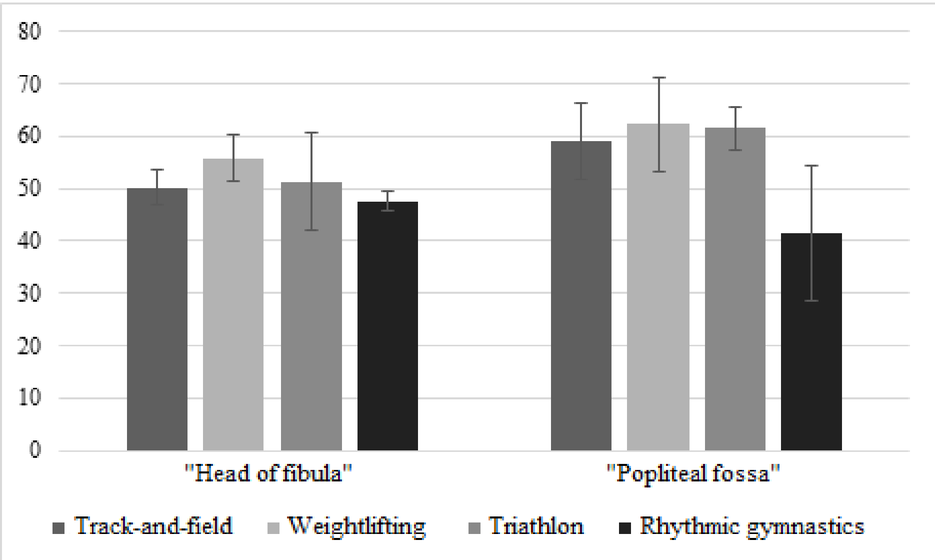

Fig. 9. Nerve conduction velocity parameters on the right in female athletes specialized in track-and-field, weightlifting, biathlon, rhythmic gymnastics

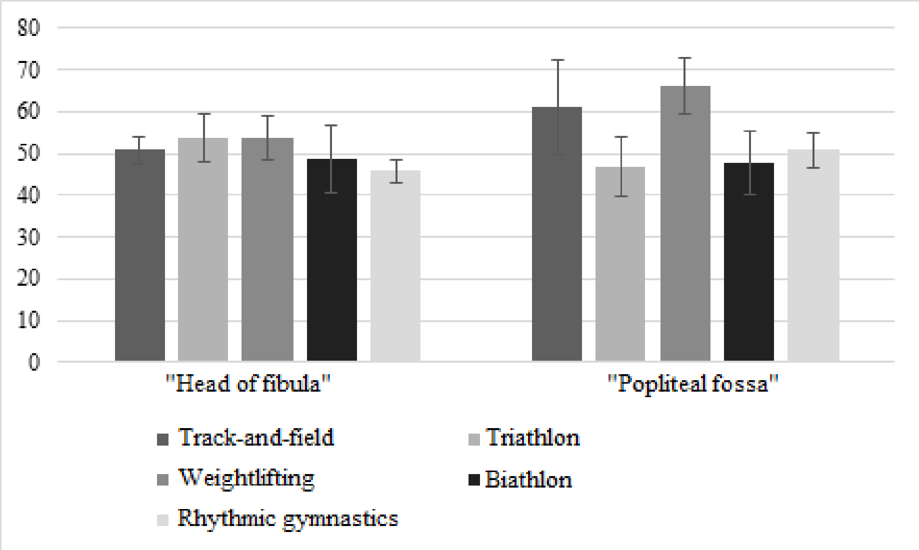

Fig 10. Nerve conduction velocity parameters on the left in female athletes specialized in track-and-field, triathlon, weightlifting, biathlon, rhythmic gymnastics

The data obtained as a result revealed that parameters of the neuromuscular transmission are different in female athletes of different specialization. Moreover, motor response parameters are higher in athletes training speed, power and endurance (track-and-field, weightlifting, biathlon, triathlon) than in athletes of complex coordination sports (rhythmic gymnastics. We have found higher values of the nerve conduction velocity in track-and-field athletes and weightlifters compared to triathlon and biathlon athletes. Meanwhile, gymnasts have lower values than triathlon and biathlon athletes.

Conclusion. Therefore, as a result of the conducted study, we have discovered features of the neuromuscular transmission parameters in female athletes of different sports. The highest values of motor response were registered in athletes training speed-power qualities and endurance. Meanwhile, higher nerve conduction velocity was identified in athletes following the speed-power direction of the training process, lower values were found in athletes of complex coordination sports.

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ASSESSMENT OF MOTOR FUNCTIONS OF PRIMARY SCHOOL CHILDREN WITH SPASTIC DIPLEGIA OF CEREBRAL PALSY

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Annotation. This article presents data on the assessment of motor functions of primary school children with spastic diplegia of cerebral palsy. The results of goniometry reflected a decrease in the amplitude of movement in all joints of the lower extremities. According to the Ashworth scale, moderate spasticity and hypertonicity of the lower extremities were revealed. According to the Gross Motor Function Measure scale, a violation of dynamic equilibrium was revealed, the quality of walking and the level of coordination abilities of the studied group were reduced. According to the Berg scale, a low level of stability, reduced support capacity, decreased coordination and general imbalance of children with spastic diplegia of cerebral palsy were noted. The data obtained are going to form the basis for the development of a physical rehabilitation program, taking into account age and existing disorders.

Keywords: motor functions, primary school children, spastic diplegia, cerebral palsy.

Introduction. According to the World Health Organization, 13 to 15 cases of cerebral palsy are registered per 1000 newborn, spastic forms take the leading role in occurrence [1-2].

Cerebral palsy is one of the most severe diseases of the central nervous system, which is shown in combined motor, speech and mental disorders of various severity [3]. Structures of the brain, which regulate voluntary movements, speech and other cortical functions, suffer the most.

The disease is characterized by a broad variation of clinical signs, accompanying symptoms, severity of motor disorders, degrees of compensation, causes that create complications when forming and developing skills needed for life-sustaining activity [1, 2, 4].

The purpose of this study was to evaluate motor functions of lower extremities in children of primary school age with spastic diplegia of cerebral palsy.

Methods and organization. When evaluating motor functions of lower extremities, we used following research methods:

- goniometry of joints in lower extremities;
- evaluation of global motor functions (Gross Motor Function Measure (GMFM-66) scale);
- muscle spasticity evaluation (modified Ashworth scale);
- equilibrium evaluation (Berg scale);
- mathematical statistics methods (mean value, standard derivation).

The study was carried out within the period from September 2020 till December 2021 in the Moscow City Center of Rehabilitation and the pool of the Secondary School of Olympic Reserve “Moskvich” specialized in rehabilitation of individuals with disorders of the musculoskeletal system.

The group of children of primary school age with cerebral palsy was formed in cooperation with pediatricians, attending traumatologists – orthopedists and neurologists. The examined group involved 12 children of the primary school age with spastic diplegia (average age – 8,5 years), with predominant damage of the lower extremities and the level of motor function development according to the Gross Motor Function Classification System (GMFCS) I and II (two children had the first level, others – the second level).

Main criteria of being included into the study: age, disorders of the central nervous system, damage of the musculoskeletal system.

In order to identify the initial level of motor capabilities, evaluation of muscles’ spasticity and presence of joint contractures in children of primary school age with cerebral palsy, we conducted testing of participants and goniometric measurement.

The statistical data processing was meant to define mean values and standard mean error (M±m).

Results and discussion. An adequate mobility in joints, characterized by flexibility, appropriate state of the capsular ligament and muscle apparatuses that make movements is needed for normal functioning. The goniometric study was carried out for all joints of the right and left leg: hip, knee and ankle joints. Results of joint goniometry indicators are presented in table 1.

Table 1

Goniometric measurements of the lower extremities' joints in primary school aged children with cerebral palsy, M±m, °

№	Indicators	Main group	
		Right leg	Left leg
1	Hip joint abduction with the legs unbent	51.4±9.1	51.6±9.4
2	Hip joint abduction with the legs bent	74.4±12.8	74.4±12.6
3	Internal hip rotation	65±18.4	65.4±18.6
4	External hip rotation	51±9.1	50.8±9.5
5	Hip joint flexion	113.8±6.3	114.4±7.02
6	Hip joint extension	10.6±7.9	10.4±8.8
7	Knee joint flexion	150±18.6	149.6±18.8
8	Knee joint extension	159.8±16.8	160.6±16.04
9	Ankle joint dorsiflexion with the knee bent	58.8±16.7	60±11.7
10	Ankle joint dorsiflexion with the knee unbent	62.6±11.4	62.8±9.12

Data from the goniometric study have revealed rapid derivation from the physiological norm and decrease in amplitude of movement in all examined joints of the right and left leg.

Limitation of the movement amplitude in joints of the lower extremities matches with moderate spasticity and hypertonicity of the lower extremities, which are examined according to the Ashworth scale (1.8±0.83 points) (table 2). The existing joint contractures, moderate spasticity and hypertonicity of the lower extremities sharply limit volume and quality of performing motor actions.

The GMFM-66 scale study allowed us to assess the dynamic equilibrium level, to examine nature and quality of walking, level of coordination abilities of the examined group of children with spastic diplegia of cerebral palsy (table 2).

Table 2

Indicators of muscle spasticity and global motor functions of the lower extremities, statokinetic equilibrium level of the examined group, points

№	Indicators	M±m
1	Muscle spasticity level according to the Ashworth scale	1.8±0.83
2	Evaluation of global motor function according to the GMFM-66 scale (E Block)	29.8±13.08
3	Equilibrium level according to the Berg scale	37.4±8.20

Global motor functions were evaluated according to the GMFM-66 scale and amounted to 29.8±13.08 points in total, which indicates changes in the capsular ligament apparatus of children with cerebral palsy, possible secondary complications, lowered walking skills and disturbed coordination abilities of the lower extremities.

The equilibrium level in children with cerebral palsy was examined according to the Berg scale, the total rating amounted to 37.4±8.2 points, which indicates lower stability, reduced support capacity, lower coordination and general imbalance in patients with cerebral palsy, which, in whole, demonstrates a high risk of falling and additional injury of children.

Conclusion. The study of the lower extremities' motor functions in primary school aged children with spastic diplegia of cerebral palsy has revealed a decrease in goniometry indicators in all joints of the lower extremities, moderate level of spasticity and hypertonicity of muscles, presence of changes in the capsular ligament apparatus of children, lowered skills of walking, equilibrium function and disturbed coordination abilities of the lower extremities. The data obtained are going to serve as a foundation for developing the physical rehabilitation program, considering age and present disorders.

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REACTION OF THE CARDIOVASCULAR SYSTEM OF ADOLESCENT SKIERS IN RESPONSE TO FUNCTIONAL TESTS DURING THE PREPARATORY TRAINING PERIOD

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Annotation. This article presents results of studying functional state of the cardiovascular system in adolescents aged 15-18 years, who are specialized in ski racing, during the preparatory training period. We have studied main indicators of the cardiovascular system at rest and in case when loading tests are applied. We also evaluated reaction types in response to following tests: the Martinet-Kushelevskij test, the Physical Working Capacity test and the Ruffier-Dickson test. The individual analysis of athletes' reaction to loads in each of conducted tests was the most informative one. In the Martinet-Kushelevskij test, 60% of test subjects had the normotonic type of reaction to loads, 40% – the dystonic type. When conducting the Ruffier-Dickson test, we found that 20% had good performance, 30% – average performance, 40% had poor performance. The Physical Working Capacity test with the two-step load revealed satisfactory indicators of the maximal oxygen consumption (VO_2 max). Results of conducted studies are going to serve as a foundation for correction of the training process of adolescents and selection of recovery measures of the examined group.

Keywords: functional state, cardiovascular system, ski racing, preparatory period of the training process, adolescence.

Introduction. The sports activity of skiers takes place in conditions of significant physical and psychoemotional loads. Achievement of the highest athletic performance is possible only in case of appropriate construction of the training process, based on physical, functional capabilities and reserves of athletes [1-3].

This aspect has the highest relevance during puberty, because adolescence is related to significant system-related alterations of a young athlete's body. The training process, constructed without considering age, gender, morphofunctional features and periods of sensitive development of physical qualities and functional features can lead to overtraining, failure of adaptive capabilities and early "burn-out" in sports [4]. Therefore, stage-based and current control of body state of adolescents engaged in sports has a certain significance in construction of the training process. Meanwhile, the training process's efficiency depends significantly on adequately selected recovery measures [5-6], which should promptly correct the revealed disorders in the state of health.

The purpose of this study was to examine main indicators of the cardiovascular system in skiers aged 15-18 years during the preparatory training period at rest and in case when load tests are applied.

Methods and organization. Assessment of the cardiovascular system's functional state was carried out at rest and in response to following tests: the Martinet-Kushelevskij test, the Ruffier-Dickson test and the Physical Working Capacity test.

The study was conducted within the period of November 2015 to April 2017 in the Budgetary Healthcare Institution of the Omsk Region "Exercise Therapy Center". We studied functional state of the cardiovascular system in 10 young men aged 15-18 years engaged in ski racing, with the first adult sports category.

The results obtained were processed with methods of mathematical statistics (mean value, standard derivation).

Results and discussion. Assessment of functional state of the cardiovascular system in adolescent skiers during the preparatory training period was carried out in conditions of rest and loading tests. At rest, the heart rate (HR, beats/min) was 76±0.06 beats/min, systolic blood pressure (sBP) – 110±12.7 mm of Hg, diastolic blood pressure (dBP) – 68±0.08 mm of Hg, which match the age norms and correspond to values typical for people engaged in sports.

Results of average group values of the cardiovascular system's reaction in response to the Martinet-Kushelevskij test are presented in table 1.

Table 1

Reaction of the cardiovascular system in adolescent skiers in response to the Martinet-Kushelevskij test

Measurement stages	sBP, mm of Hg (M±m)	dBP, mm of Hg (M±m)	HR, beats/min (M±m)	Character of the pulse (Ps)
Rest	107±0.09	76±0.06	84±0.05	regular
1 minute of recovery	130±0.03	68±0.08	120±0.05	regular
2 minute of recovery	110±0.08	70±0.09	111±0.04	regular
3 minute of recovery	107±0.08	66±0.1	96±0.02	regular

HR at rest amounted to 84±0.05 beats/min, character of the pulse is regular, blood pressure – 107/76 mm of Hg.

After loads, in the 1 minute of recovery, HR increased by 30% compared to initial values and amounted to 120±0.05 beats/min. Growth rate of the sBP was 5.3% from initial values. dBP decreased by 11.7%. In the second minute of recovery, HR decreased by 6.5%, sBP – by 2.6%, dBP increased by 2.8%. In the third minute of recovery, following values were obtained: HR increased by 12%, sBP increased by 2.7%, dBP decreased by 7.8%.

In response to the Martinet-Kushelevskij test, growth rate of HR and pulse pressure was synchronous. Pulse growth rate amounted to 35.5%, remained within limits of standard values and was rated as a favorable reaction of the cardiovascular system to loads.

When analyzing individual indicators, we discovered that 60% of athletes (n=6 people) have the normotonic type of the reaction to loads. 40% (n=4 people) have the dystonic type, which indicates physical overstraining, vegetative-vascular dystonia. These signs can be noticed in adolescents during puberty.

In order to evaluate performance of adolescent skiers, we used the Ruffier-Dickson test, results of which are presented in table 2.

Table 2

Assessment of the performance of adolescent skiers, according to the Ruffier-Dickson test

Measurement stages	sBP, mm of Hg (M±m)	dBP, mm of Hg (M±m)	HR, beats/min (M±m)	Character of the pulse (Ps)
Rest	108±0.07	62±0.11	72±0.06	regular
After loads	115±0.06	58±0.1	114±0.02	regular
1 minute of recovery	110±0.09	60±0.05	108±0.04	regular

Before the test, HR indicators at rest amounted to 72±0.06 beats/min, sBP – 108±0.04 mm of Hg, dBP – 62±0.11 mm of Hg. In response to the Ruffier-Dickson test, HR increased by 5.2% immediately after loads, sBP – by 7% respectively. Meanwhile, sBP remained unchanged. In the 1 minute of recovery, HR (beats/min) increased by 33%, sBP increased by 6%, dBP increased by 4.3% compared to initial indicators. In total, the performance amounted to 6 points and was rated as ordinary physical performance.

When analyzing individual indicators of skiers' recovery, we have found that 20% of test subjects (n=2) had good performance, 30% (n=3) – average performance, 10% (n=1) – satisfactory performance, 40% (n=4) – poor performance. Rating of the physical performance test revealed unsatisfactory results that are related to discovered frequent cases characterized by the heterochronic physical development, occurrence and increase of overstrain processes.

Before the Physical Working Capacity test (PWC-170), HR was 79 beats/min, which corresponds with age norms and matches values typical for people engaged in ski sports. sBP and dBP at rest also matched age norms and the specificity of athletic activity, and amounted to 109±0.05/63±0.09 mm of Hg respectively (table 3).

Table 3

Results of the Physical Working Capacity test (PWC-170) in adolescent skiers during the preparatory training period

Measurement stages	sBP, mm of Hg (M±m)	dBP, mm of Hg (M±m)	HR, beats/min (M±m)	Character of the pulse (Ps)
Rest	109±0.05	63±0.09	79±0.03	regular
1 load	120±0.02	62±0.09	108±0.02	regular
2 load	115±0.04	64±0.08	93±0.03	regular

After the two-stage Physical Working Capacity test (PWC-170), when assessing the examined indicators in the 5 minute of recovery, we have discovered a following reaction of the cardiovascular system: HR and sBP increased by 19% and 6% respectively, dBP decreased by 3% compared to initial values. Value of the maximal oxygen consumption (MOC) amounted to 5.27±0.08 l/kg/min, rated as the perfect condition of the cardiovascular system. However, when examining individual indicators, two athletes (25% of the whole selection) revealed satisfactory indicators of the maximal oxygen consumption.

When evaluating the type of reaction to physical loads, we revealed that 90% of the group have the normotonic type, while the hypotonic type was found in 10% of cases.

After the PWC-170 test, when evaluating the examined indicators of recovery, we obtained following information. Compared to initial data, HR increased by 26% and amounted to 174±0.03 beats/min. Average value of sBP amounted to 120±0.02 mm of Hg, growth rate amounted to 9% from initial values. dBP decreased by 1.5% from initial values and amounted to 62±0.09 mm of Hg. Nine athletes (90% of the group) had the normotonic type, one athlete (10%) had the hypotonic type of the cardiovascular system's reaction to physical loads.

Conclusion. In studies on evaluation of functional state of the cardiovascular system in adolescent ski racers at rest and during loading tests, the individual analysis of the body reaction to loads was the most informative. It was justified due to a high risk of morphofunctional changes and system-related alterations in adolescent age, which in case of irrational construction of the training process can lead to overtraining, failure of adaptation capabilities and early "burnout" in sports. The revealed derivations in the reaction of the cardiovascular system in skiers in response to loading tests allowed assessing the training process and served as a foundation for selection of appropriate recovery measures.

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METHODOLOGICAL APPROACHES OF GLYCEMIC CONTROL IN SPORTS PRACTICE BASED ON CONTINUOUS GLUCOSE MONITORING DATA

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Annotation. The innovative continuous glucose monitoring method over a long period of time based on the flash monitoring ecosystem is a more effective and accurate method of predicting the glycemic response compared to traditional methods. In clinical practice, such devices are used actively in acute and long-term complications of type 1 and type 2 diabetes mellitus management and prevention. Assessment of glycemic variability – the most important component of glycemic control – may be of great scientific and practical interest in the context of evaluating metabolic strategies of glucose homeostasis in a group of people who need increased intake of carbohydrates. Athletes are a group of people who traditionally use hyperglycemic diets in order to develop indicators of speed and strength endurance against the background of glycolytic loads. A comparative analysis of glycemic variability parameters in individuals with different levels of physical activity compared with healthy individuals of the Caucasian race revealed a significant increase in the average values of glucose excursions exceeding modulo one standard deviation in the group of athletes (Mann-Whitney U-test, p=0.022). A study of continuous glucose monitoring indicators using the FreeStyle Libre glycemia flash monitoring system made it possible to track the presence of personalized glycemic portraits in healthy volunteers reflecting the strategy of blood glucose homeostasis within a lifestyle with different levels of physical activity. Analysis of the percentage of time intervals of being in a state of hyper-, normo- and hypoglycemia in participants revealed significant quantitative differences. The minimal time interval in the range of euglycemia (66%) was observed in a female “non-athlete” with the lowest level of physical activity. The minimal time interval in hyper- (15%) and hypoglycemia (1%) was recorded in an active athlete, who is in the transition period during a one-year training cycle. Methodically grounded use of continuous glucose monitoring in sports practice can become a tool for effective assessment of the power and capacity of the glucose homeostasis system and personalized correction of glycemic status using various lifestyle-modifying strategies.

Keywords: continuous glucose monitoring, glycemic variability, clinical ranges of normoglycemia, glucose homeostasis, individuals with various indicators of physical activity, glycemic control in sports practice.

Introduction. Continuous glucose monitoring (CGM) is one of the main tools of glycemic control, including evaluation of the glycemic variability (GV) and time ranges (TR) of normo-, hypo- and hyperglycemia, which is used in patients with the type 1 and 2 diabetes mellitus (DM) [1]. Within the clinical practice, CGM is used for assessing quality of glycemic control, predicting hyper- and hypoglycemia, as well as DM’s vascular complications [2-4]. Variability of daily blood glucose indicators was thoroughly studied within a group of individuals with the type 1 and 2 diabetes, which increased the efficiency of glucose-lowering therapy significantly.

Currently there are no generally accepted reference values of TR and GV in healthy people that allow to differentiate normal (physiological) and excessive glucose fluctuations. In particular, the World Health Organization (WHO) defines normal glycemia as an empty stomach glucose level of less than 6.1 mmol/L. The organization recommends that the glucose level should be less than 7.8 mmol/L, 2 hours after the glucose tolerance oral test with 75 g of glucose [5]. The American Diabetic

Association considers individuals with the level of 5.6-6.9 mmol/L on an empty stomach and the blood glucose (BG) level of less than >7.8-11.0 mmol/L after the oral test as a group with the increased risk of diabetes [6]. However, as the WHO explains in their recommendations, there is no final threshold of “normoglycemia”. Therefore, an issue of evaluating GV, based on CGM of healthy people is still under study. Studies of glycemia with the CGM method in healthy individuals are random and not systemic.

The search in the PubMed/MEDLINE and Cochrane databases revealed only one publication related to studies of normal reference ranges in average glucose level with the CGM method in healthy patients within different ethnic groups [7]. The Russian scientific database eLibrary (https://www.elibrary.ru/) also has few publications dedicated to research of GM according to the CGM data in individuals with normal tolerance to glucose [8].

Small invasiveness of the daily CGM method gives an opportunity to examine GV indicators in various groups of healthy people. Within foreign literature, there is only one publication dedicated to research of these indicators in athletes. There are no publications on this issue in the domestic scientific literature [9]. It is obvious that athletes are the most vulnerable group of people, who endure high loads of carbohydrate metabolism’s pathways. Glycolytic mechanisms of energy support and their power contribute significantly to the effect of competitive activity in sports requiring maximal manifestation of speed and strength endurance. A possibility to develop this mechanism depends on factors that define glucose homeostasis and its accessibility as an oxidation substrate within the process of muscle activity.

The important point is that athletes are recommended to eat products with high carbohydrate content to ensure adequate glycogen supply and increase athletic performance [10-11]. It is known that physical training improves sensibility of tissues to insulin immediately before training and at the expense of the long-term adaptation of glucose transportation and metabolism mechanisms [12]. However, it is also known that loaded exercises increase concentration of circulating catecholamines, such as adrenaline and noradrenalin, to pathological levels [13-14], which leads to hypo-, hyperinsulinemia after intensive exercises [15-16].

Therefore, the aforementioned data evidence the practical significance of evaluating the glycemic state in individuals, engaged in sports, over a long period of time.

The purpose of this study was to evaluate capabilities of existing methodological approaches of glycemic control in healthy people with different levels of physical activity.

The study’s main tasks are:

1. Compare indicators of intra-day and inter-day variability, frequency and time characteristics of the glycemic profile in the group of healthy volunteers with the group of people of the Caucasian race without type 1 and 2 diabetes.

2. Reveal features of glycemic indices of athletes compared to non-athletes.

Methods and organization. The study involved four healthy individuals of both genders. They led an ordinary lifestyle and did not receive adapted nutrition programs. Male athletes of sub elite level: athlete 1 – heart rate (HR) at rest <60 beats/min, 2 low-intensity training sessions per week, average number of steps per day – 9.5 thousand; athlete 2 – HR at rest <56 beats/min, 4-5 training sessions per week, 11 thousand steps per day in average. Two healthy volunteers, not engaged in sports: non-athlete 1 – a woman, HR at rest <62 beats/min, sedentary lifestyle, occupation – musician, 4 thousand steps per week; non-athlete 2 – a young man, HR at rest <68 beats/min, active lifestyle, 3 fitness training sessions of average intensity per week, 12 thousand steps per day. All participants were selected in accordance with the informed written consent for research of the optimal nutrition of individuals characterized with normal indicators of glycemia. Table 1 presents general characteristics of the examined group.

Table 1

Description of the study's participants

The study's participants	athlete 1	athlete 2	non-athlete 1	non-athlete 2
Physical activity level (c.u.)	1,9	2,2	1,4	2,1
Age (full years)	20	20	24	12
Gender (m/f)	m	m	f	m
Height (cm)	178	181	164	154
Weight (kg)	61.9	78	74.8	40.7
Body mass index (kg/m^2)	19.5	23.8	27.8	17.2
Abdominal circumference (cm)	67.2	79.9	85.4	60.1
Chosen sports	soccer	soccer	none	swimming
Sports mastery rank (age-group class)	1 adult	Candidate for master of sports	none	1 youth
Athletic experience (years)	13.5	14	0	8

The anthropometric indicators and values of the body mass index (BMI) were obtained with the biological impedance technique on the Accuniq BC 300 multifrequent body composition analyzer (Accuniq, South Korea, 2017).

In order to identify the physical activity (PA) level in each participant, we evaluated following lifestyle parameters: level of professional motor activity, average amount of steps per day and a number of training sessions or outdoor activities per week [17]. To count the average amount of steps per day in the course of 14 days, we applied the cross-platform fitness app for smartphones called "Pedometer, step counter Health" (Health and Fitness Apps Group, Republic of Belarus, 2021).

To evaluate GV in healthy volunteers in "natural" life conditions, we used the FreeStyle Libre ecosystem (Abbot, USA, 2018). This technology incudes the flash sensor that allows carrying out a continuous round-the-clock glucose monitoring for 14 days, the FreeStyle LibreLink app for smartphones and the LibreView 5 software – a free cloud system with web interface. The approach of evaluating the glycemic profile in 10 key indicators (table 2) [18] was tested and is successfully used for patients with type 1 and 2 diabetes. The International Consensus of Endocrinologists accepted these recommendations in 2019 [19].

Table 2

Key indicators of glycemic control and prediction of risks of long-term complications, based on CGM

1. Number of days for carrying out continuous glycemia monitoring	14 days recommended
2. Time share (%), within which the data were scanned	≥70% and more for 14 days
3. Mean glucose value (mmol/L)	4.1–6.1
4. Indicator of glycemic control (%)	<6.5
5. Glycemic variability (%)	<36
6. Time above the range >13.9 mmol/L	2 level
7. Time above the range 10.1–13.9 mmol/L	1 level
8. Time within the range 3.9–10.0 mmol/L	Range
9. Time below the range 3.0–3.8 mmol/L	1 level
10. Time below the range <3.0 mmol/L	2 level

The GV assessment (range and frequency of fluctuations, time structure) was conducted on the basis of “raw” data from the CGM curve with the EasyGV © software, version 9.0 (available free for non-commercial use on www.easygv.co.uk). We examined following GV parameters as main indicators: M – mean glucose; SD – standard deviation of glucose level, a degree of glycemia dispersion; CONGA – continuous overlapping net glucose index, a value of dispersion in the difference of glycemic values (in absolute values) within the 60 minute interval during the whole period of monitoring; LI – lability index, indicates risks of hypoglycemic states; index J – quality indicator of glycemic control; LBGI – low blood glucose index; HBGI – high blood glucose index; MAGE – mean amplitude of glycemic excursions, during calculation all fluctuations with the amplitude of less than 1 SD are ignored; MAG – mean absolute glucose, allows assessing the ratio of glycemic fluctuations' amplitude to time; ADRR – average daily risk range, a highly sensitive tool for evaluating total risks of hypo- and hyperglycemia and identifying people with high glycemic lability; MODD – mean of daily differences, a parameter of assessing inter-day glycemic fluctuations; GRADE – glycemic risk assessment diabetes equation. Figure 1 shows the algorhythm of calculating GV parameters with the EasyGV software.

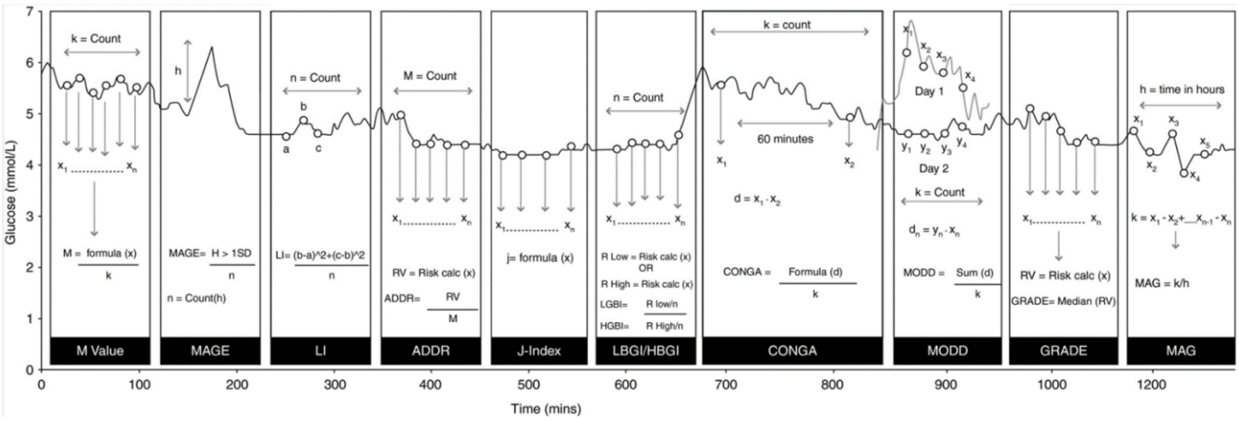

Fig. 1. Mathematical model of evaluating glycemic variability in the Easy glycemic variability (GV) software

Note: graphic image of calculating 10 parameters of GV evaluation, based on the data from the CGM curve within 14 days

Arrangement of source information and visual presentation of results obtained were made in the form of Microsoft Excel 2016 tables. The statistical analysis was conducted with STATISTICA 10 (StatSoft.Inc), EasyGB, version 9 (the calculator was developed by the Oxford University Research Group, free access).Values were deemed as statistically significant if p<0,05.

Results and discussion. The outpatient glycemic profile (OGP) report is presented for each participant (fig. 2-5).

Table 3 presents a comparative analysis of glycemic profile in the group of healthy volunteers compared to recommended GV values for patients with type 1 and 2 diabetes.

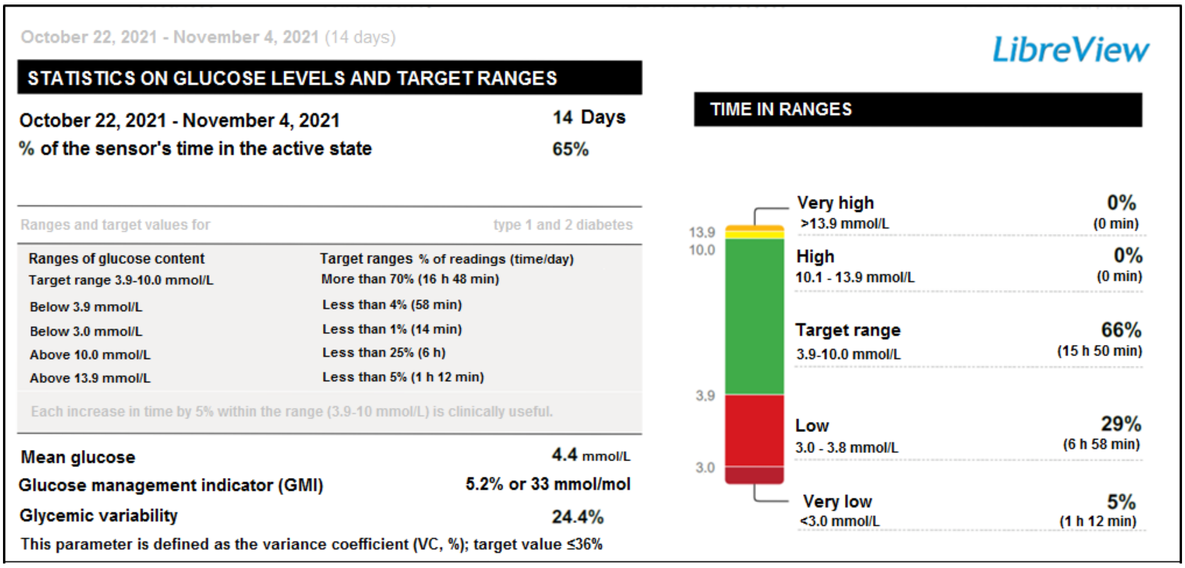

Fig. 2. OGP report, a woman, non-athlete, 24 years

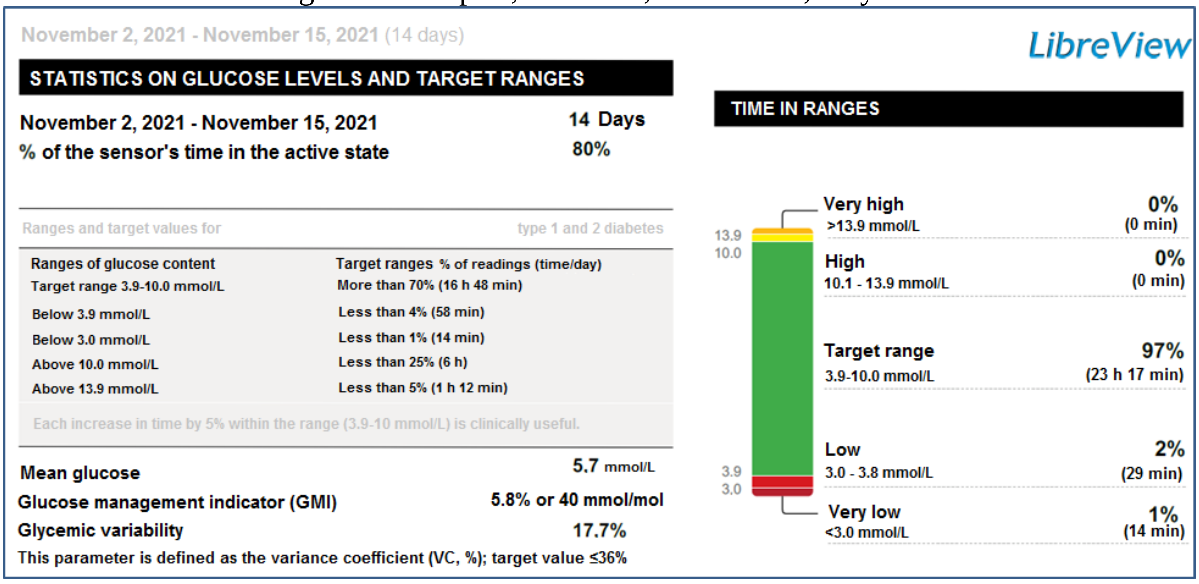

Fig. 3. OGP report, a young man, non-athlete, 12 years

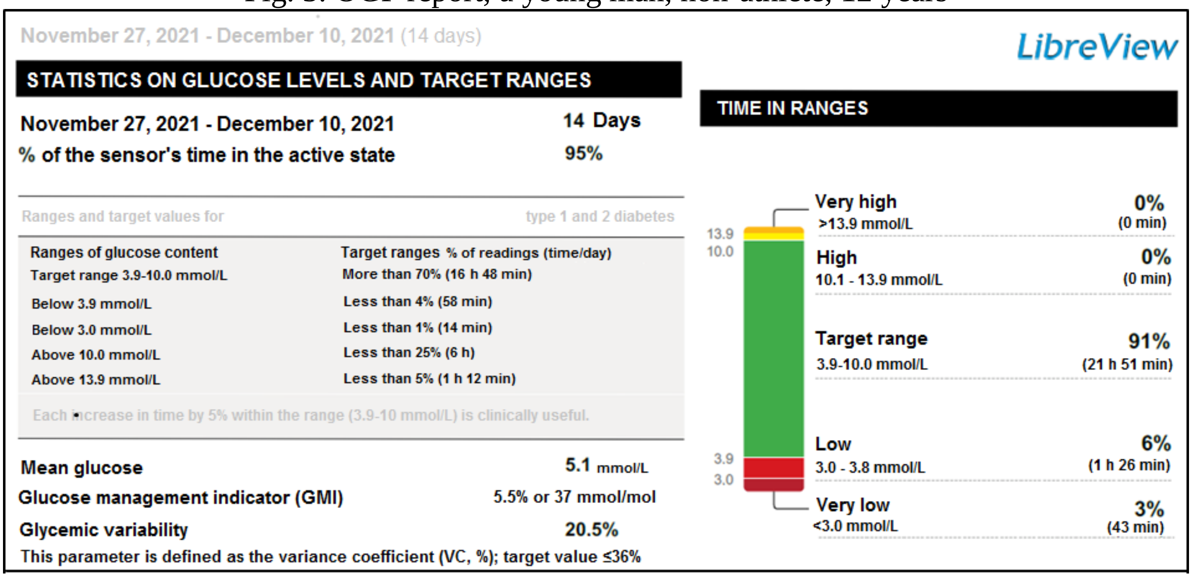

Fig. 4. OGP report, a man, athlete (more than 6 years out of the training process), 20 years

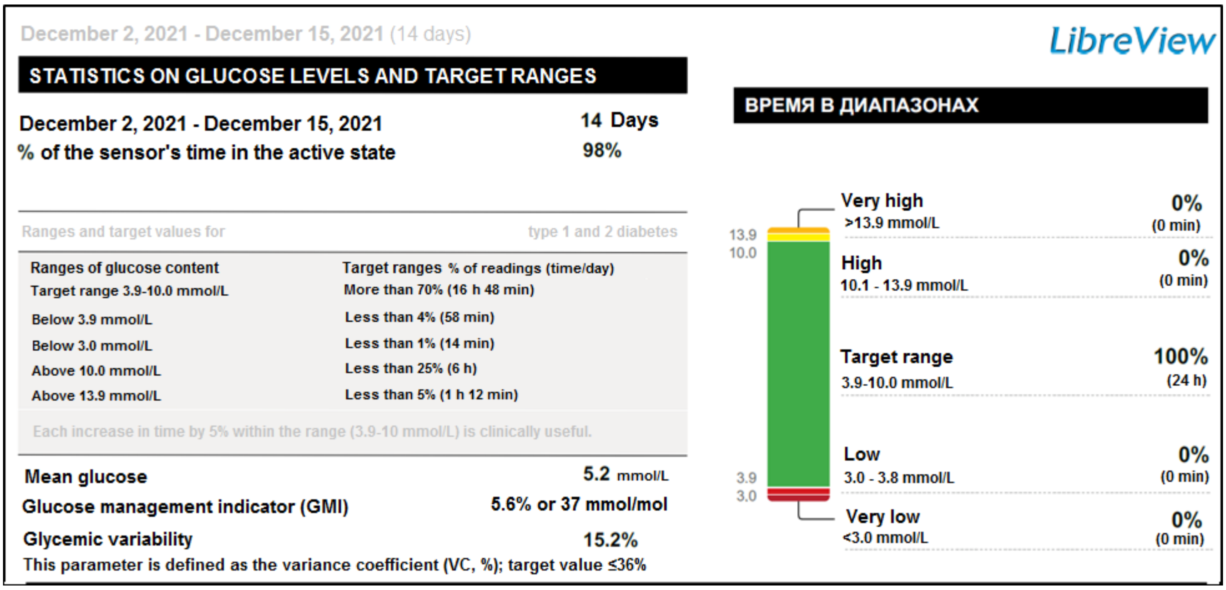

Fig. 5. OGP report, a man, athlete (transferring period of the training cycle), 20 years

Table 3

Glycemic control key indicators in the examined groups if healthy volunteers compared to target glycemia ranges of the OGP protocol

Glycemic control indicators*	OGP protocol values	Group 1 Athletes	Group 2 Non-athletes
1. Time share (%), in which the data were accepted	≥70 and more	95-98	80-100
2. Mean glucose value, mmol/L	4.1-6.1	5.1-5.2	4.4-5.7
3. Indicator of glycemic control, possible level of glycated hemoglobin (%)	<6.5	5.5-5.6	5.2-5.8
4. Glycemic variability (%)	<36	15.2-20.5	17.7-24.4
5. Time above the range >13.9 mmol/L (min, %)	<5 (1 h 12 min)	0	0
6. Time above the range 10.1–13.9 mmol/L (min, %)	<25 (6 h)	0	0
7. Time within the range 3.9–10.0 mmol/L (min, %)	>70 (16 h 48 min)	91 (21 h 51 min) - 100% (24 h)	66 (15 h 50 min) - 97 (23 h 17 min)
8. Time below the range 3.0–3.8 mmol/L (min, %)	<4 (58 min)	0-6 (1 h 26 min)	2 (29 min) - 29 (6 h 58 min)
9. Time below the range <3.0 mmol/L (min, %)	<1 (14 min)	0-3 (43 min)	1 (14 min) - 5 (1 h 12 min)

Note: glycemia indicators in groups are presented in minimal and maximal values

In the non-athletes group, the indicator of time in target range was lower than target values, time of glucose values within the range of higher than 10.0 mmol/L was not found. Average glucose value, higher than reference values for children under 14 years of age (3.3-5.6 mmol/l), was revealed. The glycemic control and GV indicator remained within limits of target ranges. The average daily time spent in the 1 and 2 level hypoglycemia was higher than target values of OGP reports in the non-athletes group (29% versus 4% and 5% versus 1%). Therefore, the glycemic control analysis shows low values of glycemic variability in the athletes group and higher time of exposition in hypoglycemia in the non-athletes group compared to recommended values of the OGP report.

Main benefits of the examined parameters are the simplicity of calculation and absence of special requirements to the frequency and duration of glycemic control, the main disadvantage – limited informational capacity when evaluating GV in individuals with normal tolerance to glucose. These parameters do not consider frequency, duration and amplitude of glycemic fluctuations within reverence ranges of hypo-, hyper and normoglycemia in healthy people with different levels of physical activity.

We applied the graphic method of analyzing initial glycemic indicators obtained from the CGM data in order to conduct personalized evaluation of glucose homeostasis and metabolic flexibility in healthy people with different levels of physical activity. We calculated a percent ratio of time intervals in the state of hyper- normo- and hypoglycemia in all examined individuals. The generally accepted standard glucose range (4.1 to 6.1 mmol/L), accepted by WHO for people aged 14-60 years, was used as the reference range. Figure 6 shows cumulative graphs of time intervals of hyper-, normo- and hypoglycemia of healthy participants, showing a share of cases when glucose indicators (%) exceeded limits of the glycemic target range (4.0-6.0 mmol/L).

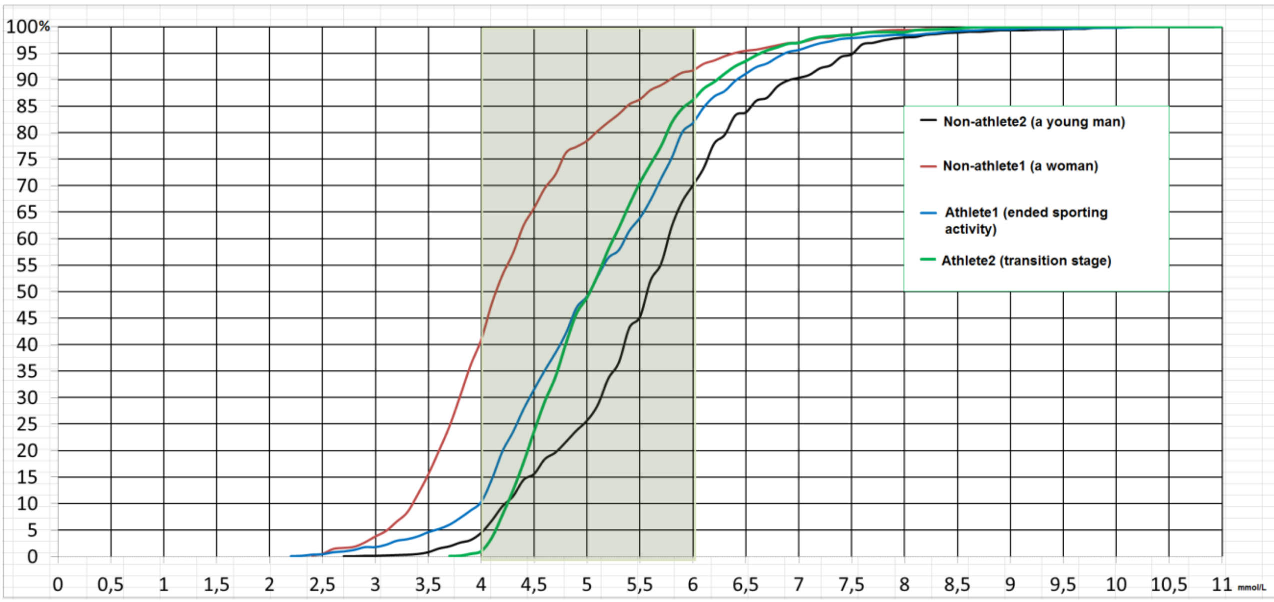

Fig. 6. Cumulative graph with distribution of glucose indicators, measured with CGM in four healthy participants

Note: light green line – reference glucose values

When measuring the target range of normoglycemia (compared to generally accepted clinical OGP protocols), we obtained following results: athlete 1 (PA – 1.9), time in hypoglycemic state – 10%, in euglycemic state – 72%, in hyperglycemic state – 18%, athlete 2 (PA – 2.2) – 1%, 85% and 14% respectively; non-athlete 1, a woman (PA – 1.4), time in hypoglycemic state – 40%, in euglycemic state – 52%, in hyperglycemic state – 8%; non-athlete 2, a young man (PA – 2.1) – 4%, 66% and 30% respectively. Thus, the least time spent in the euglycemic range (66%) was found in the non-athlete, a woman with the lowest level of physical activity. The most time spend in the normoglycemic state (84%) was found in the actual athlete during the transitioning stage of the training cycle.

The integral approach in evaluating glycemic risk of type 1 and 2 diabetes is implemented according to CGM parameters with the use of mean value and relative percentage contribution in the average-weighted evaluation from values of hypoglycemic, euglycemic and hyperglycemic ranges. Indicators of the CGM's glycemic profile within clinical practice of high risk of diabetes correspond to following values (hypoglycemia %, euglycemia %, hyperglycemia %): type 1 diabetes (20%, 8%, 72%), type 2 diabetes (2%, 7%, 91%) [20]. Ranges of normo-, hyper- and hypoglycemia, received during the study, differ significantly from the average-weighted ratings of high risk of diabetes, obtained in clinical practice. Currently, there is no consensus regarding indicators of the normal glucose level in clinical practice. Moreover, many studies demonstrated that prolonging time of staying within the range of 4 to 6 mmol/L leads to an improvement in patient treatment outcomes [21-22]. Many studies also demonstrated linearly increasing risk of diabetes complications, related to an increase in time of staying within the hyperglycemia range, regardless of the diabetes state, with lower limits of the norm between 4 and 6 mmol/L [5, 22, 23, 24, 25].

Table 4

Mean value and standard deviation for glucose level indicators and glycemic variability within the group of Caucasian people and in general population of people without diabetes compared to the data from the study

	Group/ethnicity				Mann-Whitney U-test $p_{(3-1)}$
Glycemic variability indices	Caucasian individuals (M±SD) n=44	General population (M±SD) n=70	Athletes (M±SD) n=2	Non-athletes (M±SD) n=2	
Group number	1	2	3	4	
Age (years)	27.3 (5.8)	27.9 (5.2)	21(0.4)	18 (8.5)	0.284
Mean glucose level (mmol/L)	5.0 (0.5)	5.1 (0.5)	5.2 (1.14)	5.0 (1.04)	0.872
Mean standard deviation (mmol/L)	1.5 (0.7)	1.5 (0.7)	0.88 (0.05)	0.77 (0.08)	0.319
CONGA (c.u.)	4.4 (0.6)	4.6 (0.5)	4.6 (1.01)	4.4 (0.93)	0.865
LI (c.u.)	0.4 (1.9)	0.4 (2.2)	2.0 (0.44)	1.03 (0.22)	0.412
J-Index (c.u.)	13.7 (4.9)	14.3 (4.7)	13.09 (2.88)	12.08 (2.54)	0.914
LBGI (c.u.)	3.5 (1.9)	3.1 (1.9)	2.9 (0.64)	4.3 (0.90)	0.764
HBGI (c.u.)	0.4 (4.2)	0.2 (3.8)	1.0 (0.22)	0.8 (0.17)	0.886
GRADE (c.u.)	0.4 (2.0)	0.4 (2.1)	0.5 (0.11)	0.6 (0.13)	0.960
MODD (c.u.)	0.8 (1.3)	0.8 (1.4)	0.8 (0.18)	0.8 (0.17)	0.258
MAGE (c.u.)	1.4 (0.5)	1.4 (0.7)	2.8 (0.32)	1.5 (0.33)	**0.022**
ADRR (c.u.)	0.4 (4.5)	5.5 (4.1)	7.0 (1.54)	2.9 (0.61)	0.165
M-value (c.u.)	5.5 (4.1)	4.7 (3.8)	4.9 (1.08)	6.8 (1.36)	0.888
MAG (c.u.)	1.4 (0.3)	1.3 (0.4)	1.4 (0.31)	1.5 (0.32)	0.998

Note: CONGA – continuous overlapping net glucose index, LI – lability index, J-Index – mean amplitude of glycemic deviations, LBGI – low blood glucose index, HBGI – high blood glucose index, GRADE – glycemic risk assessment diabetes equation, MODD – mean of daily differences, MAGE – mean amplitude of glycemic excursions, ADRR – average daily risk range, M-value – index of blood glucose control, MAG – mean absolute glucose. Each parameter rates independently the whole range of glucose indicators during the CGM process for 14 days

We compared glycemic variability parameters in individuals with different level of PA with methods of non-parametric statistics (Mann-Whitney U-test for non-related groups and Wilcoxon T-test for related groups) with normal GV values obtained by a group of scientists from the Oxford Center for Diabetes, Endocrinology and Metabolism of the Churchill Hospital (table 4) [7]. As a reference group, we have chosen values of glycemic variability indicators in individuals of Caucasian race (44 people). We also analyzed GV values of general population of people participated in that study (70 people).

Mean values of glycemic excursion in athletes that exceed one standard deviation (the MAGE index) is statistically higher (Mann-Whitney U-test, p=0.022) (table 4) compared to healthy Caucasians. The MAGE index is a statistic measure of glycemic variability. It is used to evaluate quality of glycemic control in clinical practice. We have discovered a more pronounced mean amplitude of glucose fluctuations in athletes compared to normal values in the Caucasian group without diabetes. According to other parameters that evaluate GV, there were no statistically significant differences between studied groups and Caucasians.

Conclusion. The study of variability of physiological indicators demonstrating dynamics of adaptation and recovery of the body's reserves is applied widely in sports, clinical, aerospace and preventive medicine. Methodological approaches of analyzing mechanisms of the homeostasis control on the level of humoral, autonomic and central links of the heart rate regulation were elaborately worked on based on the variational heart rate monitoring evaluation (R.M. Baevskij, 1979 г.). Ranges of the heart rate variability and their rating with the spectral analysis for various situations, including sports practice, were clearly described [26]. Currently, the sports practice demonstrates that decrease in the heart rate variability against the background of increasing heart rate frequency means less adaptation reserves and slower recovery processes in contrast to training loads [27]. Excessive blood pressure variability in clinical medicine is an unfavorable sign related to cardiovascular complications. In fact, physiological process that participate in short-term and long-term adaptation is described with the sinusoidal response, which, on the one hand, supports the implementation of certain potential, on the other hand – has an ability to restore it. Glucose metabolism is that basic energy-related process that ensures development of power and capacity of glycolytic mechanisms of the muscle activity's energy support. The initial analysis of glycemic profiles in healthy volunteers demonstrated individual features of metabolic strategies of implementing glucose homeostasis in a body of an athlete and a non-athlete. Moreover, modern methodological approaches are aimed at predicting the development of diabetes and its complications within clinical range of glycemia. These indicators in healthy people, athletes with many reserves of glucose homeostasis, have limited value, because they do not indicate possible reserves and resources that are formed during sports activity. There is an urgent need in a new methodological approach of defining a special state of an athlete from the point of implementing glycemic homeostasis. The development of approaches for evaluating glycemic profile, based on statistic and geometric methods of analyzing frequency and amplitude indicators of CGM that characterize power of regulatory systems supporting glucose homeostasis and an ability to recover against the background of high energy expenditure, would serve as an informative tool for predicting influence of glycolytic loads on the carbohydrate status and its management.

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