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MANIFESTATIONS OF NEUROPLASTICITY IN NEUROMOTOR PARAMETERS OF ATHLETES OF VARIOUS SPORTS UNDER SUBMAXIMAL AND MAXIMAL LOADS

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Annotation. The purpose of this study was to examine and compare neuromotor parameters in athletes, according to characteristics of the neuromuscular system at rest and under submaximal and maximal loads with different direction of the training process. The study involved 110 elite athletes (Masters of Sports and Masters of Sports of International Class). As a result of studying characteristics of the neuromuscular apparatus at rest (according to the data from stimulation electromyography), under submaximal (according to the data from surface electromyography when performing the Bosco repetitive jump test) and maximal (according to the data of surface electromyography when performing weightlifting exercises) loads, we have identified the manifestations of neuroplasticity, associated with fatigue compensation phenomena, urgent and long-term adaptive changes in the neuromuscular system to specific physical activity.
Keywords: neuroplasticity, neuromotorics, athletes, functional state, submaximal load, maximal load, neuromyography.

Introduction. Neuromotorics is the specifically organized type of motor activity, based on neuropsychology (connection of the brain functioning and mental functions) and directed towards developing functions of the brain structures through movement (motor skills). Voluntary movement (physical exercises, technique of motor actions) occurs under control of consciousness, manifestation of motor qualities – with participation of conation. Therefore, the neurodynamic characteristics of a man are a fusion of psychological and physiological mechanisms for managing movements, motor actions, reflected in the manifestation of various motor qualities. Athletic actions are described by not only the degree of perception, but also the structure of the main variables of movement: dynamic, temporal and spatial [1].

Scientists of the modern sports physiology, when analyzing central and peripheral mechanisms of adaptation to the specific sports activity, note with increasing frequency the phenomena of neuroplasticity [2] – the ability of neural networks in the brain to change through growth and reorganizing. These changes vary from separated neural pathways, which create new connections, to systematic correction, such as cortical remapping. According to the data given by different researchers, the adaptation of a man's motor system to the specific sports activity is shown through changes of sensorimotor reactions [3-4], plastic functional rearrangements in the neuromuscular apparatus [5-7] and neural structures of motor control [8]. In this connection, studies of neuroplasticity in the characteristics of neuromotor processes of a man during sports activity are relevant.

The purpose of this study was to examine manifestations of neuroplasticity in neuromotor parameters of athletes, specialized in different sports.

Methods and organization. The study involved 110 elite athletes (Masters of Sports, Master of Sports of International Class). It included 12 boxers (women), 52 weightlifters (35 men and 17 women), track-and-field athletes (6 men), triathlon athletes (8 men), mixed martial artists (8 men), volleyball players (7 men), fencing (7 men) and field hockey players (10 men).

The muscle electroactivity characteristics at rest were identified with the stimulation elec-

tromyography (EMG). To identify motor response from the extensor digitorium brevis of the foot, innervated by the peroneus nerve, we have stimulated the following points: “tarsus”, “head of fibula” and “popliteal fossa” with the 4-channel hardware and software complex “Neuro-MVP” produced by Neurosoft (Ivanovo). The electric stimulation was made with rectangular pulses, stimulation time – 0.2 ms, the electric current was selected individually in the range of 15-30 mA.

The neuromotor parameters when performing the submaximal load was identified with the Bosco repetitive jump test (for boxers). The test (maximal vertical jumps for 60 s) is carried out on tensodynamic platforms with the recording electrophysiological signals using the wireless EMG. The program registers and analyzes following indicators: maximal push strength before the jump for each 15-second jump interval, average specific capacity of jumps, average jump height, mean root square deviation of the jump height, maximal jump height, number of jumps, values of bioelectric EMG potentials of the rectus femoris, the biceps femoris, the fibularis longus and the gastrocnemius (in each leg) for periods of 0-15 s, 15-30 s, 30-45 s, 45-60 s. We have calculated the fatigue index and the maximal push strength, maximal capacity and strength endurance.

We have also identified neuromotor parameters (according to the data from neuromyography) in athletes when performing competitive weightlifting exercises (under maximal load).

The study was carried out with the Smart BTS motion system. For the biomechanical analysis of movement and test exercises, we have developed special diagnostic protocols in form of computer programs for the BTS SMART-Clinic software:

1) “Bosco repetitive jump test” (Certificate of the computer program registration No. 2021619879, 18.06.2021) [9] (fig. 1);

2) “Biomechanical and electromyographic express evaluation of the weightlifting snatch” (Certificate of the computer program registration No. 2020660142, 28.08.2020) [10];

3) “Biomechanical and electromyographic express evaluation of the weightlifting clean and jerk” (Certificate of the computer program registration No. 2020660143, 28.08.2020) [11].

These programs allow a quick assessment of biomechanical and electrophysiological parameters of the competitive weightlifting exercises (fig. 2)

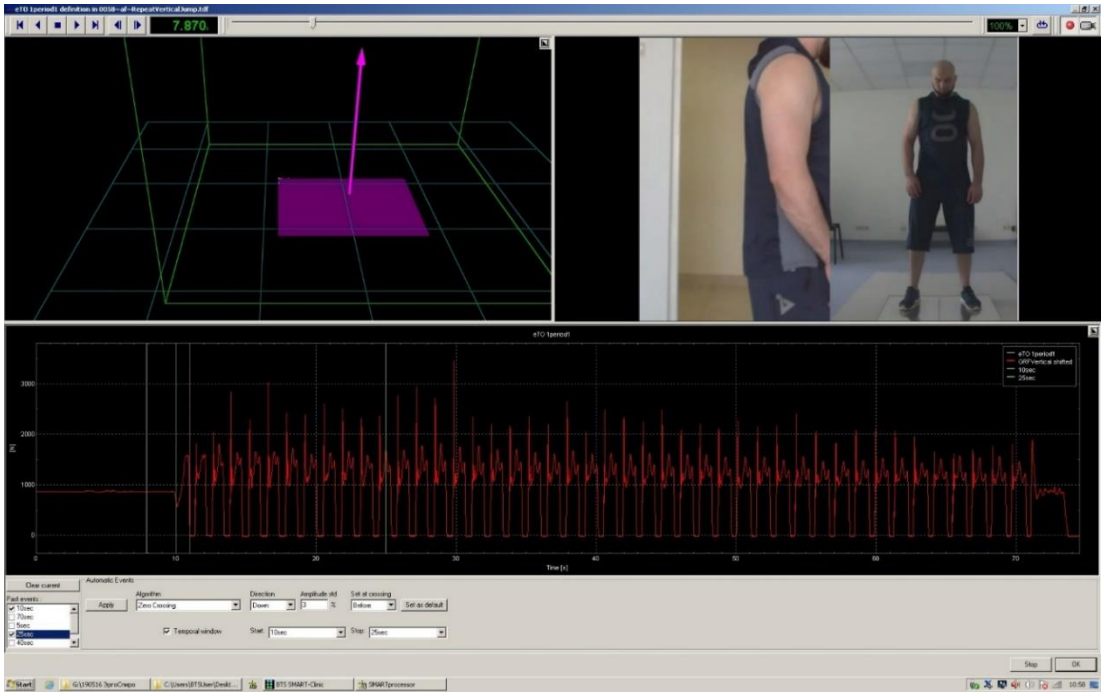

Fig. 1. Program window with test results

A B

Fig. 2. Beginning of the Squat phase 3.2 (A – snatch, B – clean and jerk)

The programs register and record in result protocols temporal, strength, speed indicators, indicators of distance, kinematics, capacity, as well as electrophysiological parameters (average and maximal EMG amplitude of a muscle, dominating (peak), average and median frequency of the muscle bioelectric activity of the left and right trapezius, the quadriceps femoris, the biceps femoris and the gastrocnemius.

All test subjects gave an informed consent for participation in compliance with the WMA Declaration of Helsinki, as well as a permission for personal data processing. The study was approved by the bioethics committee in the FSBI "North-Caucasian Federal Research-Clinical Center of the Federal Medical and Biological Agency".

The statistical data processing was made with the Statistica 13.0 software, differences between groups were identified with the Mann-Whitney U-test.

Results and discussion. Neuroplasticity in muscle electric activity characteristics in athletes at rest. The study of muscle electric activity indicators with the stimulation EMG has revealed that values of amplitude and M-response area in track-and-field athletes was higher ($p \leqslant 0.03$) in the "tarsus" stimulation point (amplitude – 7.28±2.36 mV, area – 22.88±7.29 mV×ms), than in mixed martial artists (amplitude – 4.16±1.17 mV, area – 12.85±5.03 mV×ms). In the "head of fibula" and "popliteal fossa" points, the M-response amplitude of track-and-field athletes ("head of fibula" – 7.77±2.60 mV, "popliteal fossa" – 8.00±2.30 mV) differs significantly from the same indicator of triathlon athletes ("head of fibula" – 5.45±1.74 mV, $p \leqslant 0.01$, "popliteal fossa" – 5.45±1.90 mV, $p \leqslant 0.03$) (fig. 3).

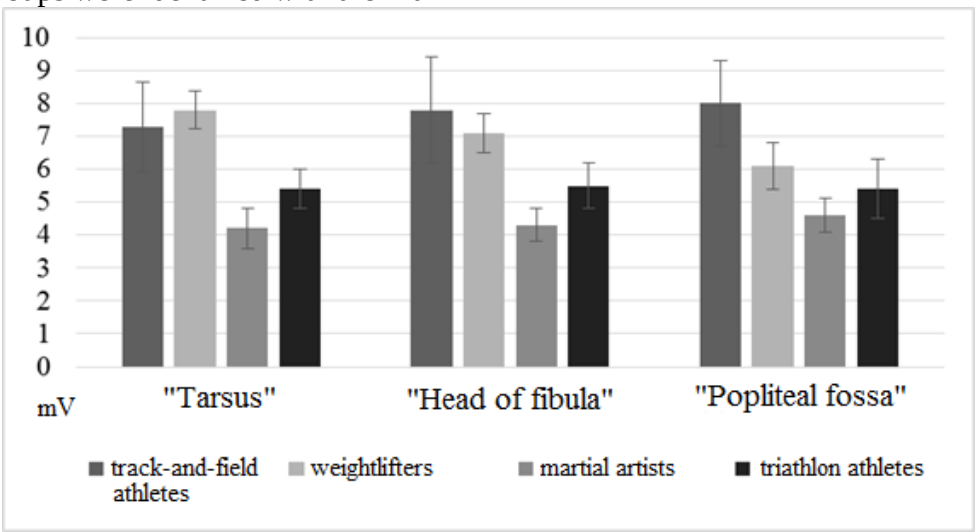

Fig. 3. Motor response amplitude, registered from the extensor digitorium brevis when stimulating the peroneus nerve on the right in male athletes

The nerve conduction velocity (NCV) in the "tarsus" – "head of fibula" segment on the right in weightlifters (54.43±4.02 m/s) is statistically higher, than in triathlon athletes (48.43±5.03 m/s, $p \leqslant 0.04$), volleyball players (48.44±2.61 m/s, $p \leqslant 0.004$) and hockey players (49.33±3.89 m/s, $p \leqslant 0.02$). The NCV in the "tarsus" – "head of fibula" segment on the left is higher in weightlifters (53.88±1.55 m/s), than in fencers (48.10±5.00 m/s, $p \leqslant 0.02$), mixed martial artists (48.98±2.89 m/s, $p \leqslant 0.02$) and field hockey players (49.73±3.70 m/s, $p \leqslant 0.02$).

Therefore, the specific adaptation to sports activity characterizes the plasticity of the neuromuscular system in athletes. Athletes of cyclic and acyclic sports, who train mainly speed-strength qualities, have higher values of muscle fiber bioelectric activity compared to the parameters of athletes in situational sports.

Manifestations of neuroplasticity in neuromotor indicators of athletes when performing the Bosco repetitive jump test (under submaximal load). The study of neuromotor indicators in the lower extremities when performing the Bosco repetitive jump test has revealed that the greatest biomechanical parameters in female boxers during its 1st period were due to high stress, and therefore activation and synchronization of motor units primarily in the rectus femoris (1-4 period on the right: 1.46±0.59 mV; 1.39±0.55 mV; 1.16±0.54 mV; 1.30±0.48 mV; on the left: 1.10±0.29 mV; 0.65±0.33 mV; 1.24±0.29 mV; 1.25±0.59 mV). During the 3rd and the 4th period of the test, the stress in the biceps femoris that supports body stabilizing in case of landing and pushing becomes stronger (1-4 period on the right: 0.71±0.40 mV; 0.61±0.30 mV; 0.58±0.32 mV; 0.57±0.31 mV; on the left: 1.15±0.36 mV; 0.62±0.35 mV; 1.17±0.35 mV; 1.31±0.64 mV). This, as well as an increase of muscle electric activity in the left leg and a decrease of physical parameters by the end of the test (number and height of jumps) indicates the development of first compensated and then uncompensated fatigue.

Dynamics of electric activity indicators of leading muscles in the lower extremities that support jump movements during the multiple jump test allows describing local physiological processes and neuroplasticity phenomena, which cause the manifestation of functional capabilities and fatigue.

Manifestations of neuroplasticity in neuromotor parameters of athletes when performing competitive weightlifting exercises (under maximal load). When examining the amplitude and frequency parameters of the surface EMG of working muscles during performance of weightlifting exercises from the point of plasticity of the nervous system and neurodynamic properties [2], we have found a significant increase of EMG indicators within phases of the weightlifting snatch. Male weightlifters have shown multiple enhancements of the amplitude of muscle EMG, compared to the resting state, in separate occasions – up to 40 times. The electroactivity of the trapezius is increasing in both men and women. Average EMG amplitude within separate phases increases 33 times in women (average EMG amplitude of the left trapezius during the Squat phase 3.1) and up to 40 times in men (average EMG amplitude of the left trapezius during the Squat phase 3.1). The electric activity of all muscles increases more in men than in women. During performance of the exercises, the average EMG amplitude increases mainly, frequency characteristics change no more than 2.2 times (in women – the dominant (peak) frequency of the left biceps femoris in the Snatch phase 2.1; in men – the dominant (peak) frequency of the right trapezius in the Snatch phase 2.1).

Conclusion. Therefore, the conducted research of neuromotor parameters in athletes, according to the characteristics of the neuromuscular system at rest and under submaximal and maximal load has demonstrated manifestations of plasticity of these parameters, associated with compensation phenomena in case of fatigue, urgent and long-term adaptation changes of the neuromuscular system to specific physical loads.

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THE USE OF BREATHING EXERCISES FROM HATHA YOGA FOR ACCLIMATIZATION OF ATHLETES TO HIGH ALTITUDE CONDITIONS

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Annotation. This study analyzes an influence of a set of breathing exercises from Hatha yoga on the body of athletes for improving adaptation capabilities and accelerating the acclimatization process to high altitude conditions. Results of the study indicate an increase of tolerance to mixed hypercapnia and hypoxia, associated with a general condition of oxygen-support systems of the body under high altitude conditions.
Keywords: mountaineering, high altitude, preparation of athletes to high altitude conditions, acclimatization, breathing exercises, Hatha yoga, yoga in high altitude.

Introduction. Mountaineering is one of the extreme sports, since in the high altitude zone, athletes are exposed to a complex of environmental stress factors. At the same time, the climber needs to perform complex physical work associated with climbing, moving through various forms of mountain terrain, carrying the additional weight of the necessary equipment. If an athlete is insufficiently prepared, all these factors negatively affect the body, disturbing the physiological and mental balance, thereby complicating the actions of a climber in the high altitude conditions [1-12]. It is known that the main cause of physiological changes leading to a decrease in performance in the mountains is hypoxia, as a result of which the cardiovascular system (increased blood pressure, increased heart rate, etc.) and the respiratory system experience the greatest stress. Leading scientists studying the issue of hypoxia in the mountains claim that moderate hypoxia stimulates the development of acclimatization (adaptation) mechanisms [13-18], but for each athlete in the mountains acclimatization takes place in different ways. For example, acclimatization process occurs much faster for the most trained and experienced athletes. Mountaineering is more of a team sport, where successful ascent depends on each participant. In this connection, there is an urgency and the need to search for new methods of preparing the respiratory and cardiovascular system of climbers to the high altitude conditions [19-21].

If we turn our attention to the eastern health-improving system of Hatha yoga, which describes in detail the technique of performing breathing exercises (pranayama), then undoubtedly pranayama is assigned the role of educational, balancing and spiritual power of a person. Apart from spiritual aspect, pranayama improves the functions of the respiratory, cardiovascular and nervous systems in the most optimal way. This automatically improves the functioning of the heart and the circulatory system, increases the adaptive abilities of the body, enhances the processes of digestion and excretion, supports the elimination of toxins, etc. [22-26].

The aim of the study was to develop a set of Hatha yoga breathing exercises for active acclimatization of athletes to the high altitude conditions, during the preparatory period of sports training of climbers.

Methods and organization. Research methods: analysis of scientific and methodological literature; study and analysis of archival materials on the research topic; physiological measurement methods: heart rate monitoring, spirometry; pedagogical experiment; methods of mathematical and statistical analysis (comparison of data with the Student's t-test).

26 climbers participated in the study. Age – 20-35 years, gender – 11 women and 15 men. Sports qualification – from the III category to the II category.

The test subjects were engaged in a set of breathing exercises, which included the following:

1) Nadi Shodhana (alternate breathing through the left and right nostrils) – balances the nervous system and increases concentration.

2) Ujjayi (performed due to the work of the vocal cords) – warms up and gently massages the heart, prepares the body for the upcoming load.

3) Kapalabhati (emphasis on sharp exhalation and active work of the abdominal muscles) – tones the work of the brain, heart and internal organs.

4) Full yoga breathing (diaphragmatic breathing and chest breathing) – restores the body after performing Kapalabhati.

5) And again Nadi Shodhana – brings the autonomic system into balance.

Athletes passed an initial examination, where the following indicators were measured: LC (lung capacity), RV (respiratory volume), MRV (maximum respiratory volume), MPV (maximum pulmonary ventilation) etc., indicators of the respiratory system, heart rate at rest, functional tests of breathing on inhale and exhale. The subjects were instructed in detail on performing breathing exercises. Every day they performed exercises on their own according to the set.

During the month, breathing exercises were performed once a week under the supervision of a specialist, where they received methodological notes and guidelines for implementation.

Results and discussion. The measurements were carried out at rest before and after the 10-minute breathing test. The following changes have been identified.

When performing Nadi Shodhana, there was a slight decrease in the average value of the heart rate indicators after performing the respiratory set for a month (in each test) by 2 beats per minute. This breathing technique helps to balance the autonomic nervous system. For example, it slightly reduces this indicator with an increased heart rate.

When performing Ujjayi, a slight decrease in heart rate was also observed, which suggests that, in general, this type of breathing is perfectly mastered by athletes and does not cause an increase in heart rate, but achieves a positive effect for the nervous system and increases concentration.

Kapalabhati is performed by sharp and short exhalations through the nose, while the abdominal muscles contract as much as possible. The effect of this breathing exercise in the group is manifested by a slight increase in blood pressure and an increase in heart rate. Kapalabhati stimulates the sympathetic nervous system, increases the brain activity, has a cleansing and toning effect and massages the heart and internal organs.

When performing full yoga breathing, there was a slight decrease in the average heart rate for the group after the exercise in each test by 4-5 beats per minute. The obtained results of the use of breathing exercises by climbers shows a positive effect on the nervous and cardiovascular system of a person, thereby helping athletes to adjust to the high altitude conditions in the best way.

When assessing the differences in the average values of the two samples according to the calculations of the respiratory system indicators (unrelated samples) with the Student's test, reliable results ($p<0.01$) were revealed.

From the statistical analysis of the indicators of the functional breathing tests among men, the following can be seen: an increase in the arithmetic mean in the 3rd and 4th tests in the inhalation delay by an average of 7.9 seconds and 24.4 seconds from the arithmetic mean in the 1st test. The standard deviation of the mean in the inhalation delay ranges from ±1.6 to ±0.5, the exhalation delay – between ±1.1 and ±0.4.

From the statistical analysis of the indicators of the functional breathing tests among women, the following can be seen: an increase in the arithmetic mean in the 2nd, 3rd and 4th tests in the inhalation delay by an average of 10 seconds from the arithmetic mean in the 1st test. The standard deviation of the mean for the inhalation delay ranges from ±1.5 to ±1.1 s, the exhalation delay – between ±0.9 and ±0.4 s. There is a tendency for the results of the average value to increase in the whole group in the inhalation and exhalation delay from the initial

level. The difference between the inhalation delay between the initial level and the 4th test was 26 s. The result in the exhalation delay between the initial level and the 4th test also increased by 13 s.

Comparative characteristics of the increase in the arithmetic mean indices of the respiratory system in % among men showed an increase in in the LC by 8% from the initial data, in the second and third – by 23% and 24%. A small result in the 4th test – an increase of only 9% – can be explained by the fact that 2 athletes out of 5 were examined after a cold and did not have time to recover.

The increase in RV was 51%, in inspiratory capacity (IC) – 42% at the end of the month from the initial result. In case of MRV with the MPV, the increase is insignificant – 23% on average, in MRV alone – 16%, the respiratory rate (RR) increase was 20% on average.

There is also a positive tendency among men in the inhalation delays (breathing test on inhale) – by 56.8% of the initial level and the 4th week, and in the exhalation delays (breathing test on exhale) – by 45.1% of the initial level and the 4th week.

In the results we obtained among women in the comparative characteristics of the increase in the arithmetic mean indicators of the respiratory system in % of the initial data, during the month of examination we observe a stable increase in all indicators of the respiratory system. In LC, the increase was 39.3%, in RV – 57.5%, in IC – 36%. In case of MPV (32%), MRV (37%), RR (30.8%), the increase is slightly larger and more stable than in men.

We have also identified positive dynamics in the inhalation delays (breathing test on inhale) – by 59.6% of the initial level and 4th week, and the exhalation delays (breathing test on exhale) – by 37.9% of the initial level and the 4th week.

Conclusion. As a result of the conducted research, it can be concluded that the human body's resistance to mixed hypercapnia and hypoxia increases, reflecting the general state of the body's oxygen-supplying systems in the high altitude conditions.

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FEATURES OF THE FUNCTIONAL STATE OF THE VEGETATIVE MUSCULAR ACTIVITY SUPPORT SYSTEMS IN ELITE ATHLETES OF VARIOUS SPORTS IN THE MIDDLE ALTITUDE

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Annotation. The training process in the conditions of the middle altitude has a number of positive advantages, the most important of which is to increase the functionality and performance of athletes. At the same time, the adaptation of the athletes' body to environmental conditions is often accompanied by stress of functional systems. The aim of the work was to study the features of the functional state of the vegetative muscular activity support systems in elite athletes of various sports in the middle altitude. The results obtained demonstrated a greater stress of the autonomic nervous regulation in baseball players. At the same time, the athletes of underwater sports revealed a decrease in the level of blood oxygen saturation. The hemodynamic parameters of all athletes were within the normal range. However, higher parameters were identified in athletes of cyclic sports in comparison with acyclic and situational ones.
Keywords: athletes, middle altitude, adaptation, track-and-field, weightlifting, triathlon, boxing, underwater sports, baseball, ski mountaineering, sudomotor analysis, hemodynamics, heart rate variability.

Introduction. The high efficiency of the training process in the middle altitude conditions is associated with an increase in the functional reserves and capabilities of the athletes' body [1-3]. Scientists note that such trainings are highly specific and increase the level of fitness in athletes of cyclic sports that train endurance [4-5]. Along with this, intensive training in the middle altitude without taking into account the functional state of athletes causes a high risk of strain of adaptation processes and deterioration of the functional state [6-7]. In this connection, the study of mechanisms and signs of the adjusting systems of vegetative support of athletes' muscular activity to the middle altitude conditions during intense physical loads is a relevant direction in sports medicine and sports physiology [8-9].

The aim of the work was to study the features of the functional state of the vegetative muscular activity sup-port systems in elite athletes of various sports in the middle altitude,

Methods and organization. The study was conducted at the Center of Biomedical Technologies, FSBI "North-Caucasian Federal Research-Clinical Center of the FMBA of Russia" in the city of Kislovodsk on the Maloe Sedlo Mountain (height – 1240 m) during training camps for 3-5 days of training at the DSBI "Yug Sport". The study involved athletes of the following specialties: track-and-field (7 people), weightlifting (7 people), underwater sports (13 people), baseball (26 people), taekwondo (6 people), ski mountaineering (17 people), boxing (10 people), triathlon (7 man). 93 people participated, 36 of them are women, 57 are men. Qualification of athletes – Candidate for Master of Sports (CMS), Master of Sports (MS), Master of Sports of International Class (MSMC). The average age – 23.2±4.9 years.

The study of the functional state of athletes was carried out on the ESTECK System Complex (LD Technology, USA) hardware and software complex. The following indicators were analyzed: 9-10 SDC+, 10-9 SDC- – skin-galvanic reaction in the "head" segment; 11-12 SDC+, 12-11 SDC- – skin-galvanic reaction in the "hands" segment; 13-14 SDC+, 14-13 SDC- – skin-galvanic reaction in the "legs" segment; HF – heart rate variability (HRV) capacity in the high frequency range of 0.15-0.4 Hz; LF –

HRV capacity in the low frequency range of 0.04-0.15 Hz; LF/HF – balance of sympathetic/parasympathetic nervous system activity; stress index – the oxygen demand of the heart muscle associated with the work of the heart; SDNN – standard deviation of cardiointervals; SpO_2 – the level of arterial blood oxygen saturation; stiffness index – an indicator of the stiffness of the large arteries; reflection index - an indicator of the stiffness of small and medium arteries; AI – augmentation index; PVR – peripheral vascular resistance; CO – cardiac output; CI – index of volumetric blood flow rate; MAP – mean arterial pressure; VO_2 – indicator of impaired oxygen uptake from the microcirculation system**.**

Statistical processing of the data was carried out using the Statistica 10.0 software. The non-parametric Mann-Whitney U-test was used to assess the differences between the two independent groups.

Results and discussion. The sudomotor function analysis in athletes in the first days of their stay in the middle conditions have revealed higher values in swimmers in the "9-10 SDC+ head" segment (43.0±6.7 microSi) and in the "10-9 SDC- head" segment (42.9±6.6 microSi) in comparison with taekwondo athletes ("9-10 SDC+ head" – 18.3±6.3 microSi, $p \leqslant 0.04$) and ski mountaineers ("9-10 SDC+" – 22.9±3.9 microSi, $p \leqslant 0.03$) ("10-9 SDC-" – 22.5±4.0 microSi, $p \leqslant 0.02$). In addition, taekwondo athletes in the "9-10 SDC+ head" segment (18.3±6.3 microSi) and in the "10-9 SDC- head" segment (18.8±6.4 microSi) have lower skin-galvanic reaction rates than baseball players ("9-10 SDC+" – 45.2±3.3 microSi, $p \leqslant 0.004$; "10-9 SDC-" – 45.1±3.4 microSi, $p \leqslant 0.04$). In the "10-9 SDC- head" lead, statistically significant differences were revealed between the indicators of ski mountaineers (22.5±4.0 microSi) and boxers (37.6±5.7 microSi, $p \leqslant 0.04$) (fig. 1).

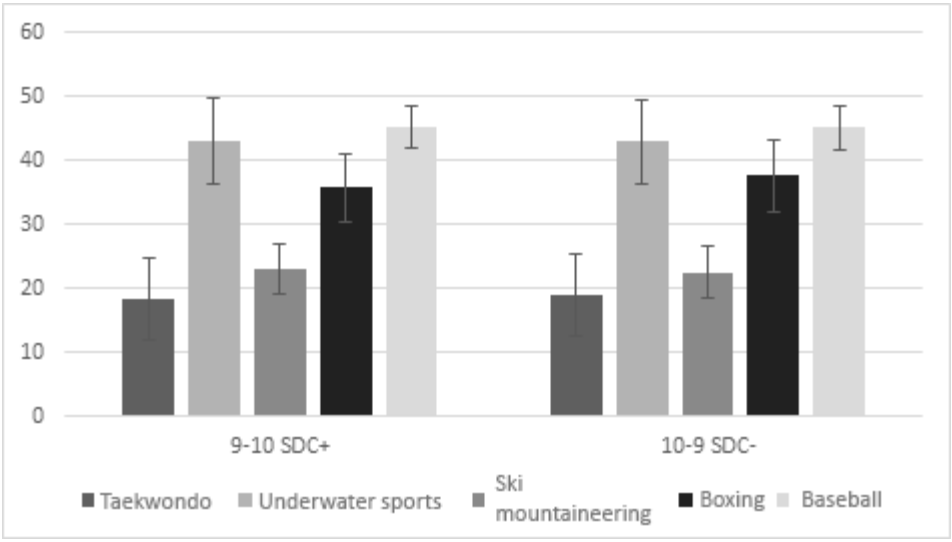

Fig. 1. Comparative analysis of the parameters of the sudomotor function in the "head" segment of athletes specializing in taekwondo, underwater sports, ski mountaineering, boxing, baseball in the first days of their stay in the middle altitude

The highest segmental reaction at hand level in the "11-12 SDC+" lead was registered in baseball players (71.4±0.9 microSi), which differed from the indicators of taekwondo athletes (65.0±2.3 microSi, $p \leqslant 0.03$), swimmers (64.9±2.2 microSi, $p \leqslant 0.006$), weightlifters (63.2±4.1 microSi, $p \leqslant 0.02$) and boxers (55.0±4.5 microSi, $p \leqslant 0.0001$). The lowest values of the skin-galvanic reaction in this lead were found in boxers. They differed not only from the parameters of baseball players, but also from similar indicators of track-and-field athletes (68.3±1.9 microSi, $p \leqslant 0.02$) and triathlon athletes (67.5±3.1 microSi, $p \leqslant 0.02$) (fig. 2).

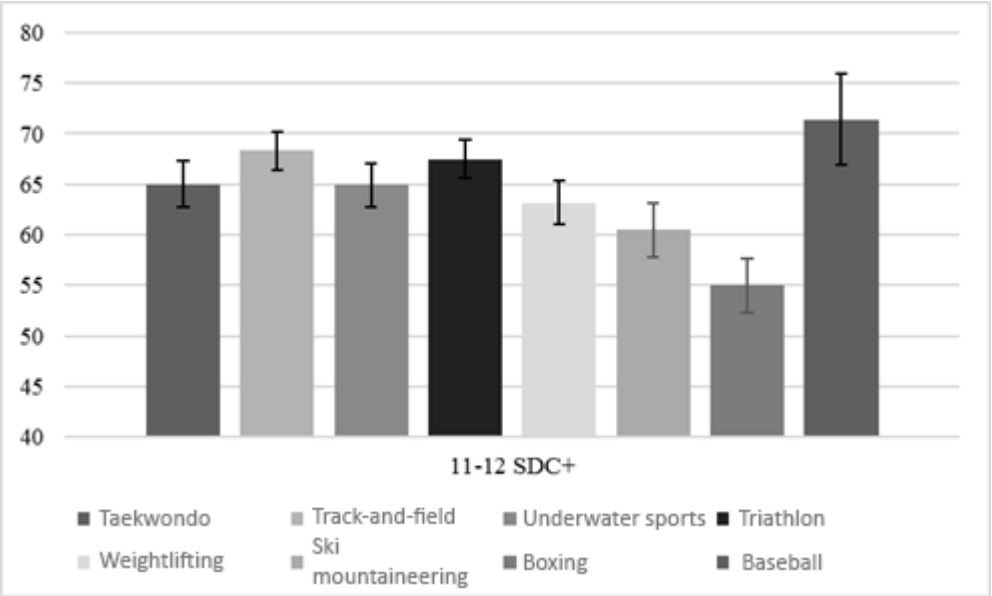

Fig.2. Comparative analysis of the parameters of the sudomotor reaction in the "hands" segment in the "11-12 SDC+" lead in athletes specialized in taekwondo, track-and-field, underwater sports, triathlon, weightliftinh, ski mountaineering, boxing, baseball in the first days of their stay in the middle altitude

Analysis of the sudomotor reaction in the "hands" segment of the "12-11 SDC-" has shown higher parameters in track-and-field athletes (82.9±1.5 microSi) in comparison with athletes of underwater sports (74.6±3.0 microSi, $p \leqslant 0.04$), triathlon (74.0±3.1 microSi, $p \leqslant 0.02$), ski mountaineering (69.0±3.1 microSi, $p \leqslant 0.01$), boxing (65.1±5.3 microSi, $p \leqslant 0.006$). In addition, there were significant differences between the groups of boxers (65.1=5.3 microsSi) and baseball players (79.2=1.0 microSi, p=0.01) (fig. 3).

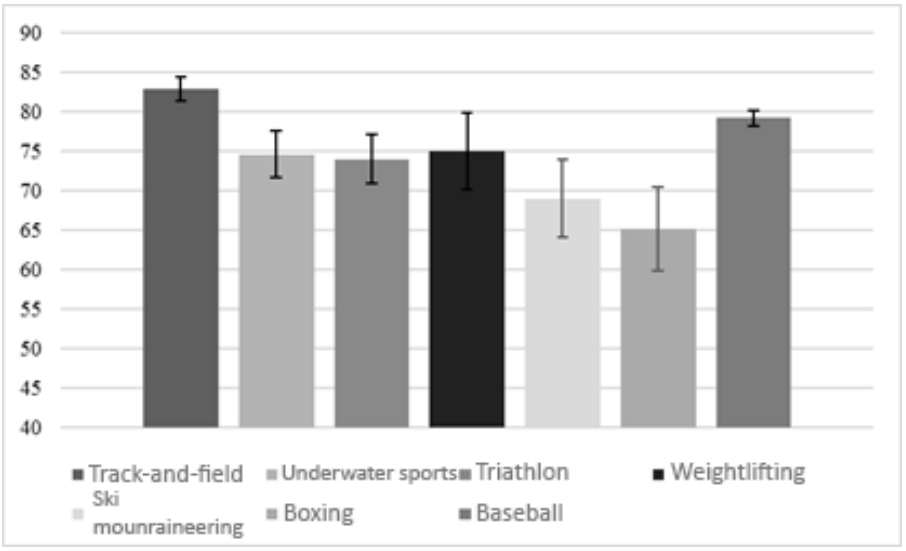

Fig. 3. Comparative analysis of the parameters of the sudomotor reaction in the "hands" segment in the lead "12-11 SDC-" in athletes of specialized in track-and-field, underwater sports, triathlon, weightlifting, ski mountaineering, boxing, baseball in the first days of their stay in the middle altitude

A study of galvanic skin reaction at the level of the legs in the "13-14 SDC+" lead revealed that the parameters of the sudomotor reaction of boxers (62.0±2.1 microSi) differ from similar parameters of triathlon athletes (68.5±1.6 microSi, p⩽0.02) and baseball players (68.7±1.9 microSi, p⩽0.02). In the "14-13 SDC-" lead, the indicators of track-and-field athletes (85.3±2.9 microSi) are higher than those of swimmers (74.8±2.2 microSi, p⩽0.02), triathlon athletes (76.2±2.0 microSi, p⩽0.04) and boxers (75.0±3.7 microSi, p⩽0.03).

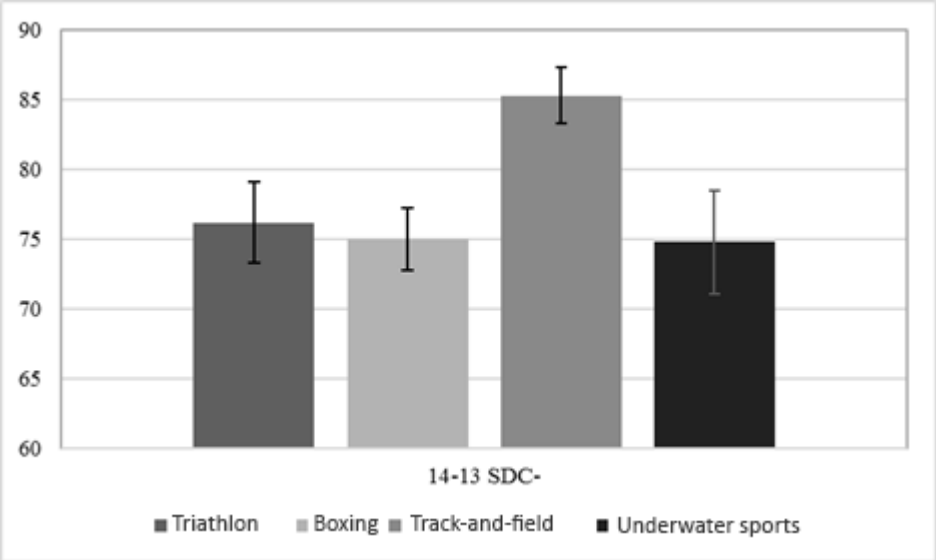

Fig. 4. Comparative analysis of the parameters of the sudomotor reaction in the "hands" segment in the "14-13 SDC-" lead in athletes specialized in track-and-field, underwater sports, triathlon, boxing, in the first days of their stay in the middle altitude

The HRV study revealed that the heart rate of baseball players (84.1 ± 1.7 beats/min) is higher than in triathletes (76.4± 4.3 beats/min, p⩽0.01). In addition, the values of the standard deviation of the duration of cardiac intervals in baseball players (48.3±2.4 ms) are lower in comparison with swimmers (59.8±4.4 ms, p⩽0.04) and track-and-field athletes (58.1±4.6 ms, p⩽0.01).

The study of the HRV capacity in the high and low frequency range revealed higher values of low frequency waves in baseball players (39.0± 2.2 Hz) in comparison with swimmers (29.7± 3.4 Hz, p⩽0.007). In addition, the values of the ratio of low-frequency to high-frequency waves are also higher in baseball players (1.4±0.1 Hz), which indicates a greater activity of the sympathetic department of vegetative nervous regulation than swimmers (0.9±0.1 Hz, p⩽0.01). This is also evidenced by higher values of the stress index (baseball – 142.2 ±13.0, scuba diving – 111.4 ± 21.0, p⩽0.05).

Hemodynamic parameters in the first days of stay in the middle altitude also differed among athletes of different sports. Thus, it was found that the stiffness index of the large arteries in track-and-field athletes (6.6±0.2) is higher than in taekwondo athletes (5.9± 0.1 m/s, p⩽0.02), weightlifters (6.0±0.01 m/s, p⩽0.04) and boxers (5.8± 0.2 m/s, p⩽0.02).

Statistically significant differences in the values of peripheral vascular resistance were found between the athletes of the underwater sports (1253±43 din*s/cm^2), baseball players (1053.8±24.5 din*s/cm^2, p⩽0.0004), taekwondo athletes (1043.6±41.4 din*s/cm^2, p⩽0.009) and weightlifters (1247.9±49.3 din*s/cm^2, p⩽0.02) (fig. 5).

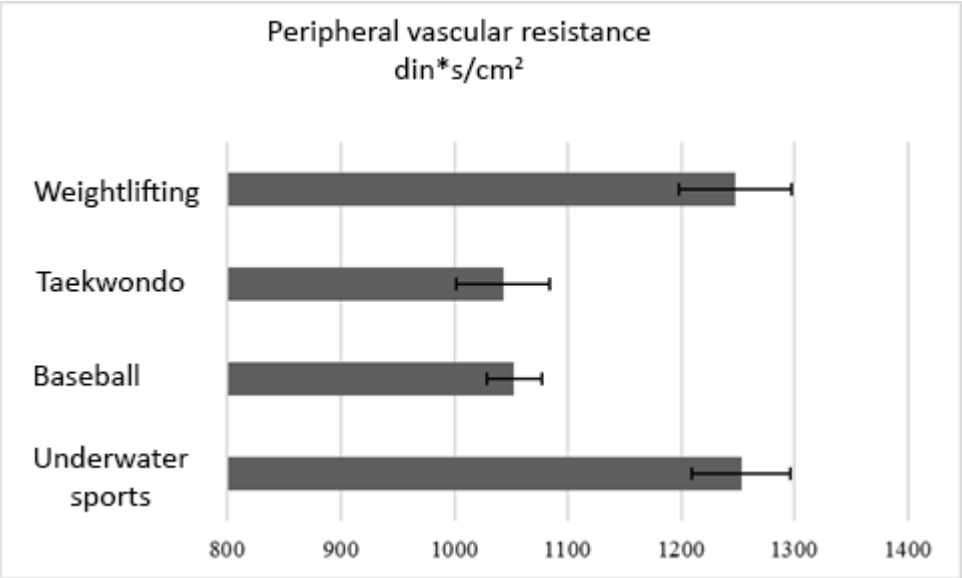

Fig. 5. The peripheral vascular resistance parameters in athletes of the following groups: weightlifting, taekwondo, baseball, underwater sports in the first days of their stay in the middle altitude

The parameters of cardiac output in weightlifters (5.4±0.2l) are lower than in taekwondo (6.4± 0.3 l, p⩽0.03) and triathlon athletes (6.1± 0.2 l, p⩽0.04). The values of cardiac output in track-and-field athletes (7.0±0.1 l) are higher than in swimmers (5.8±0.2l, p⩽0.0001) and triathlon athletes (6.1±0.2l, p⩽0.006).

The index of volumetric blood flow velocity in swimmers (3.1±0.1 l/min/m^2) is lower than in taekwondo athletes (3.5±0.1 l/min/m^2, p⩽0.03) and baseball players (3.5±0.1 l/min/m^2, p⩽0.003). In addition, it was found that the index of volumetric blood flow rate in athletes (3.6 ± 0.1 l/min/m^2) is higher than in swimmers (3.1± 0.1 l/min/m^2, p⩽0.005), ski mountaineers (3.2±0.1 l/min/m^2, p⩽0.02), weightlifters (3.1±0.1 l/min/m^2, p⩽0.006) and boxers (3.2±0.1 l/min/m^2, p⩽0.009).

The level of blood oxygen saturation in underwater athletes (94.1 ±0.5%) is lower than in baseball players 95.2± 0.2%, p⩽0.05).

The parameters of systolic arterial pressure in baseball players (129.4±2.5 mm of Hg) are higher than in triathlon athletes (117.9±2.7 mm of Hg, p⩽0.02), swimmers (119.5±3.1 mm of Hg, p⩽0.02) and track-and-field athletes (115.1±3.7 mm of Hg, p⩽0.01). The values of diastolic arterial pressure in swimmers (74.7±1.3 mm of Hg) are higher than in taekwondo athletes (66.5±1.8 mm of Hg, p⩽0.005), weightlifters (69.6±1.1 mm of Hg, p⩽0.03) and boxers (67.9±1.9 mm of Hg, p⩽0.03).

Conclusion. Thus, the HRV data indicate a greater stress of the regulatory systems during the period of adaptation to the middle altitude conditions in baseball players in comparison with athletes of other sports. This is evidenced by higher indicators of sudomotor analysis, heart rate, stress index, the ratio of low-frequency waves to high-frequency waves when analyzing the capacity of the HRV spectrum, as well as lower parameters of the standard deviation of the duration of cardiac intervals. At the same time, a decrease in the level of blood oxygen saturation in underwater sports athletes was found, which is most likely due to the simultaneous influence of a number of factors – staying in the middle altitude conditions (low oxygen content in the air) and the systematic effect of training loads (the systematic occurrence of acute hypoxia due to breath retention when diving). The hemodynamic parameters of athletes in the first days of their stay in the middle altitude were within the normal range. However, it was found that such indicators as the index of volumetric blood flow velocity, the in-

dex of stiffness of large arteries and cardiac output are predominantly higher in athletes of cyclic sports in comparison with acyclic and situational sports, which is connected with the direction of the training process and the features of adaptation of the cardiorespiratory system to specific physical loads.

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COMPLEX APPLICATION OF MAGNET, HYDRO- AND PRESSOTHERAPY FOR RESTORATION OF THE FUNCTIONAL STATE OF BASEBALL PLAYERS UNDER THE CONDITIONS OF INTENSE TRAINING IN THE MIDDLE ALTITUDE

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Annotation. The purpose of this work was the scientific substantiation of the comprehensive application of magnet, hydro- and pressotherapy to restore the functional state of baseball players under conditions of intense training in the middle altitude. The study involved 22 highly qualified male baseball players. During 14-day training camps in the middle altitude (Kislovodsk, altitude of 1240 m above sea level) in a specialized sports base, athletes had intense training loads (2 times a day), after training, the athletes under-went a set of procedures, including magnet therapy, hydrotherapy and pressotherapy, the course of rehabilitation treatment included 7 of the abovementioned procedures. For scientific substantiation of the complex's effectiveness, the functional state of the musculoskeletal system was identified using the methods of rheography and electromyography. According to the results of the study, the use of the course of restorative procedures had a positive effect on the functional state of the musculoskeletal system of baseball players during intense training loads in the middle altitude, contributing to the improvement of peripheral hemodynamics of the lower extremities, increasing vascular tone and venous out-flow, to a greater extent in the right leg. We have also noted the prevention of deterioration in the functional state of the neuromuscular system, which occurs under the influence of performing great training loads and insufficient recovery.

Keywords: functional state, athletes, neuromyography, vasography, magnet therapy, hydrotherapy, hardware massage, middle altitude, adaptation.

Introduction. One of the important factors in ensuring the effectiveness of the process of training athletes and their medical and biological support is an effective system of recovery and medical rehabilitation [1-3], which can be provided by the availability of scientifically sound technologies with the use of therapeutic programs using modern means of water and physiotherapy, as well as mechanotherapy.

The musculoskeletal system (MSS) and the neuromuscular system, ensuring the performance of movements, are maximally involved and limit the effectiveness in all sports, the autonomic support of motor actions is carried out by the cardiovascular and respiratory systems. If the systems are overstressed, there may be a failure in the balance between the resources of the functional systems of the body and their adaptive capabilities. "Functional" and later structural changes may appear, which may cause states of fatigue and overtraining, so-called "fatigue" injuries or damage [4-6].

In this connection, it is relevant to develop technologies for the comprehensive application of various physical factors for the recovery and medical rehabilitation of athletes. Particularly the development of recovery programs and rehabilitation of athletes during training in extreme environmental conditions, which are the conditions of the middle altitude of the North Caucasus (Kislovodsk), are relevant.

The purpose of this work was the scientific substantiation of the comprehensive application of magnet, hydro- and pressotherapy to restore the functional state of baseball players in conditions of intensive training in the conditions of the middle altitude.

Methods and organization. The study involved 22 highly qualified male baseball players.

The characteristics of the electroactivity of athletes' muscles at rest were identified using the method of stimulation electromyography (EMG). To register motor responses from the

extensor digitorum brevis, innervated by the peroneal nerve, stimulation was performed at the points: "tarsus", "head of the fibula", "popliteal fossa" using a 4-channel hardware and software complex (HSC) "Neuro-MVP" manufactured by "Neurosoft" (Ivanovo). Electrical stimulation was performed with rectangular pulses, the stimulus time was 0.2 ms, the current was selected individually in the range of 15-30 mA.

The study of the blood flow of the lower extremities was carried out on the thigh-shin-foot segment on the "Valenta" rheograph (St. Petersburg).

During the 14-day training camps in the middle altitude (Kislovodsk, altitude of 1240 m above sea level) in the specialized sports base, athletes had intensive training loads (2 times a day). After training, athletes underwent a set of procedures including magnet therapy, hydrotherapy and pressotherapy, the course of rehabilitation treatment included 7 of the above-mentioned procedures.

Magnet therapy was performed on a Physiomed Mag-Expert device with coil of 60 cm, the impact area – the knee and ankle joint, the exposure time – 15 minutes, the magnetic flux density is 0.006 T, the frequency is 25 Hz. The course of treatment is 7 procedures per day. For hydrotherapy, the “Beka hospitec” four-chamber jet-contrast bath for hands and feet was used, the procedure time is 10 minutes, the temperature of hot water is 38 ^{o}C, cold water – 14 ^{o}C, the cycle – 45 s, the flow – 220 l/min, the pressure – 1 atm. The course of treatment is 7 procedures per day. Pressotherapy was performed on a 12-channel BTL-6000 LYMPHASTIM 12 device, Physiological mode (physiological therapy), the procedure area – the lower extremities, the procedure time – 30 minutes, the cuff pressure – 60 mm of Hg.

All athletes gave informed consent to participate in the study in accordance with the Helsinki Declaration of the World Medical Association Ethical Principles for Medical Research Involving Human Subjects (2013), as well as permission to process personal data. The study was approved by the Commission on Bioethics of the FSBI NCFRCC of the FMBA of Russia.

Statistical data processing was performed using the Statistica 13.0 software, differences between groups were identified with the Mann-Whitney nonparametric U-test for independent variables, differences in the dynamics of indicators of the main and control groups at the beginning and end of training camps – with the Wilcoxon nonparametric test for dependent variables.

Results and discussion. A study of the blood flow of the lower extremities in male baseball players revealed that in the main and control groups, hemodynamic indicators at the beginning of the training camp (before the use of the complex of rehabilitation measures) did not differ significantly. After applying the complex of restorative procedures, including magnet, hydro- and pressotherapy, statistically significant changes in rheographic parameters occurred in the athletes of the main group (fig. 1-4).

In the left foot, the indices of elastic modulus (before – 12.7±2.3%, after – 15.2±3.0%, $p<0.03$), diastolic index (before – 0.4±0.2, after – 0.5±0.1, $p<0.03$) and left ventricular filling pressure (before – 20.1±6.5 mm of Hg, after – 24.6±3.6 mm of Hg, $p<0.03$). In the right foot, the elastic modulus increased (before – 13.3±2.3%, after – 15.8±2.9%, $p<0.02$), dicrotic index (before – 0.3±0.2, after – 0.5±0.1, $p<0.002$), diastolic index (before – 0.3±0.1, after – 0.5 ±0.1, $p<0.004$) and the left ventricular filling pressure (before – 20.0±4.8 mm of Hg, after – 25.3±2.8 mm Hg, $p<0.003$). In the left lower leg, the rheowave transmission time increased from 0.1±0.0 to 0.2±0.0 s, in the right lower leg, the change in this indicator was less pronounced. There were no statistically significant changes in hemodynamics of the lower extremities in the control group.

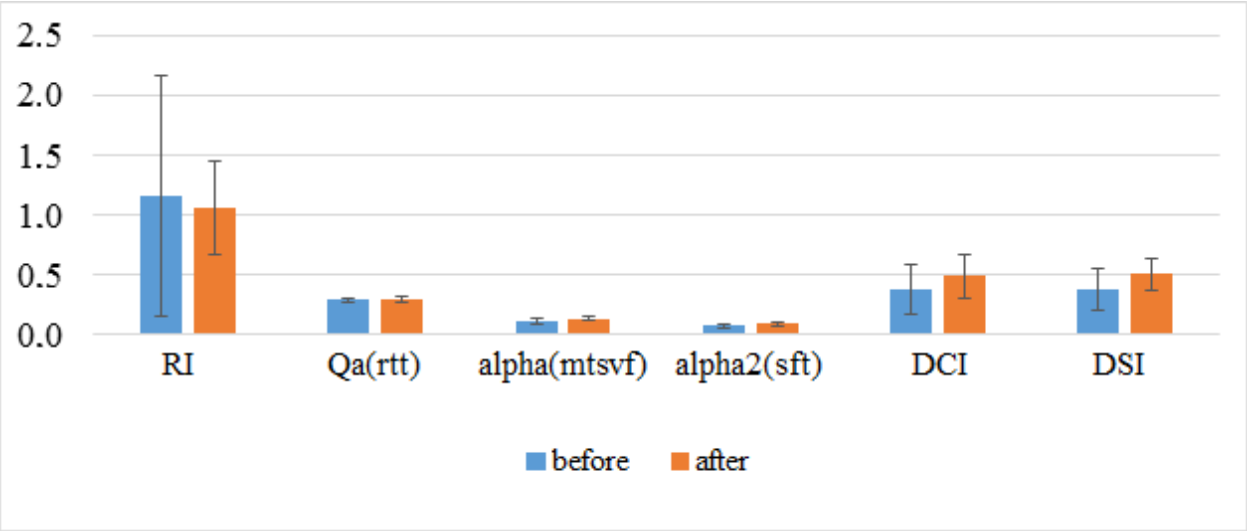

Fig. 1. Indicators of rheography of the left foot in male baseball players before and after the course of rehabilitation procedures during intensive training in the middle altitude

Note: RI – rheographic index; Qa (rtt) – rheowave transmission time; alpha (mtsvf) – maximal time of systolic vessel filling; alpha2 (sft) – slow filling time; DCI – dicrotic index; DSI – diastolic index

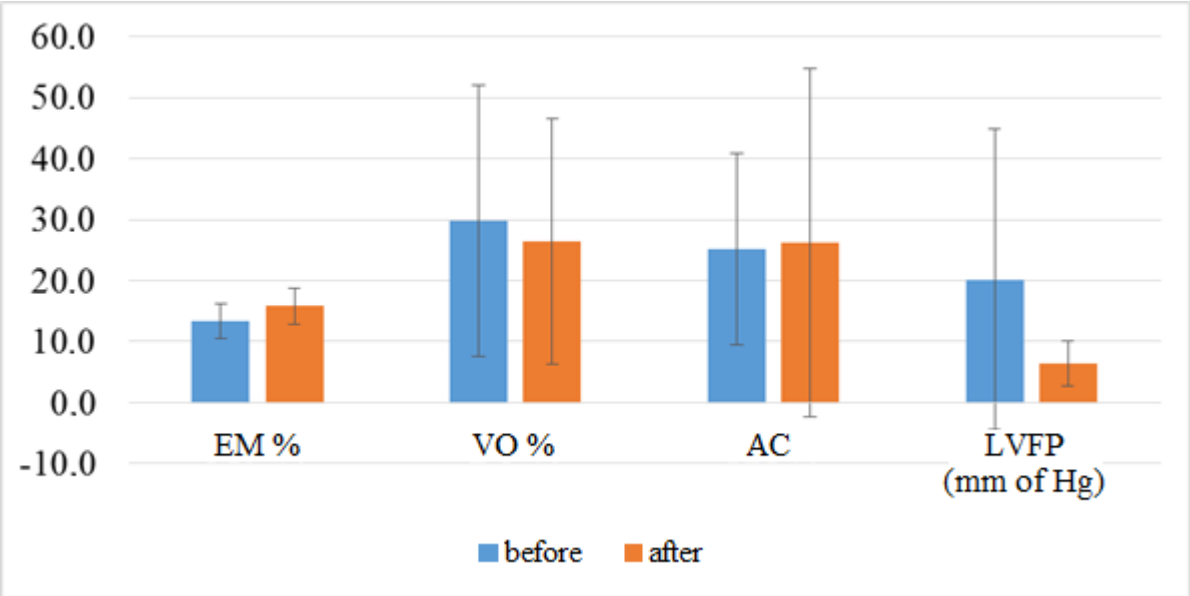

Fig. 2. Indicators of rheography of the left foot in male baseball players before and after the course of rehabilitation procedures during intensive training in the middle altitude

Note: EM % – elastic modulus, VO – venous outflow; AC – coefficient of asymmetry; LVFP – left ventricular filling pressure

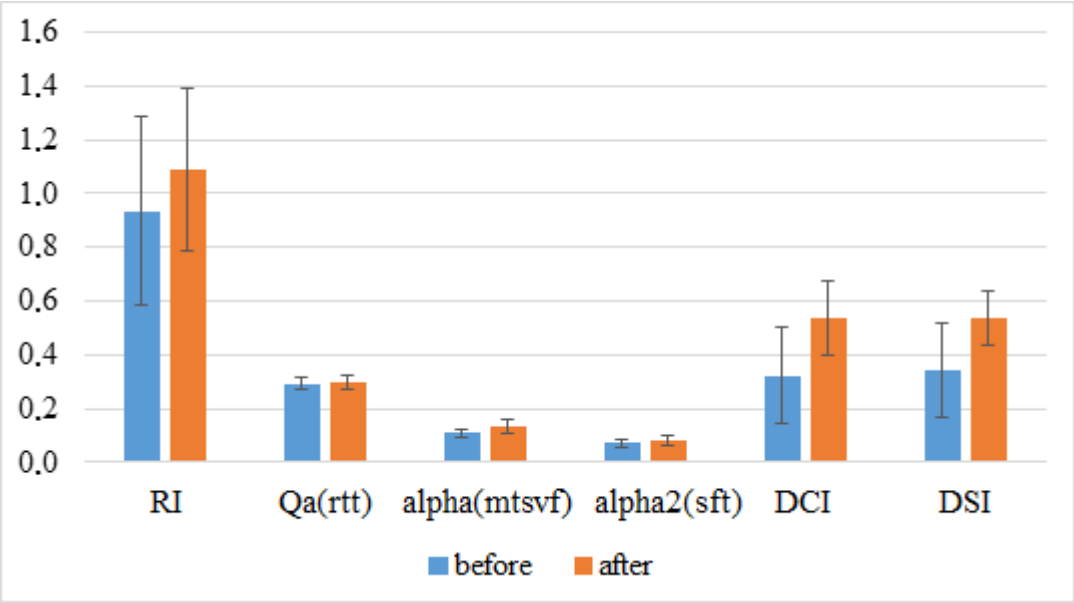

Fig. 3. Indicators of rheography of the right foot in male baseball players before and after a course of rehabilitation procedures during intensive training in the middle altitude

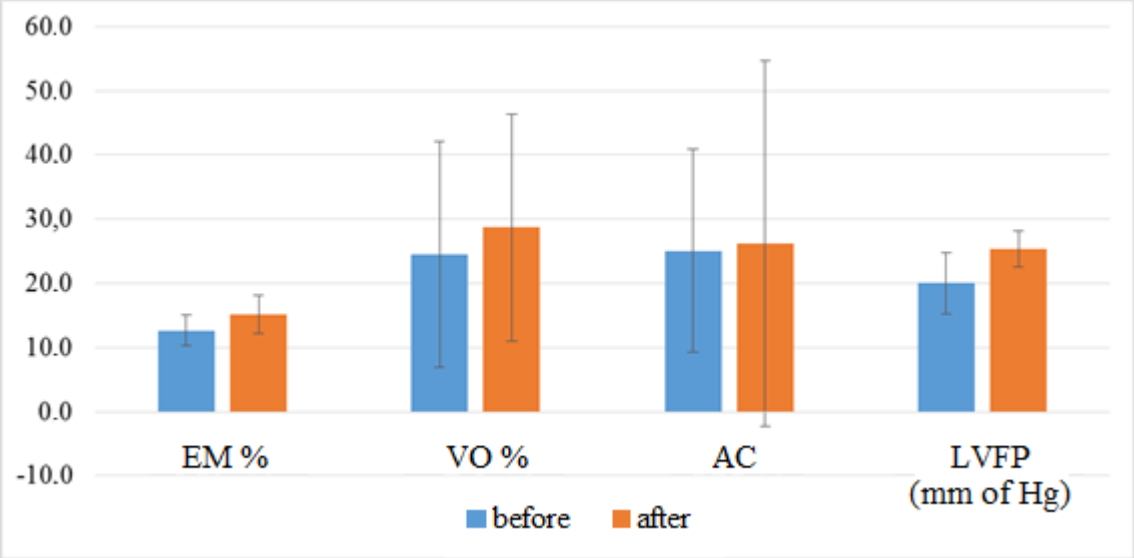

Fig. 4. Indicators of rheography of the right foot in male baseball players before and after the course of rehabilitation procedures during intensive training in the middle altitude

Consequently, the use of a course of restorative procedures had a positive effect on the functional state of the musculoskeletal system of baseball players during intense training loads in the middle altitude, contributing to the improvement of peripheral hemodynamics of the lower extremities, increasing vascular tone and venous outflow, to a greater extent in the right leg.

The study of the functional state of the neuromuscular system according to the stimulation EMG data in athletes of the main and control groups before the use of the complex of restorative procedures did not reveal statistically significant differences. After undergoing a complex of restorative procedures (table), latency decreased in athletes of the main group in the “popliteal fossa” stimulation point and the nerve conduction velocity increased. No statistically significant changes in EMG parameters were detected in the remaining stimulation points.

Table

Indicators of electromyography of the lower extremities in male baseball players before and after the course of rehabilitation procedures during intensive training in the middle altitude

Indicators	Main group		p	Control groop		p
	Before	After		Before	After	
The right head of the fibula						
Velocity, m/s	51.9±3.1	51.5±5.9	0.03	55.7±3.9	49.8±3.1	0.03
Right popliteal fossa						
Latency, ms	12.3±1.1	12.0±0.9	0.003	11.7±1.2	12.0±0.9	
Duration, ms	7.0±0.8	7.0±1.1		6.4±0.8	7.2±0.8	0.03
Velocity, m/s	62.1±7.8	69.4±13.3	0.08	72.5±9.1	66.6±14.7	
The left head of the fibula						
Duration, ms	6.6±0.8	6.5±0.8		6.7±0.9	7.1±0.8	0.03
Left popliteal fossa						
Duration, ms	6.5±1.0	6.5±1.0		6.3±0.7	7.1±0.7	0,03
Velocity, m/s	63.1±10.0	64.3±12.9		68.7±11.4	57.3±15.9	0.04

In the control group, apparently, due to heavy training loads and under-recovery, athletes had a deterioration in EMG parameters (table). In the “right head of the fibula” stimulation point, the nerve conduction velocity decreased. In the “right popliteal fossa” and “left and right head of the fibula” stimulation points, the M-response duration increased. In the “left popliteal fossa” stimulation point, the nerve conduction velocity decreased.

Therefore, the application of the developed set of procedures in athletes of the main group contributed to the prevention of deterioration of the indicators of the functional state of the neuromuscular system, which occurs due to the performance of great training loads and insufficient recovery. In the athletes of the control group (who did not receive complex restorative procedures), these negative changes were pronounced.

Conclusion. Thus, in the conducted clinical study, using rheography and electromyography methods, the effectiveness of the complex application of magnet, hydro- and pressotherapy (7 procedures each) for restoring the functional state of baseball players in the conditions of intensive training in the Middle altitude was proved. The use of these procedures contributed to the improvement of hemodynamics of the lower extremities, mainly the leading right leg, as well as the manifestation of a negative fatigue-based decrease in EMG parameters of the speed of muscle conduction, increased latency and duration of the M-response.

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RESTORATION OF AMPLITUDE-POWER CHARACTERISTICS OF THE LOWER LIMB OF BOXERS AFTER RUPTURE OF THE ANTERIOR CRUCIATE LIGAMENT AT THE STAGE OF SPORTS REHABILITATION

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Annotation. The article presents the content of a comprehensive program of physical rehabilitation for boxers after reconstruction of the anterior cruciate ligament at the stage of sports rehabilitation, aimed at restoring the amplitude-strength characteristics of the knee joint.
Keywords: boxers, anterior cruciate ligament rupture, sports rehabilitation stage.

Introduction. Among all injuries of the musculoskeletal system, knee joint injuries of athletes occupy about 50% [1], among which cruciate ligament injuries are on second place in incidence. Damage to the anterior cruciate ligament and meniscus occurs in 70% of cases [2]. This injury is one of the most serious ones, as the supporting ability of the limb and the walking process are disrupted, which leads to a restriction of the patient's motor activity and a decrease of social adaptation [3].

Rupture of the anterior cruciate ligament (ACL) is a serious injury requiring immediate medical care, rapidly reducing the mobility and performance of athletes, requiring a systematic approach to recovery and the use of comprehensive rehabilitation for the functional restoration of the injured limb [4]. Rehabilitation measures usually take from 5 months to 1 year, however, even after the restoration of limb function, there is a high percentage of complications associated with the consequences of injuries and diseases caused by knee joint injury [3-4], mainly related to a decrease in the amplitude-power characteristics of the injured joint. At the same time, the risk zone of injury recurrence is represented by the stage of sports rehabilitation – the period of transition to full-fledged training sessions, in which the intensification of physical loads initiated by a coach or athlete can occur without taking into account the functional fitness of the injured joint to the proposed loads.

It should be taken into account that as a result of the injury, the athlete's performance and fitness noticeably decrease, while the athlete at the stage of sports rehabilitation after the removal of immobilization overestimates his capabilities, which can lead to overstrain, deterioration of the general condition and slowing down the recovery process [3].

In connection with the above, the urgency of restoring the amplitude-strength characteristics of the knee joint of boxers after reconstruction of the anterior cruciate ligament at the stage of sports rehabilitation is identified.

Methods and organization. The functional state of the lower limb after reconstruction of the anterior cruciate ligament (ACL) during rehabilitation measures was studied by the dynamics of following indicators: the amplitude of flexion and extension of the knee joint, the strength of the muscles of the lower leg, the presence of pain syndrome at rest and during exercise, presented in a scaled score. We have identified the strength endurance of the lower leg muscles using manual muscle testing, in which 0 points corresponded to the absence of muscle contraction, 5 points corresponded to normal muscle strength. The amplitude of movement in the knee joint was registered with a goniometer. The evaluation scale is presented in table 1.

Table 1

Evaluation of the amplitude of movements in the knee joint

Condition	Norm	Limited movement		
		Minor	Moderate	Significant
Points	3	2	1	0
Flexion	30-45	46-50	51-60	>60
Extension	180-170	169-150	149-130	<130

The presence and severity of pain syndrome in the injured limb was assessed at rest and during physical loads on a visual analog scale (VAS), 10 points in total. The dynamics of the results of the study during the recovery measures were processed using mathematical statistics methods with the calculation of the average value, standard deviation, the level of confidence was calculated using the Wilcoxon T-test ($p<0.05$).

The study was conducted in the V.P. Ageev National Boxing Center (Moscow), the study involved athletes (n=8) professionally engaged in boxing, the level of sports qualification – Candidates for Masters of Sports (CMS) and Masters of Sports (MS). All participants were active athletes who have a high rating both in the Russian Boxing Tour and in the international arena. Criteria for inclusion in the study: sport – boxing; sports qualification – CMS, MS; diagnosis – rupture of the ACL; the period is no more than 3 months after the ACL reconstruction surgery; the stage of rehabilitation treatment is the stage of sports rehabilitation. The exclusion criteria are the presence of combined knee joint injuries, exceeding the period of post-surgical intervention for the ACL reconstruction for more than 3 months.

A preliminary study of the studied indicators demonstrates low amplitude values and indicators of the strength of the muscles flexing and extending the lower leg, a significant pain syndrome, especially pronounced during exercise (table 2).

The principles of constructing a program for restoring the amplitude-power characteristics of the knee joint in particular and the functional state of the musculoskeletal system as a whole, at the stage of sports rehabilitation, athletes had a differentiated type of physical activity depending on the morphofunctional state of the damaged link, the functional state of the body and the level of physical fitness.

Table 2

Initial results of the studied pain indicators and amplitude-power characteristics of the knee joint in boxers after the ACL reconstruction

Studied indicators	Pain assessment by VAS (points)		Strength of the flexor muscles of the lower leg (points)	Strength of the extensor muscles of the lower leg (points)	Estimation of the amplitude of movement (points)	
	At rest	Under loads			Flexion	Extension
Values of indicators	4.87±0.04	6.47±0.01	1.33±0.03	1.47±0.02	1,67±0,04	1,73±0,02

The program of functional recovery is designed for 4 weeks, included a comprehensive application of means and forms of physical rehabilitation.

The predominant importance in the recovery process of the amplitude-strength characteristics of the injured link of the musculoskeletal system was the use of physical exercises. Following general developmental exercises for all muscle groups, breathing exercises of a dynamic and static nature, special exercises for the injured link of the musculoskeletal system were used: passive, passive-active and active exercises performed with a free maximally possible

amplitude in the joints of the injured link, stretching exercises of a free and forced nature, exercises with a free and increasing amplitude in the joints of the injured link, exercises with gradually increasing resistance and weights, with subsequent relaxation of the loaded muscles.

At the beginning of the course, the exercises were performed with equipment that facilitates the performance of exercises (elastic expanders of varying degrees of rigidity, TRX loops, mechanotherapy devices), then the emphasis was placed on the correctness of the technique of performing exercises. After the restoration of the technical parameters of the structure of the exercises performed, further emphasis was placed on their complication by adding new elements, changing the initial position, conditions (unstable support, weights, reduction of the area and points of support, etc.) of the exercises, the use of equipment, etc. Successfully mastered elements were included in the technical elements of the main actions performed in boxing.

Exercises with a therapeutic and restorative purpose were used not only in the gyms, but also in the aquatic environment, in the form of hydro-kinesiotherapy, freestyle swimming with equipment, then with equipment and weights with a gradual increase in the distance covered.

After performing a training session or a set of exercises for therapeutic purposes, massage was applied to the muscles endured greater load in the training session, as well as the muscles of the injured segment. Along with this, athletes performed self-massage of muscles and joints after exercise and in the sets between them.

For fixing, limiting and anti-inflammatory purposes, kinesio taping of the injured link of the musculoskeletal system was used, the volume and technique of applying tapes were selected taking into account the individual characteristics of the functional state of the injured link of the musculoskeletal system of athletes.

Mechanotherapy, the use of block and pendulum type simulators aimed at restoring the amplitude of movement in the joints of the injured link (first free, then forced, with weights and resistance), the use of simulators (elliptical machine, stepper, exercise bike, rowing simulator, treadmill) were widely used. Elements and game exercises with a soccer ball were included, performed individually, in pairs and in small groups.

After the performed load, athletes were recommended a short rest in conditions of unloading the spine and an elevated injured link of the musculoskeletal system.

Meanwhile, we were solving tasks to restore impaired motor skills, professional skills with simultaneous recovery and development of physical qualities against the background of an increase in the functional state of the rehabilitated athlete.

The use of means and forms of physical rehabilitation was carried out under control not only in order to improve performance, but also to prevent physical overloads of the body of the injured link of the musculoskeletal system of athletes.

Results and discussion. After the physical rehabilitation program, boxers were retested the studied indicators (table 3).

There was a decrease in pain syndrome when performing loads, the results of pain assessment by VAS at rest significantly decreased (by 52%) from the initial values and, on average, amounted to 1.67±0.02 points, indicating only minor soreness. After the load, athletes identified an increase in pain, however, it reaches values of 4.87±0.03 points, which is (74%) below the initial values.

The reduction of pain in the knee joint of the injured limb is probably associated with the use of stretching, relaxation exercises, with the use of hydro kinesotherapy, therapeutic massage and self-massage, kinesio taping, which had an anti-edematous, anti-inflammatory, resorbing, regenerating effect.

Table 3

Comparison of the pain assessment results before and after the experiment

Indicators	X±σ		Difference in %	p<
	Before PR	After PR		
Assessment of pain at rest (points)	4.87±0.04	1.67±0.02	52	0.05
Assessment of pain during exercise (points)	6.47±0.01	4.87±0.03	74	0.05
Strength of the flexor muscles of the lower leg (points)	1.33±0.04	4.9±0.01	73	0.05
Strength of the extensor muscles of the lower leg (points)	1.47±0.02	4.8±0.01	69	0.05
Knee flexion amplitude (points)	1.67±0.04	3.0±0.02	58	0.05
Knee extension amplitude (points)	1.73±0.02	3.0±0.01	55	0.05

Note: PR – physical rehabilitation

There was an increase in the strength of the flexor (4.9±0.01 points) and extensor muscles of the lower leg (4.8±0.01 points), which reflects an increase in muscle strength endurance by 73% and 69% accordingly, approaching the values typical for normal muscle strength, estimated at 5 points in healthy athletes.

It should be noted that a significant increase in the strength of the flexor and extensor muscles of the lower limb is additionally due to a decrease in pain syndrome and symptoms of inflammation, which allowed athletes to cope with the load on the injured limb, close to the maximum (habitual training).

The amplitude of movement in the injured knee joint during flexion, on average, was 3.0±0.02 points, when extended – 3.0±0.01 points, increased by 58% and 55% respectively, and reached the normal values of movement in the knee joint.

The increase in the amplitude of movements is explained by the use of stretching exercises for muscles and ligaments, which increased the elasticity and, accordingly, the mobility (amplitude of movements) of the joint.

Conclusion. As a result of the application of a comprehensive physical rehabilitation program for boxers after the reconstruction of the anterior cruciate ligament of the knee joint at the stage of sports training, there is an improvement in the functional state of the injured link of the musculoskeletal system, reflected in a significant reduction of pain syndrome both at rest and under stress, in an increase in the amplitude of movements of the damaged joint and the strength of the flexor and extensor muscles of the lower leg. The restoration of the amplitude-strength characteristics of the knee joint after the anterior cruciate ligament reconstruction of against the background of a significant reduction in pain syndrome at rest and during physical loads makes it possible for athletes to transition to full-fledged training loads, which is the ultimate goal for the application of a comprehensive rehabilitation treatment program at the stage of sports training.

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PHYSICAL REHABILITATION OF MIDDLE-AGED MEN AFTER AN ISCHEMIC STROKE IN THE EARLY RECOVERY PERIOD

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Annotation. The article presents the results of the effectiveness and content of the physical rehabilitation program for middle-aged men in the early recovery period after an ischemic stroke. The study included 50-59 years old men with a following diagnosis: an ischemic stroke of the left temporal lobe, moderate spastic hemiparesis on the right. The study was conducted in the early recovery period at the inpatient treatment stage. The duration of the physical rehabilitation program, which began in the early recovery period after and ischemic stroke, was 21 days and was divided into 3 periods: introductory (4 days), main (12 days) and final (5 days). According to the data obtained, the use of the developed program in the early recovery period for middle-aged men who suffered an ischemic stroke allowed to restore daily activity, alleviate depression and improve the psychoemotional state.

Keywords: physical rehabilitation, ischemic stroke, early recovery period.

Introduction. Brain diseases are an important problem of society, it is one of the main causes of fatal outcomes and long-term disability of the population. At the same time, strokes are increasingly occurring in people of working age, i.e. there is a tendency to "rejuvenation" of cerebral stroke: among patients with acute cerebral circulation disorders, up to 25% are people aged 41-50 years. Rehabilitation and social adjustment of patients who have suffered a brain stroke is becoming increasingly important in modern clinical neurology. The lack of timely and adequate restorative treatment leads to the emergence of irreversible anatomical and functional changes and the violation of the psychoemotional status of a person, leading to disability, the growth of which has been steadily increasing in recent years [1].

In Russia, the level of disability varies from 75% to 85% a year after a stroke, while in Western European countries this indicator is 20-30%. In our country, among patients who have suffered a stroke, 3-23% return to work, 85% require constant medical and social support, and 20-30% remain disabled throughout their lives [2]. Early rehabilitation reduces the percentage of disability, restores daily activity, reduces the risk of complications and alleviates depression in people who have suffered an ischemic stroke, which confirms the relevance of this work.

The aim of the study was to develop and evaluate the effectiveness of the physical rehabilitation program for middle-aged men after an ischemic stroke in the early recovery period.

Methods and organization of research. The assessment of the daily life activity of stroke patients was assessed on the Barthel scale [3]. The severity of neurological disorders and the level of personal adjustment were assessed on the Lindmark scale [4]. The assessment of depression was assessed on the Wakefield scale [5]. The obtained results were processed with mathematical statistics methods (mean value, standard deviation, validity of differences were evaluated using the Wilcoxon T-test ($p \leq 0.05$)).

The study took place in the period from November 2021 to April 2022, was carried out in the Chekhov Regional Hospital (Chekhov, Moscow region). Men (n=6) aged 50-59 years with a diagnosis of an ischemic stroke of the left temporal lobe, moderate spastic hemiparesis on the right participated in the study with voluntary consent. The study was conducted in the early recovery period at the inpatient treatment stage.

The duration of the physical rehabilitation program, which began in the early recovery period after an ischemic stroke, was 21 days and

was divided into 3 periods: introductory (4 days), main (12 days) and final (5 days).

During the introductory period, the following tasks of physical rehabilitation were set: prevention of orthostatic and stagnant phenomena; preservation of motor amplitude in the limbs; reduction of muscle spasticity; improvement of the functioning of the cardiovascular and respiratory systems; improvement of articulation and speech skills; improvement of the psychoemotional state.

The tasks in the main period of physical rehabilitation were: improvement of the functioning of the cardiovascular, respiratory systems; improvement of articulation and speech skills; reduction of muscle spasticity; formation of correct motor stereotypes; improvement of the psychoemotional state; expansion of motor activity; social and personal adjustment of patients.

During the final period of physical rehabilitation, the following tasks were solved: maintaining an improved state of the cardiovascular and respiratory systems; fixing the correct stereotypes of the movement of basic motor actions; consolidating the skills of voluntary muscle relaxation; maintaining the positive psychoemotional state; improving articulation and speech skills; improving the endurance of the body; social and personal adjustment.

To implement the tasks of physical rehabilitation in the early recovery period after an ischemic stroke, the means and methods included in the content of the rehabilitation treatment program were selected in the studied group (table 1).

Table 1

Physical rehabilitation (PR) program for middle-aged men after an ischemic stroke in the early recovery period

PR Period	Means and forms of rehabilitation	Dosage	Guidelines
1. Introductory period (4 days)	1. **MHG:** **BE:** - static – 70% - dynamic – 30% **Calisthenics**: for upper and lower limbs, trunk and neck (without and with the use of a myofascial roller)	Daily, 1 time per day, 10-15 min.	MHG starts from the first day with passive exercises, then – passive-active exercises. S. P. – lying, sitting. The pace is slow. Calisthenics:BE= 1:1
	2. **TG:** **Calisthenics:** passive-active for upper and lower limbs **BE**: - static – 70% - dynamic – 30% **SE**: - passive – 70% -active-passive – 30%	Daily, 1 time per day 15-20 min.	TG begins from the first day with passive exercises, then – passive-active exercises. S.P. – lying, sitting. Pace – slow, medium. Rest pauses – every 2-3 exercises (muscle tone control).
	3. **Therapeutic massage**	Daily, 10-12 min.	Perfomed according the method of A.A. Biryukov, paravertebral massage is performed (along the neck, thoracic and lumbar spine). After TG or 1.5-2 hours after eating.

Table 1 (continued)

	4. **Ergotherapy:** a mobile simulator and manual for the development of manual skills	Daily, 1 time per day, 10 min.	Carried out individually.
	5. **Mechanotherapy:** for lower limbs – a mobile transformer stepper (horizontal, vertical)	Daily, 10 min.	Application scheme: lying – horizontally; lying – vertically; sitting – horizontally; sitting –vertically. The pace is slow.
	6. **Dosed walking**	Daily, 2 times per day, 10-15 min.	The pace is slow. First – with the help and supporting devices, and then – stimulation of independent movement with supporting devices.
	7. **Physical therapy** Electrophoresis	Daily, 1 time per day, 7 min.	Applied in the area of the neck-collar zone. Composition: 2% eufillin, 1-2% nicotinic acid, 1-2% no-spa, 5% novocaine.
	8. **Art therapy:** Origami	Every second day, 30 min.	Small group lessons with a therapist, making paper figures with oral instructions.
2.Main period (12 days)	1. **MHG** **BE**: - static – 50% - dynamic – 50% **Calisthenics:** for upper extremities, body and neck (without a use of a myofascial roller)	Daily, 1 time per day, 10-15 min.	MHG – active and active-passive exercises. S.P. – lying, sitting, standing. Pace is slow and medium. Calisthenics:BE=2:1
	2. **TG** **Calisthenics**: active-passive, active for upper and lower limbs. **BE**: - static – 50%; - dynamic – 50%. **SE**: -active-passive – 50%; - active – 50%.	Daily,1 time a day 20-25 min.	LG exercises with objects, auxiliary aids. S.P. – lying, sitting, standing. Pace – slow, medium. Calisthenics:SE:BE =1:2:1. Rest pauses – every 2-3 exercises with an increase in muscle tone (control of muscle tone)
	3.**Therapeutic massage**	Daily, 15-20 min.	Perfomed according the method of A.A. Biryukov, massage, after TG or 1.5-2 hours after eating

Table 1 (continued)

	4. **Ergotherapy:** a mobile simulator and manual for the development of manual skills	Daily, 1 time per day, 15-20 min.	Carried out individually.
	5.**Mechanotherapy:** for lower limbs – a mobile transformer stepper (horizontal, vertical)	Daily, 10 -20 min.	Application scheme: lying – horizontally; lying – vertically (up and down); sitting – horizontally; sitting – vertically. The pace is slow, in the process of learning – is increased to medium
	6. **Dosed walking**	Daily, 2-3 times per day, 15-20 min.	The pace is slow and medium. Training, then – learning the ways of walking up the stairs.
	7. **Physical therapy:** electrophoresis	Daily, 1 time per day, 10 min.	Applied to the area of the neck-collar zone. Composition: 2% eufillin, 1-2% nicotinic acid, 1-2% no-spa, 5% novocaine.
	8. **Art therapy:** Origami	Every second day, 30 min.	Small group lessons with a therapist, making paper figures with oral guideless.
3. Final period (5 days)	1. **MHG:** **BE:** - active – 50% - dynamic – 50% **Calisthenics:** for upper and lower limbs, body and a neck (without a use of a myofascial roller)	Daily, 1 time per day, 10-15 min.	MHG – active and active-passive exercises. S.P. – lying (when needed), sitting, standing, if possible – while walking (on a place, while moving). The pace is slow and medium. Calisthenics:BE=2:1
	2. **TG:** **Calisthenics:** -active-passive, active for upper and lower extremities **BE:** - static – 50%; - dynamic – 50%. **SE:** -active – 50%; - active-passive – 30%; - with resistance and weights – 20%.	Daily, 1 time per day, 20-25 min.	LG exercises with objects, auxiliary aids. S. P. – lying, sitting, standing. Pace – slow, medium. Calisthenics:SE:BE =1:2:1 Rest pauses – with an increase in muscle tone (control of muscle tone).

Table 1 (continued)

	3.**Therapeutic massage**	Daily, 15-20 min.	Perfomed according the method of A.A. Biryukov, massage, after TG class or 1.5-2 hours after eating.
	4. **Ergotherapy:** a mobile simulator and manual for the development of manual skills	Daily, 1 time per day, 15-20 min	Carried out individually.
	5.**Mechanotherapy**: for lower limbs – block and pendulum simulators (horizontal, vertical)	Daily, 10-20 min.	Exercises: free, in case of correctly formed stereotype of movement – with weights, with resistance. The pace – slow, while learning – increased to medium.
	6. **Dosed walking**	Daily, 2-3 times per day, 15-20 min.	The pace is slow and medium. Walking up the stairs, different types of walking.
	7. **Physiotherapy** Wax bath therapy	Daily, 1 time per day, 7-10 min.	Applied as an application in the neck-collar area. It is prescribed after the LG procedure.
	8. **Art therapy:** Origami	Every second day, 30 min.	Small group lessons with a therapist, making paper figures with oral instructions.

Note: MHG – morning hygienic gymnastics; TG – therapeutic gymnastics; BE – breathing exercises; SE – special exercises; S.P. – starting position

The effectiveness of the developed program of physical rehabilitation of patients after an ischemic stroke in the early recovery period was assessed by the dynamics of the studied indicators (table 2).

There was a significant increase in the assessment of the daily activity of patients after an ischemic stroke, assessed on the Barthel scale from 78.3±0.3 points to 83.3±0.4 ($p \leq 0.05$), which indicates an improvement in their condition, with a good adjustment of the body to the constantly increasing physical, personal and social loads.

Table 2

Dynamics of the studied indicators in the process of physical rehabilitation of the studied group after an ischemic stroke in the early recovery period

Indicator (in points)	X±σ before PR	X±σ after PR	Δ (difference) %	Wilcoxon T-test (p)
Assessment of daily life activity (Barthel scale)	78.3±0.3	83.3±0.4	5	≤0.05

Table 2 (continued)

An indicator of the degree of severity of neurological disorders and the level of personal adjustment (Lindmark scale)	310±2.03	367.67±2.05	13	≤0.05
Depression indicator (Wakefield scale)	18.67±0.14	16.33±0.03	6.5	≤0.05

The indicator of the Lindmark scale, reflecting the severity of neurological disorders and the assessment of the personal adjustment level after physical rehabilitation of the studied contingent in the early recovery period increased by 13%, reaching values from 310±2.03 points to 367.67±2.05 points (p≤0.05). There was a decrease in the depression index of, determined by the Wakefield scale by 6.5% from 18.67±0.14 points to 16.33±0.03 points (p≤0.05).

Conclusion. The use of physical rehabilitation in the early recovery period in middle-aged men who suffered an ischemic stroke allowed to restore daily activity, alleviate depression, and improve the psychoemotional state.

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DOES THE PREFERRED DISTANCE OF ELITE STAYERS DEPEND ON GENETIC POLYMORPHISM?

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Annotation. The study was performed to assess the dependence of the distance preference of elite stayers on the combination of genetic markers associated with endurance, power or strength. Shares of the corresponding alleles and the "Total Genotype Score" of following genes were analyzed: ACE I/D, ACTN3 C/T, AMPD1 S/T, PPARA G/C, PPARG2 C/G, MTHFR A/C, HIF1A C/T, ADRB2 C>G, ADRB2 G>A, NOS3 C/T in the athletes preferring short (0.8 and 1.5 km), average (1.5-21.1 km) and long (21.1 and 41.1 km) distances, and the individuals, not engaged in sports. It was revealed that the proportions of the corresponding alleles and the mean Total Genotype Score values of the studied genes were higher in power and strength, but lower in endurance in stayers, who prefer short distances, compared to marathon runners and the control group, while in the last two groups they did not differ.
Keywords: sports genetics, genetic polymorphism, endurance, power, strength, running distance, elite athletes, marathon.

Introduction. Lately, the genetic aspect of achievements of elite athletes becomes more relevant for understanding, whether the athlete is able to perform under various conditions in addition to their potential trainability. However, the "one gene as the magic bullet" concept, which was earlier gaining its popularity in sports, was not proven, since such gene was never discovered [1-2]. We have found instead that elite athletes have a number of favorable alleles, but none of them has the ideal genetic profile [1, 3].

At the present moment, it is known that genetic coding of athletic activity and its determinants are polygenic. The genetic basis usually includes a complex phenotype architecture, caused by a different number of genetic variants that affect a certain attribute, their allele frequency, dimensions of their effect and multiple gene-gene and gene-environment interactions [4-6].

It was found that the so-called "genetic profile" for success in sports can be phenotypically subdivided into a number of opposite types (e.g. endurance, power, strength, speed, coordination etc.). Thus, according to the research of the I.I. Akhmedov's team [7], a total number of DNA polymorphisms, related to the athletic status, was 220 in 2021, only 97 markers of which appeared to be significant at least in two studies (related to endurance – 35, power – 24 and strength – 38).

Normally, the genetic markers, related to endurance, power or strength, are identified through the comparison of allele frequencies in groups of athletes, engaged in corresponding sports, e.g. marathon runners, sprinters or weightlifters, regarding the non-athletic control [1, 2, 4, 5]. In terms of running in track-and-field, the athletes are specialized by choosing appropriate distances.

However, during competitions, taking into account their capabilities, they can perform in other distances. For this purpose, they prepare with different training modes, since the duration and intensity of training sessions must depend on the cleared distance. For example, if the marathon distance is cleared for not less than 2.5 hours continuously, focusing mainly on saving energy and endurance, then for short-distance run, the attention should be given to developing high speed, for average-distance run, besides speed – power and endurance [8-9]. Speaking otherwise, the training mode must be constructed, according to the need in the appropriate energy supply and oxygen con-

sumption [10-11]. At the same time, these processes, often possessing opposite characteristics, must occur simultaneously in various ratios in the stayer's body when running certain distances. Nonetheless, the appropriate genetic profile of the athlete that creates a basis for successful (in terms of sports) distance clearing has not been identified.

Considering this fact, we have conducted this study to evaluate connection between the distance, preferred by elite stayers, with the combination of genetic markers, related to endurance, power and strength.

Methods and organization. The study involved 22 elite Uzbekistan athletes, engaged in track-and-field (running in particular), as well as 125 individuals, not engaged in sports. The test subjects were not divided by gender or nationality.

According to the indicators of athletic achievements at major international competitions in 2017-2020, we have divided the elite track-and-field athletes, regardless their gender, into 3 groups, depending on the distance preference, so the basis was the only the minimality of the time required to clear the appropriate distance.

Since there are no athletes in Uzbekistan, who won at international competitions on sprinter distances (100 m or 200 m), we carried out the study, involving only stayers, divided into 3 groups. Those were the winners at competitions, who cleared following distances in the shortest time:

1) short distances (800 and 1500 m);

2) short (1500 m) and average (5 and 190 km) distances, even a semi marathon (21.1 km);

3) marathon distances (21.1 and 42.1 km).

Indicators of time and average speed of clearing distance at international competitions, presented in table 1, allow to get a view on the level of test subjects.

Table 1

Time and average speed of clearing distances at international competitions by elite track-and-field athletes

Distance	Men		Women	
	Clearance time	Average speed	Clearance time	Average speed
800 m	<115 s	>6.9 m/s	<135 s	>5.9 m/s
1500 m	<4 min	>6.2 m/s	<4,5 min	>5.55 m/s
5000 m	<16 min	>5.2 m/s	<17 min	>4.9 m/s
10000 m	<32 min	>5.2 m/s	<35 min	>4.76 m/s
Semi marathon	<70 min	>5.0 m/s	<75 min	>4.69 m/s
Marathon	<148 min	>4.74 m/s	<155 min	>4.53 m/s

The genotyping was conducted with the polymerase chain reaction (PCR) amplification. Samples of venous blood were collected in the ethylenediaminetetraacetic acid (EDTA) solution and stored at the temperature of -20℃ before the analysis. The DNA isolation was made with the Ribo-prep reagent set (Interlabservis, Russia).

We detected polymorphism of studied genes with the Real-Time PCR method (OOO NPF "Litekh", Russia). In order to conduct the PCR amplification in real time, we used the GeneAmp® PCR – ABI 7500 Fast Real-Time with the 96-cell block. The real-time amplification program included 100 s of preliminary denaturation at 95 °C once, at 95 °C for 15 s and at 64°C for 40 s (included 45 repeats).

We examined genetic polymorphisms, for which connection with features of endurance, power and strength was earlier demonstrated in publications and which were recommended according to the meta-analysis results [7].

To comprehensively examine genotypes with prevailing endurance or power-strength type, we selected 10 genes (ACE, ACTN3, AMPD1, PPARA, PPARG2, MTHFR, HIF1A, ADRB2 C>G, ADRB2 G>A, NOS3), six of

which had polymorphism that demonstrated favorable allele variants for the endurance type (ACE (rs4646994)_I/D_(I), ACTN3_(rs1815739)_C/T_(T), AMPD1_(rs17602729)_C/T_(C), PPARA (rs4253778)_G/C_(G), HIF1A (rs11549465)_C/T_(C), ADRB2 (rs1042713) _G>A _(A)).

In order to identify the power type, we defined polymorphisms of 10 genes with the favorable allele: ACE (rs4646994)_I/D_(D), ACTN3 (rs1815739)_C/T_(C), AMPD1_(rs17602729)_C/T_(C), PPARA (rs4253778)_G/C _(C), PPARG2 (rs1801282)_C/G_(G), MTHFR (rs1801131)_ A/C_(C), HIF1A (rs11549465)_C/T_(T), ADRB2 (rs1042714)_C>G_(G), ADRB2 (rs1042713)_ G>A_(G), NOS3_C/T_(T). We analyzed 5 genes for identifying the strength type: ACTN3 (rs1815739)_C/T_(C), PPARA (rs4253778)_G/C_(C), PPARG2 (rs1801282)_C/G_(G), MTHFR (rs1801131)_A/C_(C), HIF1A (rs11549465)_ C/T_(T).

The so-called Total Genotype Score (TGS) (in the range from 0 to 100) was calculated with the Williams and Folland model [12]. When looking for the searched allele that shows the corresponding athletic type, we assessed the homozygote variant as "2", heterozygote variant – as "1" and absence of the allele – as "0".

Then, the total genotype score, obtained as a result of accumulated combination of polymorphism candidates that explains individual variations in endurance indicators, was calculated according to the following formula:

$TGS_{endurance}$ = (100/6x2) x ($GS_{ACE(I)}$ + $GS_{ACTN3(T)}$ + $GS_{AMPD1(C)}$ + $GS_{PPARA(G)}$ + $GS_{HIF1A(C)}$ + $GS_{ADRB2G>A(A)}$).

The same was done for power and strength indicators:

TGS_{power} = (100/10x2) x ($GS_{ACE(D)}$ + $GS_{ACTN3(C)}$ + $GS_{AMPD1(C)}$ + $GS_{MTHFR(C)}$ + $GS_{PPARG2(G)}$ + $GS_{PPARA(C)}$ + $GS_{HIF1A(T)}$ + $GS_{ADRB2C>G(G)}$ + $GS_{ADRB2G>A(G)}$ + $GS_{NOS3(T)}$);

$TG_{strength}$ = (100/5x2) x ($GS_{ACTN3(C)}$ + $GS_{MTHFR(C)}$ + $GS_{PPARG2(G)}$ + $GS_{PPARA(C)}$ + $GS_{HIF1A(T)}$).

Results and discussion. In this study, we evaluated the connection between the distance, preferred by elite athletes, and variants of 10 genes, early connected with the state of endurance, power or strength of a person.

According to a number of authors, endurance indicators are based on the features of cell metabolism and functioning of the cardiovascular system, closely connected with the prevalence of slow-twitch fibers in skeletal muscles, hemoglobin mass, maximal oxygen consumption speed (VO_{2max}) and cardiac output [13-14]. Moreover, 44-68% of the phenotype variability, connected with endurance, consist of genetic factors [15].

A great share of fast-twitch muscle fibers and muscle mass, accelerated reaction time and a number of anthropometric signs are typical for power indicators [9, 16, 17], with varying heredity from 49 to 86% in different phenotypes [18].

Signs of strength abilities in athletes are mainly based on the high glycolytic ability, hypertrophy of the skeletal system and skeletal muscles with the prevalence of fast-twitch fibers, which is different from features of endurance, but is more similar to power indicators [13, 19]. Meanwhile, genetic factors had value in 30-84% of phenotype variations [18].

We have examined polymorphisms of 10 genes, one of the alleles of which was associated to power (strength) indicators, other alleles of 5 of these genes – to endurance. The studied genes have different targets and ways to influence homeostasis. In particular, the ACE, NOS3 and ADRB2 genes code ferments, participating in the regulation of cardiovascular functions, such as blood pressure and vasodilation [10, 20, 21, 22, 23]. The ACTN3 gene codes structural sarcomeric protein α-actin-3, discovered exclusively in the type II fast-twitch muscle fibers, the function of which correlates with physical strength, speed and power of muscle contraction [1, 4, 11]. The effect of HIF1A stimulates erythropoiesis and increases the efficiency of oxygen delivery to working muscles [21]. The PPARA and PPARG genes code a receptor family (alpha and gamma), activated by the peroxisome proliferation, which contribute to consumption, utilization and catabolism of fatty acids in mitochondria instead of glucose under conditions of energy deficit

[22].

For the MTHFR C677T polymorphism, we have found the connection with such efficiency indicators, as the aerobic and anaerobic threshold values [24]. The AMPD plays a key role in production of adenosine triphosphate (ATP) by converting adenosine monophosphate (AMP) into inosine monophosphate. The T allele prevalence, which decreases the AMPD activity in skeletal muscles, is lower among elite athletes for both the endurance and the power type, compared to the control group [20, 23].

The conducted studies led to following results. Figure 1 shows indicators of the gene alleles, relevant to endurance. It is obvious that the control data of some genes differ from info from international sources (more than 10%). In particular, they were higher for PPARA and ACTN3, but lower for AMPD1 (almost by 20%) and ADRB2 A>G.

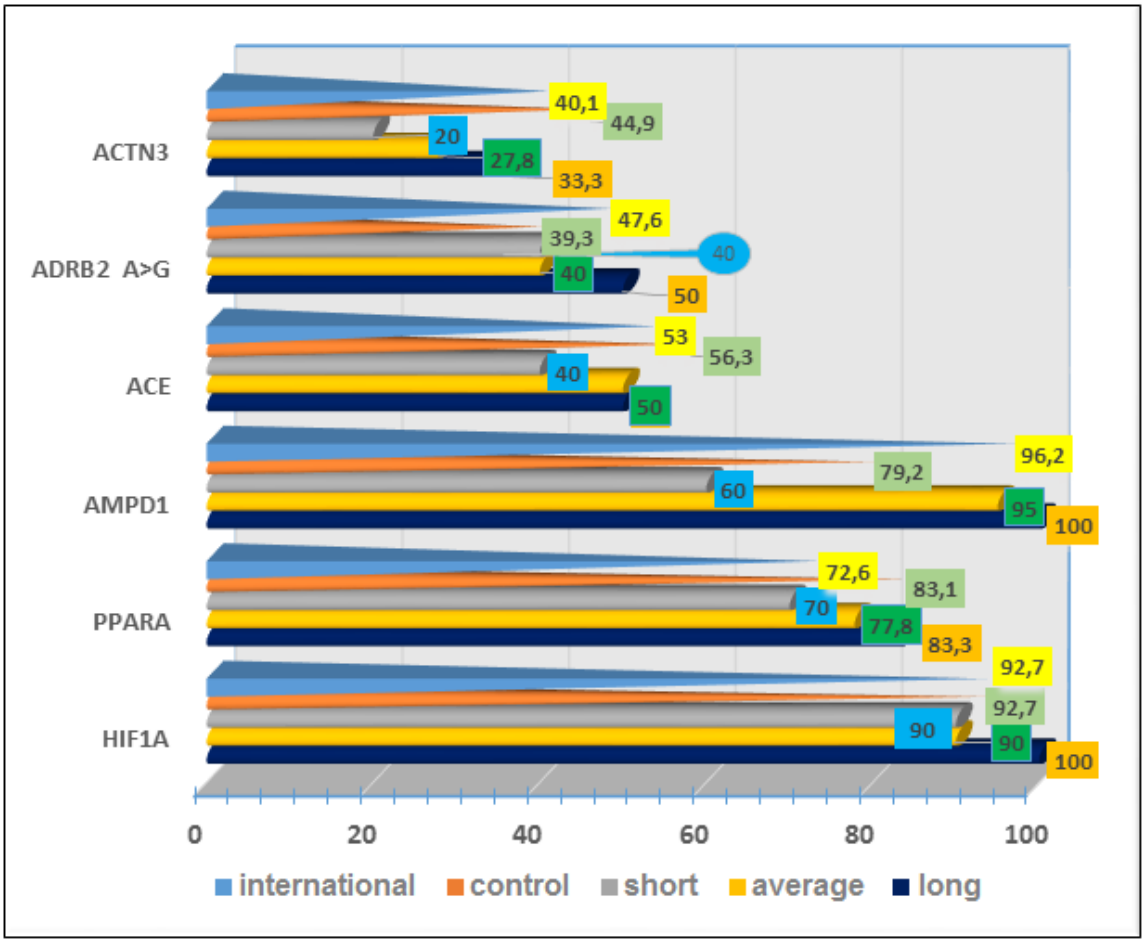

Fig. 1. Distribution of frequency of gene alleles, associated with the endurance indicator, in elite track-and-field athletes, depending on the preferred distance

Note: international – frequency of gene alleles, associated with the endurance indicator, in the total population (n=2504), according to the data from the 1000 Genomes project [7]

When analyzing the data from track-and-field athletes, depending on the preferred distance, it was revealed that the quantitative level of almost all endurance alleles has a tendency to grow with the increasing distance. Moreover, such pattern for the HIF1A and ADRB2 A>G is seen in a form of a rise from average to long distance, for AMPD1 и ACE – from short to average, for PPARA и ACTN3 – an evenly growth.

It is important to note, that shares of endurance alleles of the HIF1A and ADRB2 A>G genes in athletes, who clear short and average

distances perfectly, did not differ from indicators of the control group, while the same situation with the PPARA gene was discovered only in long distances. In other cases, the tendency of similarity with the indicators of the control group was typical for athletes, preferring marathon (ACTN3) or average distances (AMPD1 and ACE).

As it was shown in figure 2, shares of gene alleles, associated with power, have some differences with the international data in the control group. For example, this indicator was almost 2 times higher for the ADRB2 C>G и PPARG2 genes, for the PPARA – almost 2 times lower. An upward tendency was also found, regarding the ADRB2 A>G and MTHFR genes (differences more than 10%).

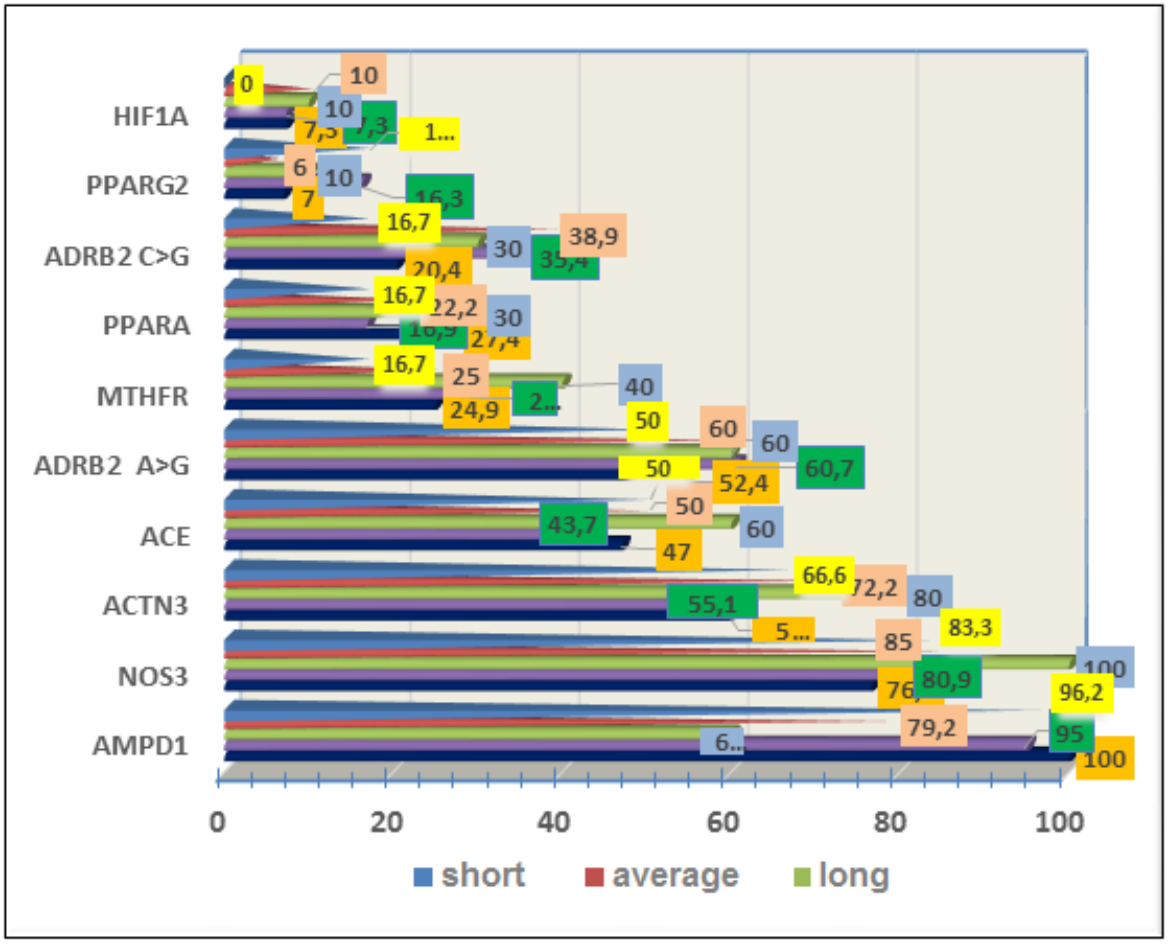

Fig. 2. Distribution of frequency of gene alleles, associated with the power and strength indicators, in elite track-and-field athletes, depending on the preferred distance

The typical feature of the changing allele share for athletes appeared to be a decrease in their number in the course of the increasing distance (except PPARG2). It was shown in both an uneven nature (for NOS3 and ACE – change from short to average distances, for ADRB2 A>G, ADRB2 C>G and HIF1A – from average to long distances) and in the form of a gradual decrease (ACTN3, PPARA and MTHFR).

The tendency of similarity with indicators of the control group in the shares of power alleles was identified mostly in athletes, who prefer marathon distances (NOS3, PPARA, PPARG2, ACE и ACTN3). However, it was typical for other genes, regarding both average distances alone (MTHFR and ADRB2 C>G) and in combination with short distances (ADRB2 A>G and HIF1A).

Since the described alleles that show power-related processes, associated to strength in athletes for 5 genes (ACTN3, MTHFR, PPARA, PPARG2 and HIF1A) are related to the manifestation of strength in athletes, the pattern, presented in figure 2, will also describe this parameter. In particular, the tendency of similarity with the indicators of the control group is demonstrated mainly in relation to marathon distances, control values have two-fold differences from international ones for the PPARA and PPARG2 genes.

Although the level of endurance alleles of other genes increases in groups of athletes with the increase of cleared distance, they only reach (PPARA) or do not reach (ACE and ACTN3) the control level.

In terms of power alleles, the highest values in the group of short-distance runners with their gradual decrease in the course of increasing distances and, in some degree, exceeding the control level of value in all marathon runners, were found for the NOS3, ACE and ACTN3 genes. In other cases (except AMPD1, dynamics of which are described above), they either did not exceed the control level in any group (ADRB2 A>G, ADRB2 C>G, HIF1A and PPARG2), or they were higher than this level for stayers, competing at short distances. However, in the course of increasing distance, they decreased and turned out to be lower than the control values for marathon runners (MTHFR and PPARA).

It became obvious, that the genetic profile of a marathon runner is characterized by an absolute prevalence of endurance alleles in the HIF1A and AMPD1 genes, as well as the high level of such allele in the ADRB2 A>G gene, which exceed the control levels. The data obtained correspond perfectly with the information from scientific literature, in which a significant connection between the beta-2 adrenergic receptor (ADRB2) rs1042713 and adenosine monophosphate deaminase 1 (AMPD1) rs17602729 and the fastest registered time of completing marathon among male athletes was discovered [23], as well as between the HIF1A activation and high value of VO_{2max}, which is an important factor, determining performance of the marathon run [21].

Among studied genes, according to the opinion of Akhmetov et al. [7], the most prospective genetic markers, regarding endurance, are PPARA rs4253778, strength – PPARG rs1801282, power – ACTN3 rs1815739, AMPD1 rs17602729 and NOS3 rs2070744.

The results of our study have made clear that the term of genetic markers' perspectivity must be approached differentially. They can differ, depending on the athlete's specialization and preferred distances. In our opinion, prospective genetic markers of stayers can be following gene alleles that significantly exceed the control level:

- for marathon runners, endurance-related – HIF1A and AMPD1, power-related – AMPD1, NOS3 and ACTN3;
- for all-round runners (average distances) – AMPD1, power-related – NOS3, ACTN3, PPARA;
- for short-distance runners, power-related – NOS3, ACTN3, PPARA, MTHFR and ACE.

It needs to be noted, that the prospective genetic markers, common to all stayers, are power alleles of the NOS3 and ACTN3 genes, for marathon and all-round runners – the AMPD1 gene additionally.

The results of our studies correspond with the data from literature, where a connection of ACTN3 and ACE with specific sprinter phenotypes was revealed. The ACTN3 rs1815739 variant influences the 200 m run greatly (sprinter speed), while the ACE ID polymorphism more involved in running longer distances – 400 m (sprinter performance) [11]. At the same time, we have revealed that the Olympic standard runners, short (100 m) to ultra-marathon distances, have the excess of the

I ACE allele (typical for endurance) [25], while the ACTN3 is the only gene that demonstrated a connection between the genotype and performance in some groups of elite strength-based athletes [4].

Since the genetic support of athletic indicators is complicated, the revealed differences between groups in the allele frequency of each polymorphism point out a need to use new approaches for identifying genetic contribution to

athletic improvement. This is the reason why we have calculated the gathered combination of 10 genes' polymorphisms, related to endurance, power and strength, using the simple model of the Total Genotype Score (TGS). It shows the additive influence of genotypes on predicting complex signs, such as athletic results. Points, given to the genotypes in TGS, must show the degree of the genotype predisposition to a certain sign [23, 26].

Average TGS levels of endurance, power and strength of athletes, depending on the preferred distance, are shown in table 2.

Table 2

Indicators of the Total Genotype Score of endurance, power and strength among elite athletes, depending on the preferred distance

№	Indicators	Control	Preferred distances		
			Short	Average	Long
1	Endurance (E)	65.9±3.1±	53.3±3.5*	63.4±3.4+	69.4 ± 3.6+
2	Power (P)	42.3±2.0	48.0±2.2*	46.43±2.3	41.7±2.4+
3	Strength (S)	24.7±1.5	34.0±2.3*	27.1±2.0+	23.3±2.4+
4	E/P ratio	1.56±0.11	1.11±0.1*	1.37±0.1+	1.66±0.14+
5	E/S ratio	2.67±0.23	1.57±0.18*	2.34±0.23+	2.98±0.25+

Note: * – difference are statistically significant regarding the control group; (+) – statistically significant differences between groups of athletes, regarding short distances ($p<0.05$)

It demonstrated an uneven increase of endurance indicators and their gradual decrease, regarding power and strength and depending on the increasing distance. Moreover, control indicators have statistically significant differences only for athletes, preferring short distances, and show a tendency of similarity with indicators of marathon runners, but they are not at the same level.

The analysis of correlation between the endurance TGS and the TGS of power and strength has revealed that only differences in athletes, who prefer short distances, were statistically significant, regarding the control level. The endurance/power TGS ratio increases in stayers with an increase in the preferred distance ($p<0.05$). The same can be noted for the endurance/strength TGS ratio. In both cases, marathon runners reach the control indicators and slightly exceed them.

As we can see, endurance plays an important role in winning a marathon, since in the course of increasing distance, the expression of the depending allele spectrum increases as well, while the share of alleles, related to power and strength, decreases. It is shown in a gradual decrease of average speed of athletes, while the distance increases, as it was shown in table 1.

It is known that slow-twitch muscle fibers react better to low-intensity training with weights or aerobic training, while high-intensity (strength) training is more suitable for fast-twitch muscle fibers [13-14]. Based on the data obtained, we can identify the recommended markers in beginner athletes, as well as use the revealed genotype spectrum for selection of training, appropriate for a certain person.

The examination of people, not engaged in sports, has demonstrated prevalence of endurance genotypes, regarding the power and strength type, which is possibly connected to the natural selection of such genotypes in order to adapt to the arid climate, where oxygen content of air is lower, than in north latitude with colder and more humid climate [27]. The control genotype is almost similar to the genotype of marathon and all-round runners (who prefer average distances). By the way, the all-round runners make a half of examined elite runners.

Such phenomenon is not surprising, since a similar pattern has been established with respect to multiple Olympic marathon-running champions of Kenyan-Ethiopian origin, where, according to results of international studies, the researchers could not find any distinctive feature in genotypes from the local population that does not engage in sports [28-29]. It follows

that any native person of these countries possesses the needed favorable genotype to, under the condition of appropriate training, become an Olympic champion. On the other hand, it can explain an absence of elite sprinters in Uzbekistan, but at the same time show the polygenic nature of complex signs of endurance.

However, this assumption needs to be confirmed by further research, primarily by providing sufficient statistical power, identifying ethnic/geographical differences and expanding the range of genetic markers. The first issue is a specific one in terms of elite level indicators, since elite athletes are by default limited with a small number of older individuals. In order to make a population description, according to existing rules, we need to examine not less than 1000 test subjects from several regions of the republic, taking into account their ethnic characteristics. Moreover, it is still unknown, which genes are directly connected to participation in elite marathons due to a small dimension of the effect. It is possible that genes, related with the electrolyte balance, hidropoiesis, body temperature and other systems' regulation, might play an important role [27].

Conclusion. We have revealed that shares of corresponding alleles and average values of the TGS of examined genes were higher in power and strength, but lower in endurance among elite stayers, preferring short distances, compared to marathon runners and the control group, while there was no difference in the last two groups. Since the combination of complex multifactor interactions between various genes and environmental factors has a significant influence on the result, the selection of genetic marker perspective for stayers must be approached differentially, depending on the preferred distance.

It was found that prospective genetic markers for all stayers are power alleles of the NOS3 and ACTN3 genes, marathon athletes also have AMPD1 and the endurance allele – HIF1A. In addition, according to the power indicator, the number of prospective markers also includes PPARA for average-distance runners, for short-distance runners – PPARA, MTHFR and ACE.

Using these markers in sports practice would allow us to select differentially effective and targeted physical training programs for every stayer.

The examination of people, not engaged in sports, has demonstrated the prevalence of endurance genotypes, regarding the power and strength type. It is possibly related to the natural selection due to living in arid climate of Uzbekistan. In order to clarify this circumstance, it is necessary to conduct further studies with an increase in both the sample size of elite groups and the population, and an expansion of the genetic markers spectrum.

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THE EFFECTIVENESS OF STRENGTH LOADS IN PHYSICAL EDUCATION CLASSES ON THE DEVELOPMENT OF SPEED COMPONENTS OF STUDENTS

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Annotation. The article discusses the use of speed-strength exercises in an increased volume performed during physical education classes in combination with general physical training loads. The effectiveness of the impact of speed-strength exercises is compared with the results of the traditional form of physical education classes with first-year students of the Kalashnikov Izhevsk State Technical University.
Keywords: students, physical culture, speed, speed-strength exercises.

Introduction. The multilateral formation of physical qualities is of great importance for a person. The extensive probability of their change to various motor activities makes it possible to apply them in many spheres of human activity in various workflows [1].

The purpose of physical education at the university is to optimize the physical development of students, to comprehensively improve physical, moral and mental qualities [2].

Students are the future employable population. And the health status of the population in the country is considered as the greatest value, as a starting condition for a full-fledged activity and a happy life of people [3]. A high degree of development of physical qualities can be achieved at the basis of good health and appropriate formation processes of functional systems of the body.

The aim of the study: to conduct a comparative analysis of the effectiveness of speed-strength loads for students during physical education classes.

Methods and organization. Research methods: analysis of scientific and methodological literature; comparative parallel pedagogical experiment; control tests; math-and-stats data processing: Student's t-test, standard error of mean.

To solve the set tasks, a six-month pedagogical experiment was conducted from October to May, the academic year of 2021-2022.

The study was organized at the Kalashnikov Izhevsk State Technical University.

Groups of first-year students were formed as test subjects. The groups consist of 54 girls, one is control (27 people), the other is experimental (27 people).

The control group was engaged in a traditional “Physical education” program, where the predominant direction was focused on calisthenic training.

The experimental group included a wide variety of general physical training (GPT) exercises.

The GPT set included the following: standing long jumps, jumps in place and over obstacles, wall runs, 20-25 m acceleration, starts from various positions, 30-60 meter run, jumping squats, squats, special running exercises [4]. Outdoor games: "To your places", "Calling by numbers", "Empty space", "Relay races", "Game of tag", etc. The training load was aimed at developing speed and strength fitness by increasing the amount of jumping and speed-based exercises, we also used outdoor games and relay races with running, jumping and swimming.

After the initial testing in September, students studied according to their programs until May 2022.

We have chosen specially selected tests as the main method of diagnosing the speed and strength ability of female students at the current

moment: standing long jump; 30 m run; 60 m run; 4x9 m shuttle run.

Results and discussion. At the end of September 2021, the first physical fitness test was conducted with first-year students, thanks to which the initial level of these indicators was identified at the beginning of the experiment. The results are presented in table 1.

Table 1

Indicators of physical fitness of female students (control and experimental groups) at the beginning of the experiment, M±σ

Control standards	30 meter run (s)	60 meter run (s)	4x9 m shuttle run (s)	Standing long jump (cm)
Control group	5.39±0.4	8.9±0.5	9.94±0.8	175.28±21
Experimental group	5.40±0.3	8.8±0.4	9.9±0.8	170.38±20

Having revealed that the data from the both groups are homogeneous, we introduced exercises into the educational process aimed at developing speed and strength training. At the end of the experiment, the physical fitness of the first-year students was reevaluated.

Let's look at how speed-strength exercises implemented in the educational process interact. Based on the indicators of control tests, we calculated the reliability between two independent results according to the Student's t-test. The results obtained are reliable, which indicates the effectiveness of speed-strength exercises (table 2).

Table 2

Indicators of physical fitness of female students (control and experimental groups) before and after the experiment, M±σ

Indicator name	30 meter run (s)	60 meter run (s)	4x9 m shuttle run (s)	Standing long jump (cm)
Before	5.40±0.3	8.8±0.4	9.9±0.8	170.38±20
After	5.26±0.4	8.5±0.3	9.71±0.7	182±22
p<	0.05	0.05	0.05	0.05

Conclusion. The use of the traditional program gives a certain positive effect. But in the experimental group, the positive shift in results is more significant. Speed-strength exercises have a positive effect not only on explosive strength and speed-strength training, but also on motor dexterity demonstrated in the shuttle run.

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