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GENDER CHARACTERISTICS OF DIFFERENT MUSCLE GROUPS OF ELITE BODYBUILDERS

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Abstract. ***Introduction.*** Bodybuilding is a relatively new type of physical activity that is very popular today. However, there are almost no scientific data on the theory and methods of preparation, morphology and physiology of bodybuilding. In this regard, the aim of this work was a comparative analysis of the strength of various muscle groups in elite male and female bodybuilders. ***Methods.*** The study involved 22 bodybuilders. The strength of different muscle groups was determined by dynamometry on the Dr. Wolff Back-Check system. ***Results.*** The comparative analysis showed significant differences in all muscle strength indicators in male and female bodybuilders. In women, the strength of the upper shoulder girdle muscles lags behind men the most, while the back and leg extensors are stronger. ***Conclusion.*** The data obtained supplement the knowledge of the morphology and physiology of bodybuilding and can be used to assess strength capabilities at different stages of preparation and in the sports selection system.
Keywords: bodybuilding, strength abilities, gender characteristics, sexual dimorphism, muscles, dynamometry.

Introduction. Bodybuilding is a process of growing and developing muscles that includes physical exercises with resistance and diet high in energy and protein sufficient for skeletal muscle hypertrophy. Bodybuilding is a relatively new type of physical activity that is very popular today. More young people engage in body-building not only for health reasons and physical strength improvement, but also for body improvement [1-3].

Among the main positive effects of bodybuilding, the experts note the following: increase of muscle mass and physical strength, reduction of fat component of body mass, improvement of endurance due to regular physical activity [3-5]. However, there are practically no scientific works dedicated to theory and methodology of bodybuilding training and physiology, to research of morphofunctional features of athletes in this sport [6]. There are also no data on strength characteristics of various muscle groups of bodybuilders and features of how female athletes are engaged in bodybuilding, while these issues had long been thoroughly resolved in other strength sports [6-8]. Studying the level of physical development, strength of various muscle groups and physiology of bodybuilding, studying the gender characteristics of this sport will improve the process of training and biomedical support in this field.

Therefore, the aim of the study is a comparative analysis of strength of the various muscle groups in elite male and female bodybuilders.

Methods and organization. The study was carried out in the Rehabilitation and Recovery Center for National Sports Teams of the North-Caucasian Federal Research-Clinical Center. The study involved 22 bodybuilders, 12 men and 10 women, the members of the Russia national bodybuilding team. Strength of various muscle groups was determined by dynamometry with the "Dr. Wolff "Back-Check" system in the following exercises: back flexion and extension, bench press, seated row, body bending to the sides, left and right shoulder adduction and abduction, left and right leg adduction and abduction, left and right hip extension. The statistical analysis was done in the STATISTICA 13.0 software using the Mann-Whitney test. The data are presented as a mean value and a sampling error – M±σ.

Results and discussion. Strength characteristics of strength sports athletes exceed the indicators in other sports. It is also known that strength as a physical quality differs significantly in terms of gender – it is greater in men compared to women. However, these differences are not completely the same for various muscle groups.

A comparative analysis of strength characteristics of muscle groups among male and female bodybuilders has shown (table) statistically reliable differences in strength of all the studied muscle groups. However, there is a difference in a percentage ratio for various muscle groups.

Table

Strength of various muscle groups in male and female bodybuilders, M±σ, kg

Indices	Men	Women	The strength ratio of women versus men, %	P<
Back extension	85.1±6.8	57.7±3.8	66	0.004
Higher part of the body, bench press	165.6±9.3	91.1±5.3	52	0.0003
Body bend to the left	62.4±4.1	37.0±5.1	56	0.006
Left shoulder abduction	55.8±5.2	26.8±3.5	41	0.0004
Left leg abduction	49.5±4.4	35.5±3.1	71	0.05
Left leg adduction	52.7±4.6	35.0±1.6	63	0.003
Left hip extension	60.0±4,7	43.5±3.1	67	0.009
Back flexion	65.0±6.5	32.4±3.3	50	0.001
Higher part of the body, seated row	116.9±4.6	64.1±4.2	51	0.0002
Body bend to the right	62.3±4.6	40.0±4.6	32	0.005
Right shoulder abduction	55.3±5.6	28.2±2.8	44	0.0008
Right leg abduction	48.6±5.8	29.6±3.0	48	0.003
Right leg adduction	55.7±4.7	35.3±2.7	71	0.003
Right hip extension	58.6±4.5	41.9±3.6	75	0.006

The analysis of percentage ratio between muscle strength of female and male bodybuilders in terms of various muscle groups has revealed that the ones that lag the most are the upper shoulder girdle muscles (muscles that perform shoulder abduction, bench press and seated row, body bending to the sides). Stronger ones are the back extensor muscles, their strength in women amounts to 66% of men's strength. The strongest ones reaching 70% and higher of men's strength are the muscles responsible for leg adduction (great adductor muscle, long adductor muscle, short adductor muscle, pectineal muscle, hip gracilis muscle) and hip extension (gluteus maximus, gluteus medius, gluteus malus).

The received data show a general trend of strength ratio between men and women, as well as its distribution in the separate muscles of the body [6, 10]. Considering the fact that men usually have greater body weight and muscle mass, ratio of the strength indicators and body weight, i.e. comparing the relative strength of men and women will further negate the strength deficit, and perhaps the strength of women's lower limbs will be comparable to men's.

According to the study's results, we have formulated model characteristics of the strength indices of various muscle groups for elite male and female bodybuilders. We have also made the strength profiles, shown on figures 1 and 2 below.

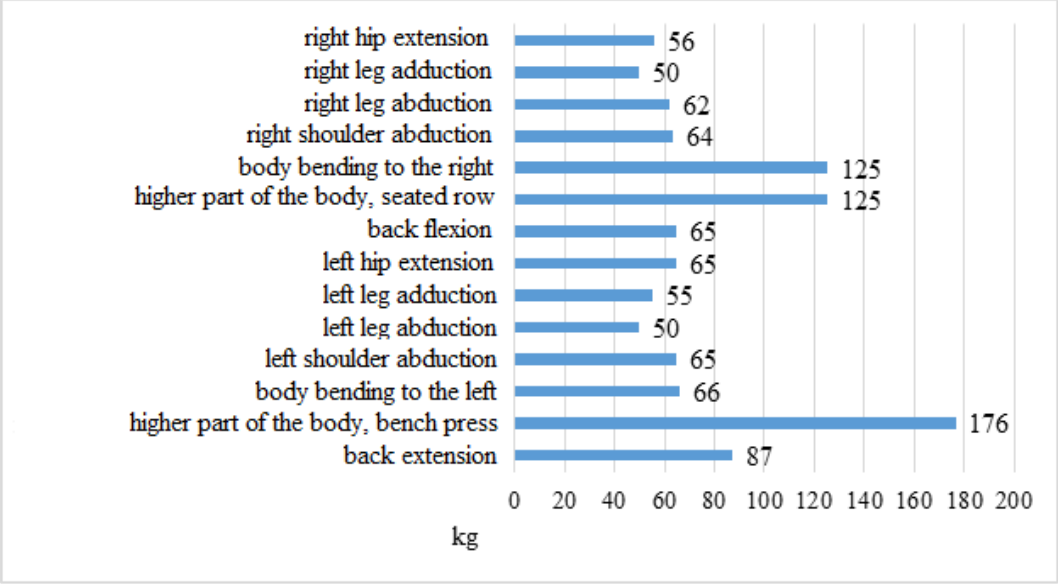

Fig. 1. Strength profile of male bodybuilders

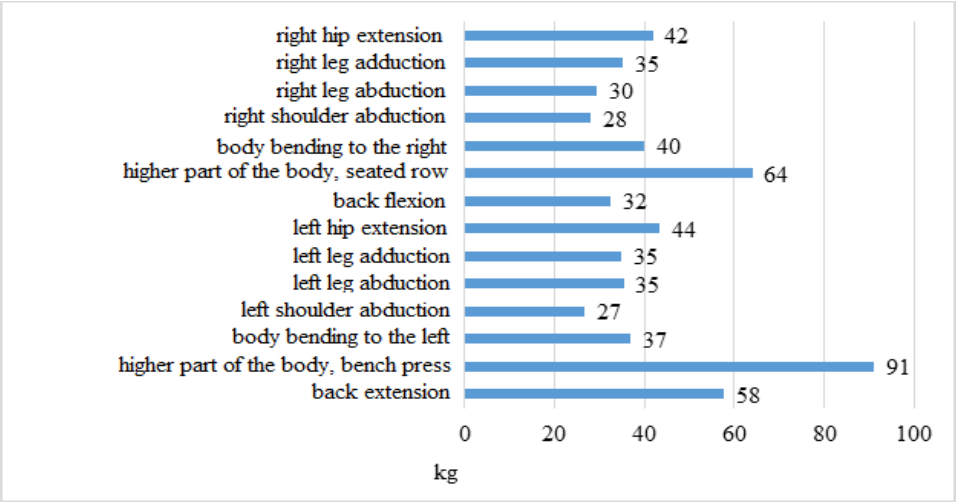

Fig. 2. Strength profile of female bodybuilders

Conclusion. The comparative analysis of strength of the various muscle groups among elite male and female bodybuilders has demonstrated statistically significant differences in all the indices. The percentage ratio comparison of female and male strength has also revealed that the upper shoulder girdle muscles lag the most, and stronger ones are the extensor back and leg muscles, and the strongest ones are the hip extensor muscles (strength amounts to 70% of male strength). The data obtained reflect a general trend of strength ratio between men and women, as well as its distribution in the separate muscles of the body. The received represents great importance for bodybuilding morphology and physiology.

The developed model characteristics and strength profiles of male and female bodybuilding athletes are recommended to assess strength capabilities at different training stages and in the sports selection system.

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

REFERENCES

1. Ivanov V.D., Sukhodoev S.E. Bodybuilding and Health. *Physical Culture. Sport. Tourism. Motor Recreation*, 2017, vol. 2(4), pp. 96-100. (in Russ.)
2. Belinskaya D.V. Sociological analysis of attitudes towards bodybuilding as a canon of masculinity. *Socio-economic phenomena and processes*, 2015, vol. 10, no. 3, pp. 99-107. (in Russ.)
3. Dvorkin L.S., Davydov O.Yu., Dvorkin I.L. Theoretical and anthropometric aspects of bodybuilding. Proceedings of the Jubilee Scientific and Scientific-Methodological Conference of the Faculty dedicated to the 40th Anniversary of the Kuban State University of Physical Education, Sports and Tourism. 2009. pp. 269-279. (in Russ.)
4. Vader D. Body building system. Moscow, 1991. 112 p. (in Russ.)
5. Kochegarov N.V., Trusova V.P. Bodybuilding as one of the areas of a healthy lifestyle. Scientific Research of Modern Scientists: collection of materials of the XV International Scientific and Practical Conference. Moscow, 2016. pp. 426-427. (in Russ.)
6. Zamchij T.P., Koryagina Yu.V. Morphofunctional aspects of adaptation to strength sports. Omsk: SibSUPC, 2012. 156 p. (in Russ.)
7. Nopin S.V. Physiological and biomechanical characteristics of lower extremities' muscles in female boxers during the maximum load test of Bosco repeated jumps. *Modern Issues of Biomedicine*, 2021, vol. 5, no. 3(16), pp. 119-129. (in Russ.)
8. Nopin S.V., Koryagina Yu.V., Ter-Akopov G.N. Functional status of locomotor system of athletes engaged in cyclic and situational sports. *Theory and Practice of Physical Culture*, 2020, no. 4, pp. 25-27. (in Russ.)
9. Koryagina Yu.V. Physiology of strength sports. Omsk: SibSUPC, 2003. 60 p. (in Russ.)
10. Iordanskaya F.A. Man and woman in elite sports. Problems of sexual dimorphism. Monograph. Sovetskij Sport, 2012. 256 p. (in Russ.)

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LACTATE-PYRAMIDAL TRAINING FOR ENHANCING STRENGTH CAPABILITIES AND MUSCLE MASS

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Abstract. ***Introduction.*** This comprehensive narrative review provides a detailed investigation of lactate-pyramidal training as a hypertrophy strategy, synthesizing mechanical tension and metabolic stress. Objective: to conduct a literature analysis of lactate-pyramidal training, focusing on biochemical and neurophysiological responses, practical implementation methods, integration strategies, and recovery. ***Methods.*** The study was conducted according to the CINAR guideline for narrative reviews and the SANRA scale for narrative review quality assessment. Literature searches were performed following the PRISMA-S and PRESS literature search checklists. Literature searches were conducted in the PubMed, Scopus, RSCI, and Cochrane Library databases. No time or language restrictions were applied during the search. ***Results.*** Thirty-six studies met the inclusion criteria (randomized controlled trials (n=24), meta-analyses (n=5), systematic reviews (n=7)). The identified literature was categorized into three areas: physiological mechanisms of the lactate-pyramidal method; classic examples of pyramidal training schemes; methodological approaches of the lactate-pyramidal method. ***Conclusion.*** Currently, this methodology represents an effective, yet consciously and carefully applied tool for overcoming training stagnation and achieving new levels of muscular definition and hypertrophy in sports characterized by maximal strength demands.

Keywords: lactate-pyramidal training, muscle hypertrophy, metabolic stress, mechanical tension, lactate, hydrogen ions, acidosis, pyramidal schemes, drop-sets, rest-pause, hypoxia, periodization, strength training, recovery.

Introduction. *Origins of the lactate-pyramidal training.* Traditional approaches to teach strength capabilities and to grow muscle mass are historically reflected in two directions of athlete training. The first one is described solely as pedagogical, while the second one takes into account a number of physiological and biochemical processes in a body. Although the peak of research in this direction occurred in 1960-1980, back in 1948 Thomas L. DeLorme & Arthur L. Watkins [1] published the work titled "Progressive resistance exercise; technic and medical application" (Archives of Physical Medicine, 1948), in which they developed the DeLorme protocol, which is essentially an ascending pyramid: 3 sets with increasing weights (10 repetitions with 50% of 10RM (repetition maximum), 10 repetitions with 75% of 10RM, 10 repetitions with 100% of 10RM (maximum weight of 10 repetitions). The focus was put on rehabilitation and strength, and the principle of weight progression and the importance of heavy sets formed the basis of strength training and bodybuilding in the 60s and 90s. Their method has been cited and applied for decades.

Pedagogical research on progressing loads was conducted in the Soviet weightlifting school in 1960s, and it was based on numerous studies of L.P. Matveev [2, 3]. For example, Yurij Vlasov [4] and Rudolph Plyukfelder [5] applied ascending pyramids to manage volume and intensity of training. On the other side, as mentioned above, it is worth noting the training approach that takes into account the physiological and biochemical changes in a body. Here we highlight the concept of metabolic training, which focused on the use of lactate as an anabolic stimulus, which became possible after the revolutionary work of Brooks [6] describing the "lactate shuttle", and subsequent studies of the signaling role of lactate in Gladden's research [7]. In general, the modern understanding of lactate-pyramid training has taken shape as a methodological response to the problem of training plateaus among elite bodybuilders and other representatives of strength sports. Some clinical observations have shown that combining pyramidal progression with targeted lactate accumulation makes it possible to overcome the muscle growth stagnation in 78% of athletes with

more than 5 years of experience. Currently, the search for synergetic training strategies that maximize hypertrophy through exposure to multiple mechanisms [8] remains the central task of strength training aimed at muscle tissue hypertrophy. According to the analysis of the problem situation, data from modern scientific literature and requests from sports biologists, physiologists, coaches and athletes, the objective of the study was formulated.

Objective: to conduct a literature analysis of lactate-pyramidal training (LPT), focusing on biochemical and neurophysiological responses, practical implementation methods, integration strategies, and recovery.

Methods and organization. The study was carried out in the Educational and Methodological Laboratory of Evidence-based Development of Natural Science Education, Phystech School of Applied Mathematics and Computer Science, Moscow Institute of Physics and Technology. It was conducted according to the CINAR guidelines (Consolidation Items for NArrative Review) [9] and SANRA (Scale for the Assessment of Narrative Review Articles) [10]. The study's protocol was constructed before the search and did not alter neither during nor after the study. The literature search was conducted in accordance with the PRISMA-S [11] and PRESS (Peer Review of Electronic Search Strategies) literature search checklists [12]. Literature searches were conducted in the PubMed, Scopus, RSCI, and Cochrane Library databases according to the following keywords: lactate AND ("pyramid training" OR "metabolic stress") AND hypertrophy, "motor unit recruitment" AND fatigue. No time or language restrictions, as well as restrictions on study design were set in the search.

Results and discussion. 1750 mentions (taking into account possible article duplication between databases) have been found in the PubMed, Scopus, RSCI, and Cochrane Library databases with the keyword combination (lactate AND ("pyramid training" OR "metabolic stress") AND hypertrophy и "motor unit recruitment" AND fatigue). Thirty-six studies corresponded with the inclusion criteria (randomized controlled studies – RCTs (n=24), meta-analyses (n=5), systematic reviews (n=7)). The identified literature was categorized into three areas:

1) physiological mechanisms of LPT;

2) classic examples of pyramidal training schemes;

3) methods of LPT.

Analysis of physiological mechanisms of LPT. Classic dynamic neuromuscular adaptation is a gradual increase of weights in ascending pyramids (e.g., 12 repetitions with 60% of 1RM → 8 repetitions with 80% of 1RM), it plays the role of the "neural warm-up" [13]. Each repetition increases excitability of motor neurons, improves motor unit (MU) synchronization and facilitates the recruitment of the high-threshold (type II) [14] fibers in the key heavy set ("top of the pyramid"). It allows achieving a more effective mechanical tension in a last set, than when performing it "cold" [15]. Recruiting and activation range: a wide range of MUs is covered: highly repetitive initial sets recruit predominantly type I oxidative fibers and type IIa intermediates, creating a metabolic base. Top of the pyramid recruits type IIx/IIb glycolytic fibers maximally [16]. This provides a more complete stimulation of the muscle pool compared to monotonous schemes. Such direction in training creates a unique subsequence – the initial pyramid sets cause a pH shift in the muscle towards acidosis and create the prerequisites for hydropic dystrophy. A heavy set on the top provides peak mechanical tension and recruitment of high-threshold MUs in conditions of already increased metabolic environment. Cell swelling: metabolite accumulation increases osmolarity of sarcoplasma. It causes flow of water from the interstitium and bloodstream into the muscle fibers, stretching the sarcolemma and perimisium. Mechanosensors (integrins, PI3K) consider the stretching as anabolic signal by activating mTOR (mechanistic target of rapamycin) pathway and suppressing proteolysis through FOXO (Forkhead box O) – a family of transcription factors that regulate protein degradation and autophagy [17, 18]. LPT maximizes metabolic stress causing extreme cell hydration and hypoxia, as well as additional recruiting through reflex mechanisms. This sequence provides powerful synergetic stimulus [19]. Osmotic pressure from lactate/ions → sarcolemma stretching → mTOR activation despite mechanical tension. It is worth noting that LPT is not a substitute for the base load, but a tool for overcoming plateaus. The key is a precise dosing: if the threshold of 15 mmol/L is exceeded, myocyte apoptosis is triggered [20]. Reflex MU activation supports the metabolite accumulation (H^+, lactate, ATP) simultaneously stimulating group III/IV of afferent nerves (nociceptors) and muscle spindles. This reflexively (through the spinal tract) increases efferent impulses to alpha

motor neurons, contributing to the recruitment of additional MUs, especially with developing fatigue – the phenomenon of "recurrent inhibition" or "metabolic facilitation" [21]. It is critically important for continuing the work in conditions of severe metabolic stress of LPT. The cytoplasmic swelling due to intense muscle activity, especially in conditions of limited blood flow (occlusion), leads to accelerated glycolysis. Pyruvate, having no time to oxidize in the mitochondria, restored to lactate, conjugately generating H^+ [22]. Low pH (acidosis) and accumulation of non-organic phosphate (Pi), ATP, creatine create high metabolic stress. Moreover, intensive dynamic muscle work provides pronounced hypoxia (forced lactate accumulation up to 12-15 mmol/l;), activating mTOR pathways, histone lactylation, IGF-1 (Insulin-like Growth Factor 1) secretion locally (+45%) [23]. Moreover, many studies by Pedersen show how metabolic stress stimulates myokine release from the working muscles [24]. Although their role is disputable, local paracrine/autocrine action (especially IL-6 (interleukin-6) and FGF21 (Fibroblast Growth Factor 21)) may provide proliferation of satellite cells and regeneration by indirectly supporting hypertrophy [25]. Mental aspect is also important, since increasing weights reduce a mental barrier between heavy sets, increasing preparedness to maximal effort. As Halperin et al noted [26], the progressing load reduces cognitive evaluation of threat, which alleviates effort mobilization in heavy approaches.

Classic examples of pyramidal training schemes. A classic ascending pyramid implies focus on progressing weights. For example, 4 sets of 15-12-10-8 repetitions [27]. A pyramid with fixed weights and decreasing rest intervals. For example, 70-75% of 1RM decreases with decreasing rest intervals (120 s → 90 s → 60 s → 30 s). The number of repetitions usually drops. In this case, the focus is set on the metabolite accumulation.

"Reverse" pyramid (descending): begins with a heavy set (small number of repetitions), then the weights decrease while the number of repetitions increases (e.g. 6-8-10-12). It is a less common training scheme, but it can be used if the main objective is the priority of heavy loads on the initial pre-start state of the central nervous system. The "Step pyramid" / "Plato pyramid" is performed in several sets with equal weights/repetitions in the middle of the pyramid (e.g. 15 → 12 → 10 → 10 → 10 → LPT). It increases the metabolic component in the middle range. The "Truncated" pyramid: skip of the easiest sets (begins from 10 or 8 repetitions), for experienced athletes or in case of limited time. The combined methods can also be used. For example, drop-set + rest-pause on the last weights; forced repetitions + partial repetitions [28], or application of the isolating exercises on the target muscle before the basic exercise (for example, leg extension between the basic multi-joint exercise in the sagittal plane (barbell squat etc.)). Not only it increases metabolic stress and focuses on the target muscle in the basic movement, but it also can decrease weights at the top of the pyramid. Moreover, if slow (4-6 s) eccentric movements with a partner or on a training device with a lever are performed after concentric failure, it will cause severe injury and additional metabolic stress [29]. If we talk about training process periodization, we should note the following periods [30]: the microcycle will be constructed at the expense of alternating muscle work for different muscle groups with training focused on strength (small number of repetitions, long rest) or on cell swelling (great number of repetitions, short rest). The mesocycles may serve as an ideal tool for 4-8-week periods focused on hypertrophy of the underdeveloped groups.

Frequency: once in 5-7 days for a muscle group. The macrocycles will be constructed according to the objectives of micro- and mesocycles.

Lactate-pyramidal method. LPT is a strategic instrument consisting of a proper construction of a collection of sets combining hypertrophy-optimal mechanical tension on the muscle system and metabolic stress. In whole, it provides a powerful stimulus for muscle growth through the both main hypertrophy mechanisms [20, 31]. We are suggesting the following method of training strength abilities with predominant influence on muscle fiber hypertrophy. The lactate-pyramidal method includes a sequence of four approaches with different number of repetitions and rest periods. We can change the number of sequences taking into account the athlete's fitness. However, it is important to note that rest between such sequences should be quite long (~5 minutes – active, ~10 minutes – passive), since a full recovery is needed after sets with multidirectional metabolic stress for all systems of a body. Nonetheless, it is also crucial that unlike generally accepted schemes of strength training for hypertrophy, LPT combines an optimal level of

mechanical and metabolic stress that allows reaching maximal results for a shorter period and with less damage on the myofibrillar system. Meanwhile, in case of higher efficiency, it would allow to shorten terms of recovery of the target muscle group down to 7 days, while in case of classic dynamic pyramid, 14 days are required for the full resolution of inflammatory infiltration [32-34]. The main principles of LPT structure are:

1. Progressing load: implies variability of external weights depending on the set's direction.

2. Lactate/metabolic component: objective – metabolite (lactate, hydrogen ions etc.) accumulation to stimulate hypertrophy through metabolic stress, especially in the last "light" set.

3. Managing fatigue: rest regulates fatigue level of the central nervous system and muscle system allowing performance of hard sets with heavier weights and achievement of the proper level of osmotic stress in the muscles during "light" sets.

The table below shortly describes the scheme of sequences for muscle fiber hypertrophy consisting of four sets with different objectives.

Table

Lactate-pyramidal method

Set (repetitions)	Objective	Rest time after a set	Reason for rest
1. Light weights, high number of repetitions (12-15)	Warm-up, metabolites accumulation, onset of stress	60-90 s	Management of pulse/metabolism, light fatigue
2. Medium weights, average number of repetitions (~10)	Increasing load	90-120 s	Partial recovery for a heavy set
3. Heavy weights, near-maximum number of repetitions (6-8)	Maximum mechanical stress	150-210 s	Restoration of the creatine phosphate mechanism and the central nervous system for a heavy set involving severe metabolic stress
4. Light weights, maximum number of repetitions (~20)	Maximum oxidation, pH shift	until full recovery	Support of high metabolite content, extreme metabolic stress in a tired muscle. In case of being followed by a series, a full recovery is required.

Conclusion. The progressing muscle load is an undeniable keystone of hypertrophy [35]. LPT is one of the ways to realize it. The scheme, which combines range of repetitions, uniting small, average and high number of repetitions, demonstrates advantages for comprehensive hypertrophy compared to the classic dynamic approach [36, 37]. Moreover, some studies of Marques et al [38] show that long-term hypertrophy is closely connected with growth in strength. LPT is a specialized instrument in the arsenal of strength sports representatives aimed at maximizing metabolic stress, which is an important, though not the only, muscle hypertrophy mechanism. Its effectiveness is based on conscious usage of signaling properties of lactate in terms of structured progression of pyramidal load. LPT is able to cause muscle hypertrophy, stimulate different types of muscle fibers and potentially strengthen the anabolic response. In sports physiology, the biological purpose of LPT is reduced to a protocol of strength exercises, the biological objective of which is to stimulate hypertrophy through the synergy of two mechanisms:

1) Progressing mechanical tension achieved by diverse pyramids with external stress, which recruits high-threshold motor units (type II) and activates the myofibrillar protein synthesis (mTOR-pathway).

2) Lactate-induced metabolic stress occurred in final sets (frequently with intensificators), where a massive accumulation of lactate and H^+ (acidosis) causes osmotic stress leading to the activation of anabolic signals via cell swelling (mechanotransduction).

This process occurs during recruitment of additional MUs (through III/IV group of afferent nerves) in a state of hypoxia causing growth factor expression (HIF-1α). New studies [20] confirm that such type of training recruits and maintains high-threshold motor units under stress, creating ideal conditions for their growth. However, its extreme character requires cautious, controlled application with priority on recovery. Future studies should define long-term effectiveness of LPT more precisely compared to other methods, optimize protocols for various body types and levels of fitness, and investigate deeper individual differences in response to lactate load. Currently,

this method is a progressive but demanding for a cautious and sensible application instrument to overcome the plateau and achieve new levels of muscular definition and hypertrophy in types of sports that imply the manifestation of the threshold strength abilities of a body. Another important thing to note is that in terms of theory and methods of physical education and sports LPT is an independent pedagogical method based on the principle of progressive mechanical stress, which may be used both solo and in synergy with different methods. Therefore, by taking into account the peculiarities of training, we may speak of LPT as a prospective for further study, physiologically substantiated instrument for muscle hypertrophy stimulation that skillfully combines the basic mechanisms of growth – progressive mechanical tension and extreme metabolic stress. Its effectiveness is confirmed by an understanding of biochemistry (lactate/H^+-induced swelling, hypoxia), physiology (recruitment, facilitation), and empirical success in strength sports.

Study limitations. 78% of the studies were conducted on 25-35-year-old men; there are insufficient data on athletes over 50 and women. The LPT effectiveness data are based mainly on short-term studies of young trained men in controlled conditions. There is a critical deficit of data on application of LPT in key population groups (women, the elderly), on its long-term effects and safety, as well as on the influence of deep individual differences (genetics, type of fibers, buffer capacity). This significantly limits the external validity (generalizability) of the results and requires extremely careful interpretation and application of the method in practice, especially for groups not represented in the research. Long-term RCTs with diverse cohorts and careful monitoring of long-term consequences are required.

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

REFERENCES

1. Delorme T.L., Watkins A.L. Progressive resistance exercise; technic and medical application. *Archives of Physical Medicine*, 1948, vol. 29, no. 5, pp. 263-273.
2. Matveyev L.P. The Problem of Periodization in Sports Training. Fizkultura i Sport, 1964. 312 p. (in Russ.)
3. Matveyev L.P. Fundamentals of Sports Training. Transl. by F.S. Wiest. Progress Publishers, 1981. 331 p.
4. Vlasov Yu.P. Overcoming Oneself. Molodaya Gvardiya, 1964. 198 p. (in Russ.)
5. Plyukfelder R.V. Weightlifting: Training Methodology. Fizkultura i Sport, 1968. 215 p. (in Russ.)
6. Brooks G.A. Lactate: Glycolytic End Product and Oxidative Substrate During Sustained Exercise in Mammals – The "Lactate Shuttle" Concept. *Journal of Comparative Physiology B*, 1984, vol. 154, no. 4, pp. 441-448.
7. Gladden L.B. Lactate metabolism: a new paradigm for the third millennium. *The Journal of Physiology*, 2004, vol. 558, no. 1, pp. 5-30. DOI: 10.1113/jphysiol.2003.058701.
8. Schoenfeld B.J. The mechanisms of muscle hypertrophy and their application to resistance training. *Journal of Strength and Conditioning Research*, 2010, vol. 24, no. 10, pp. 2857-2872. DOI: 10.1519/JSC.0b013e3181e840f3.
9. Miroshnikov A.B., Khadartsev A.A., Pavlov E.A. et al. Development and justification of a guide for narrative literature reviews: the CINAR checklist. *Journal of New Medical Technologies*, 2024, no. 6. DOI: 10.24412/2075-4094-2024-6-4-2. (in Russ.)
10. Baethge C., Goldbeck-Wood S., Mertens S. SANRA-a scale for the quality assessment of narrative review articles. *Res Integr Peer Rev*, 2019, no. 4, pp. 5. DOI: 10.1186/s41073-019-0064-8.
11. Rethlefsen M.L., Kirtley S., Waffenschmidt S. et al. PRISMA-S Group. PRISMA-S: an extension to the PRISMA statement for reporting literature searches in systematic reviews. *Journal of the Medical Library Association*, 2021, vol. 109, no. 2, pp. 174-200. DOI: 10.5195/jmla.2021.962.
12. McGowan J., Sampson M., Salzwedel D.M. et al. PRESS Peer Review of Electronic Search Strategies: 2015 Guideline Statement. *Journal of Clinical Epidemiology*, 2016, vol. 75, pp. 40-46. DOI: 10.1016/j.jclinepi.2016.01.021.
13. Zatsiorsky V.M., Kraemer W.J. Science and Practice of Strength Training. Champaign, IL: Human Kinetics, 2006. 2nd ed. 251 p.
14. Vigotsky A.D., Ogborn D., Phillips S.M. Motor unit recruitment cannot be inferred from surface EMG amplitude in voluntary isometric contractions. *Journal of Applied Physiology*, 2016, vol. 121, no. 1, p. 367. DOI: 10.1007/s00421-015-3314-6.
15. Tillin N.A., Bishop D. Factors modulating post-activation potentiation and its effect on performance of subsequent explosive activities. *Sports Medicine*, 2009, vol. 39, no. 2, pp. 147-166. DOI: 10.2165/00007256-200939020-00004.
16. Haun C.T., Vann C.G., Mobley C.B. et al. Pre-training Skeletal Muscle Fiber Size and Predominant Fiber Type Best Predict Hypertrophic Responses to 6 Weeks of Resistance Training in Previously Trained Young Men. *Frontiers in Physiology*, 2019, vol. 10, pp. 297. DOI: 10.3389/fphys.2019.00297.
17. Ogasawara R., Kobayashi K., Tsutaki A. et al. mTOR signaling response to resistance exercise is altered by chronic resistance training and detraining in skeletal muscle. *Journal of Applied Physiology*, 2013, vol. 114, no. 7, pp. 934-940. DOI: 10.1152/japplphysiol.01161.2012.
18. de Freitas M.C., Gerosa-Neto J. et al. Role of metabolic stress for enhancing muscle adaptations: Practical applications. *World Journal of Methodology*, 2022, vol. 12, no. 2, pp. 54-72. DOI: 10.5662/wjm.v7.i2.46.

19. Baz-Valle E., Balsalobre-Fernández C., Alix-Fages C., Santos-Concejero J. A Systematic Review of The Effects of Different Resistance Training Volumes on Muscle Hypertrophy. *Journal of Human Kinetics*, 2018, vol. 65, no. 1, pp. 155-169. DOI: 10.2478/hukin-2022-0017.
20. Mallett G., Schoenfeld B., Purdom T., Galpin A. Physiological factors that affect maximal oxygen uptake and lactate threshold during endurance training. Science & Sports, 2025, vol. 40, no. 3, pp. 201-213. DOI: 10.1016/j.scispo.2023.09.007.
21. Gorostiaga E.M., Navarro-Amézqueta I. et al. Blood ammonia and lactate as markers of muscle metabolites during leg press exercise. *Journal of Strength and Conditioning Research*, 2012, vol. 26, no. 10, pp. 2776-2785. DOI: 10.1519/JSC.0000000000000496.
22. Robergs R.A., Ghiasvand F., Parker D. Biochemistry of exercise-induced metabolic acidosis. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 2004, vol. 287, no. 3, pp. R502-R516. DOI: 10.1152/ajpregu.00114.2004.
23. West D.W., Phillips S.M. Associations of exercise-induced hormone profiles and gains in strength and hypertrophy in a large cohort after weight training. *European Journal of Applied Physiology*, 2012, vol. 112, no. 7, pp. 2693-2702. DOI: 10.1007/s00421-011-2246-z.
24. Pedersen B.K. From the discovery of myokines to exercise as medicine. *Danish Medical Journal*, 2023, vol. 70, no. 9, p. A12220766.
25. Nederveen J.P., Joanisse S., Snijders T. et al. Skeletal muscle satellite cells are located at a closer proximity to capillaries in healthy young compared with older men. *Journal of Cachexia, Sarcopenia and Muscle*, 2021, vol. 12, no. 1, pp. 71-81. DOI: 10.1002/jcsm.12105.
26. Halperin I., Vigotsky A.D., Foster C., Pyne D.B. Strengthening the Practice of Exercise and Sport Science. *International Journal of Sports Physiology and Performance*, 2018, vol. 13, no. 1, pp. 1-24. DOI: 10.1123/ijspp.2017-0322.
27. Angleri V., Ugrinowitsch C., Libardi C.A. Crescent pyramid and drop-set systems do not promote greater strength gains, muscle hypertrophy, and changes on muscle architecture compared with traditional resistance training in well-trained men. *European Journal of Applied Physiology*, 2017, vol. 117, no. 2, pp. 359-369. DOI: 10.1007/s00421-016-3529-1.
28. Fink J., Kikuchi N., Nakazato K. Effects of drop set resistance training on acute stress indicators and long-term muscle hypertrophy and strength. *The Journal of Sports Medicine and Physical Fitness*, 2018, vol. 58, no. 5, pp. 597-605. DOI: 10.23736/S0022-4707.17.06838-4.
29. Douglas J., Pearson S., Ross A., McGuigan M.E. Eccentric exercise: Physiological characteristics and acute responses. *Sports Medicine*, 2017, vol. 47, no. 4, pp. 663-675. DOI: 10.1007/s40279-016-0624-8.
30. Boggenpoel B.Y., Nel S., Hanekom S. The use of periodized exercise prescription in rehabilitation: a systematic scoping review of literature. *Clinical Rehabilitation*, 2018, vol. 32, no. 9, pp. 1235-1248. DOI: 10.1177/0269215518769445.
31. Schoenfeld B.J., Contreras B., Ogborn D. et al. Effects of varied versus constant loading zones on muscular adaptations in trained men. *International Journal of Sports Medicine*, 2017, vol. 38, no. 6, pp. 442-447. DOI: 10.1055/s-0035-1569369.
32. Cerqueira M.S., De Brito Vieira W.H. et al. Effects of Different Recovery Strategies on Delayed-Onset Muscle Soreness and Performance Following a Bout of Eccentric Exercise: A Systematic Review and Meta-analysis. *Journal of Human Kinetics*, 2020, vol. 71, no. 1, pp. 279-292. DOI: 10.3390/ijerph20043461.
33. Petrov I.I., Sidorov A.A. Modern approaches to training periodization in strength sports. *Theory and Practice of Physical Culture*, 2023, no. 5, pp. 12-15.
34. Paulsen G., Mikkelsen U.R., Raastad T., Peake J.M. Leucocytes, cytokines and satellite cells in human skeletal muscle after eccentric exercise. *The Journal of Physiology*, 2010, vol. 588, pt. 17, pp. 3119-3130.
35. Krieger J.W. Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis. *Journal of Strength and Conditioning Research*, 2010, vol. 24, no. 4, pp. 1150-1159. DOI: 10.1519/JSC.0b013e3181d4d436.
36. Lasevicius T., Schoenfeld B.J. et al. Muscle Failure Promotes Greater Muscle Hypertrophy in Low-Load but Not in High-Load Resistance Training. *Journal of Strength and Conditioning Research*, 2022, vol. 36, no. 2, pp. 346-351. DOI: 10.1519/JSC.0000000000003454.
37. Grgic J., Schoenfeld B.J., Orazem J., Sabol F. Effects of resistance training performed to repetition failure or non-failure on muscular strength and hypertrophy: A systematic review and meta-analysis. *Journal of Sport and Health Science*, 2022, vol. 11, no. 2, pp. 202-211. DOI: 10.1016/j.jshs.2021.01.007.
38. Marques E.A., Balshaw T.G., Funnell M.P., McDermott E.J., Maeo S., James L.J., Folland J.P. Muscle Growth Is Very Strongly Correlated with Strength Gains after Lower Body Resistance Training: New Insight from Within-Participant Associations. *Medicine & Science in Sports & Exercise*, 2025. DOI: 10.1249/MSS.0000000000003819.

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EFFECT OF WORK-TO-REST RATIO IN CLUSTER SET DESIGN ON SPEED-STRENGTH INDICATORS OF GRECO-ROMAN WRESTLERS: A PILOT STUDY

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Abstract. ***Introduction.*** Cluster sets with different work-to-rest ratios are considered an alternative to the traditional strength training aimed at reducing fatigue and increasing neuromuscular activation stability. Objective: to evaluate influence of work-to-rest ratio in construction of cluster sets on speed-strength indices of Greco-Roman wrestlers. ***Methods***. The study involved 10 Greco-Roman wrestlers, who performed bench presses according to different methods. The evaluation was conducted using surface electromyography for the pectoralis major, anterior deltoid, triceps, and biceps muscles of the shoulder, kinematic analysis of barbell accelerations, and the Borg scale. ***Results***. After application of the cluster method, a tendency was found to higher values of barbell acceleration and more stable muscle activation in final sets compared with the results of the traditional method in terms of lower subjective fatigue. Regression modeling of subjective perceived load showed a more uniform increase in fatigue in case of cluster sets. ***Conclusion***. The cluster scheme with equal work-to-rest distribution may serve as an effective tool to optimize strength training of wrestlers, reducing subjective fatigue and maintaining high level of neuromuscular activation with a comparable amount of work.
Keywords: cluster sets, strength training, speed-strength abilities, electromyography, bench press, fatigue, Greco-Roman wrestling, movement kinematics.

Introduction. The nature of sports is that athletes usually have to perform their motor skills, including jumps, kicks, lunges and throws, as fast as possible in an adjusted movement range, supporting these movements with high velocity and strength. Different training methods, load, intensity, duration and rest intervals are the important factors in developing plans for strength training sessions [1, 2]. Depending on the manipulation of these variables, various adaptations and varying amounts of strength, power, endurance, and muscle hypertrophy may occur. According to the systematic review by Santos et al. [3], traditional resistance training (TRT) may be described as "3±1 sets of 9±6 repetitions of concentric and eccentric exercises with external load of 75±20% of one repetition maximum (1RM), performed 3±1 times a week». Intra-set rest lasts 2±1 minutes. TRT is performed continuously, without rest between repetitions [4]. According to the meta-analysis by Singer et al. [5] the highest muscle hypertrophy occurs in case of TRT with intra-set rest lasting more than 60 seconds. Despite the achieved success, a question whether this method is the most effective way to stimulate muscle fibers in comparison with alternative methods remains open for discussion and requires further study.

In the course of the last years many scientists and practicing experts strive to change TRT methods in order to minimize or alleviate negative consequences of neuromuscular fatigue and cause the most significant adaptive changes [6]. It was under the guidance of this direction that cluster training arose and is developing. Cluster sets (CS) are an alternative to TRT, which implies division of the traditional set into repetition blocks with a short intra-set rest between them [7]. Modern studies have demonstrated a positive effect of CS on the optimization of neuromuscular and sports indicators, including higher jumps and better sprinting abilities, as well as enhanced strength and mechanical power [6, 8]. Currently, five terms are identified in the cluster training theory: intra-set rest (IR), inter-repetition rest (IRR), rest-pause (RP), redistribution rest (RR) and equal work-to-rest ratios (EW:R) [4, 9]. Moreover, equal work-to-rest ratio in the CS preparation it is of the greatest interest to physical training coaches.

Objective of the study: to estimate effect of work-to-rest ratio in the CS preparation on speed-strength indicators of Greco-Roman Wrestlers.

Methods and organization. On January 2025, a pedagogical experiment was conducted at the Department of Theory and Methods of Martial Arts in the Russian University of Sports "GTSOLIFK". The study involved 10 Greco-Roman wrestlers (age – 18±2 years), who passed the preliminary testing to evaluate 1 repetition maximum (1RM) of a bench press. We examined two sequences of exercises which are aimed

towards the improvement of strength indicators in a bench press, but differ in the principles of load and rest organization.

Sequence I is based on TRT: 3 sets of 8 repetitions (24 repetitions) with weights of 85% of 1RM. IRR – 60 seconds.

Sequence II is based on CS (EW:R): 24 repetitions (weights of 85% of 1RM), organized in a form of 8 mini-sets of 3 repetitions. Intra-set rest (IR) between each three repetitions was calculated according to the formula:

$$IR = 2 \times IRR / ((N / 3) – 1), (1)$$

where N – total number of repetitions = 24, IRR – inter-repetition rest in TRT = 60 s.

If we put the needed values, we will get the following result:

$IR = 2 \times 60 / ((24 / 3) – 1) = 120 / (8 – 1) = 17.14$ s

The study's participants came in the morning and performed Sequence I followed by Sequence II, rest interval between the sequences lasted 30 minutes.

The study included three key methods of evaluating the functional state of athletes, who perform bench press: the Colibri wireless system of electrophysiological signal monitoring (Russia), inertial multisensory device and subjective evaluation of perceived load (Borg scale).

The Colibri system is based on surface electromyography (EMG). Application of wireless sensors has allowed to conduct a detailed analysis of spatial and temporal characteristics of muscle involvement, including synchronization of work of different muscle groups and fatigue dynamics. We evaluated the activity of the pectoralis major, anterior deltoid, triceps, and biceps muscles of the shoulder. The biceps muscle does not participate in horizontal adduction of the shoulder joint and extension of the elbow joint, but it plays a crucial role of stabilizing the shoulder joint, which is why we decided to analyze its activity as well. Position of electrodes during the study did not change in order to reduce inaccuracy of measurements. For the analysis, we took data of the muscle activity EMG from the last repetition of first and last sets. An area of 0.5 seconds with maximum signal amplitude was chosen on the oscillogram. Area under the curve was calculated automatically in the NeuroMD Myografy software complex developed by Neurotech Company. Then normalization of the signal and comparison of values was conducted.

At the same time with EMG monitoring, we used the inertial multisensory device equipped with accelerometer and gyroscope to register 3D kinematic parameters of the barbell's movement. The device was applied to the barbell with a magnet adapter which provided synchronous fixation of linear velocity vectors along the X, Y, Z axes, was well as angle orientation of the barbell in space. The measurement protocol included minimization of inaccuracies connected with gravitational acceleration. Collection of the data was carried out with 200 Hz discretization frequency, which provided high temporal resolution capability to analyze phase movement characteristics. Analysis of descriptive statistics of barbell accelerations (mean, standard deviation, minimum, median, 25^{th} percentile, 75^{th} percentile, maximum) has allowed describing variability and movement dynamics, identifying the technique's peculiarities and potential imbalances of bench press.

To evaluate subjective intensity of physical activity, we applied the classic 15-point Rating of perceived exertion (RPE), where the values varied from 6 (no exertion) to 20 (maximum exertion). After each set, the subjects independently recorded the level of perceived exertion. The integration of objective EMG and kinematic data with subjective RPE assessments contributes to a comprehensive understanding of the functional state of athletes and the training process optimization.

Assessment of the collected data set was based on the descriptive statistics analysis and dispersion analysis. To construct the mathematical model, we used regression modeling. All calculations were done with Python libraries in Jupyter Notebooks platform using cloud technologies of Google Colab (https://github.com/vn322/Wrestling/blob/main/weight_lift.ipynb).

Results and discussion. *Comparison of the methods with the measurement of kinematic parameters of barbell movement.* To conduct the initial assessment of the present datasets we have estimated descriptive statistics parameters of barbell acceleration in bench press according to the cluster scheme (table 1).

As we can see, there are insignificant differences between mean and median values, which may serve as evidence of normal distribution of the measured value and demands for further study. Moreover, we can see a slightly different approach of athletes to manage the equipment's movement. For example, the first and the fourth athletes focus on accelerating the barbell and its smooth inhibition, the second and seventh focus on both acceleration and inhibition, the third and

eighth focus on inhibition only, and the fifth and sixth athletes prefer smooth execution of the exercise with relatively small acceleration (table 1).

In order to compare data, we would like to investigate descriptive statistics of barbell acceleration in bench press according to the traditional scheme presented in table 2.

We also observe proximity of mean and median values, presence of different approaches focusing on inhibition and acceleration of the barbell's movement. Considering all the available execution styles, it can be noted that the first focus, determined by the value of the module, falls on the third, and more often the fourth movement.

Table 1

Descriptive statistics parameters of barbell acceleration in bench press according to the cluster scheme for different athletes, m/s²

Parameter	Athlete							
	1	2	3	4	5	6	7	8
Mean	0.965	0.972	0.983	0.971	0.946	0.989	0.996	0.992
Standard deviation	0.348	0.351	0.265	0.269	0.212	0.267	0.315	0.276
Minimum	-0.559	-0.789	-0.378	-0.362	-0.513	-0.405	-1.333	-1.052
25^{th} percentile	0.840	0.893	0.937	0.885	0.872	0.918	0.934	0.938
Median	0.952	0.972	0.991	0.974	0.964	0.988	0.990	0.989
75^{th} percentile	1.039	1.023	1.032	1.023	1.016	1.016	1.046	1.024
Maximum	4.599	5.041	3.936	4.719	2.176	2.809	4.105	2.846

Table 2

Descriptive statistics parameters of barbell acceleration in bench press according to the traditional scheme, m/s²

Parameter	Athlete							
	1	2	3	4	5	6	7	8
Mean	0.979	0.947	0.985	0.920	0.916	0.941	0.967	0.986
Standard deviation	0.358	0.301	0.267	0.262	0.236	0.306	0.292	0.338
Minimum	-0.277	-0.395	-0.420	-0.209	0.015	-0.655	-0.637	-0.833
25^{th} percentile	0.872	0.875	0.918	0.877	0.812	0.827	0.893	0.921
Median	0.981	0.952	0.986	0.976	0.944	0.963	0.985	0.985
75^{th} percentile	1.070	1.005	1.033	1.021	1.012	1.005	1.044	1.028
Maximum	2.502	2.502	4.333	2.228	2.485	2.516	3.664	4.575

For TRT, "smooth" performance of exercises without any pronounced emphasis may be considered as typical, there are also cases of emphasis on the last movement (table 3). A similar situation may show that in a course of first three lifts of the barbell, an athlete warms-up and adapts to the exercise, and then they may consciously emphasize specific movements. Among other things, we can see individual peculiarities of athletes, who either perform the whole sequence "smoothly", avoiding any emphasis, or try to show maximum of their capabilities after warm-up, or "save resources" to show their maximum at the end of the exercise. Moreover, it is important to note that in most cases, higher values of acceleration are achieved in case of performing the exercise according to CS. Individual differences do not allow us to claim a single model of exercise performance inherent in all athletes, and in the future we can try to compare the results by mean and median values. It should be noted that the interval in which the acceleration values change is somewhat smaller than in CS. Among other things, according to the descriptive statistics analysis, when performing exercises according to CS, athletes achieve slightly higher acceleration values if assessed using mean and median values. To clarify the significance of these differences, a variance analysis was performed (table 3).

We used the Kruskal-Wallis H-test as less demanding to peculiarities of the examined value's distribution. As a result, we have found that despite the tendency of increasing mean and median acceleration values no statistical significance of differences ($p \leq 0.05$) was registered in speed-strength preparation of athletes when using the examined training schemes.

Assessment of fatigue level of athletes under acting load using the Borg scale. In order to identify the present differences, we have proposed a theory of different fatigue models that occur in case of applying the schemes. Linear approximation of fatigue build-up rate's mean values in application of the examined schemes is presented in figure 1.

Table 3

Dispersion analysis results of performing exercises according to the examined schemes

Scheme	Mean acceleration	Acceleration median	Kruskal-Wallis H-test	P<
CS	0.97675	0.9775	2.482	-
TRT	0.95513	0.9715	1.220	-

Note: CS – cluster scheme; TRT – traditional resistance training.

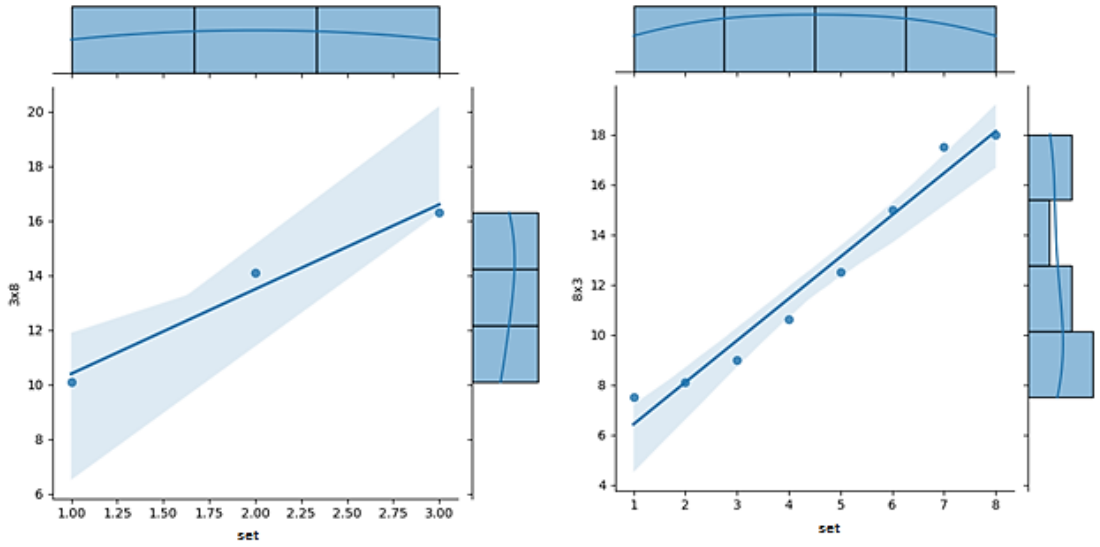

Fig. 1. Linear approximation of mean values of fatigue build-up rate in application of TRT (traditional resistance training) and CS (cluster scheme), respectively

While assessing the resulting models, we can see that the models really differ and athletes perceive most of the CS exercises as moderate when performing the same amount of work. For a more detailed study, mathematical models of performing exercises according to the examined schemes were constructed. The linear regression method was used for this purpose (table 4).

During examination of the obtained models, we can note their high productivity according to the comprehensive evaluation, which included: determination coefficient (R^2), Fischer criterion (F-statistic), Akaike information criterion (AIC) and Bayesian information criterion (BIC). The models themselves demonstrate much higher fatigue build-up rate in case of CS and better fatigue management in case of TRT. We have identified three approaches to perform these exercises depending on emphasis distribution in a sequence of bench presses. We have also compared values of acceleration in the examined schemes and constructed mathematical models of fatigue build-up rate of these schemes.

Comparative analysis of the training schemes with surface EMG. EMG activity of muscles expressed in millivolts reflects the degree of motor unit recruiting and level of neuromuscular activation. Although increase of EMG amplitude may reflect a growth of neuromuscular load, this indicator is not a direct equivalent of mechanical work, but only indirectly characterizes the degree of involvement of muscle fibers. Mean values of EMG amplitude (mV), as well as relative differences between the schemes are shown in table 5. Relative change (Δ, %) was calculated according to the formula:

$$\Delta = ((K - TR) / TR) \times 100\%, \quad (2)$$

where K – the cluster scheme value (8×3), TR – the traditional resistance training value (3×8).

The Δ calculation was done separately for the first and last sets, showing relative dynamics of EMG between the schemes as a percentage of the traditional scheme.

Table 4

Results of regression modeling of perceived stress after performing exercises according to the examined schemes

Scheme	Model equation	R^2	F-statistic	AIC	BIC
CS	y = 3.10 x + 7.30	0.973	35.59	7.369	5.566
TRT	y = 1.67 x + 4.75	0.967	176.9	21.12	21.28

Note: CS – cluster scheme; TRT – traditional resistance training; R^2 – determination coefficient; F-statistic – Fischer criterion; AIC – Akaike information criterion; BIC – Bayesian information criterion.

To prove the hypothesis we measured 1RM of the pectoralis major muscle of one of the participants with simultaneous fixation of bioelectrical system amplitude (EMG). The repetition maximum amounted to 50 kg and the normalized value of the EMG amplitude was 4920 mV. Then we took the load of 80%, 60%, 40%, 30% and 20% of 1RM, which amounted to 40, 30, 20, 15 and 10 kg, respectively. With these weights, an exercise was performed and the amplitude of the EMG signal was recorded. The results are shown in figure 2.

Table 5

Mean values of muscle electromyography amplitude in the first and last sets, mV

Sets	First				Last			
Scheme / Muscle	PM	DEL	TB	BB	PM	DEL	TB	BB
TRT	1486.25	2260.5	2830.875	590.875	1754.5	2571.75	3403.375	720
CS	1218.125	1905.75	2475	577.5	2013.25	2787.5	3865	692.5
Δ, %	-22%	-19%	-14%	-2%	13%	8%	12%	-4%

Note: TRT – traditional resistance training; CS – cluster scheme; PM – pectoralis major; DEL – deltoideus; TB – Triceps brachii; BB – Biceps brachii; Δ – relative changes in electromyography between schemes (%).

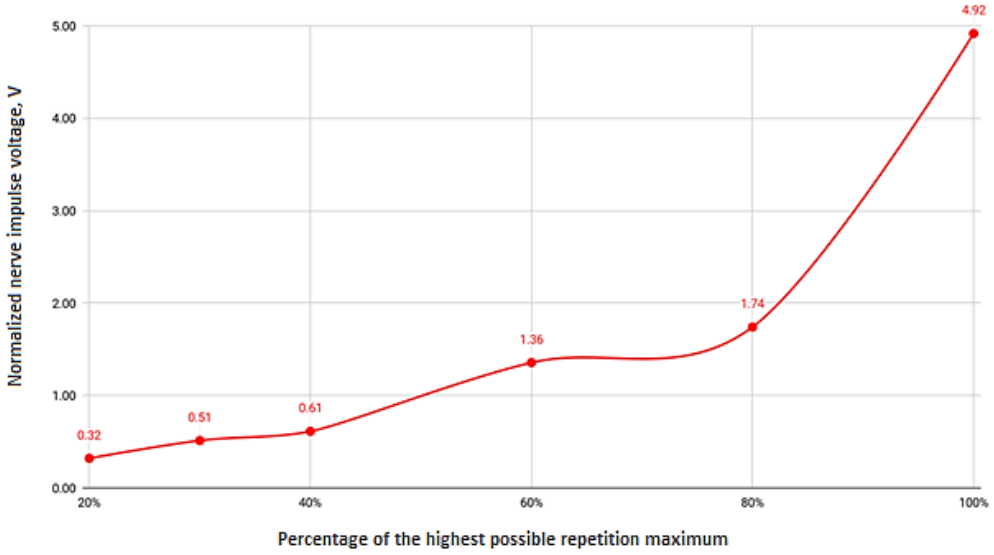

Fig. 2. Dependence of the amplitude of the biceps' electromyography on the load level (% of 1RM), V

The analysis's results demonstrate positive correlation between weights and EMG signal amplitude, however this dependence differs from the linear one. A number of repetitions in the first set of the traditional scheme exceeds that in the cluster scheme, which is shown in much higher EMG values. We have also noted an increase of EMG for all the muscles, except the biceps brachii that does not increases its EMG, since in this case it stabilizes the shoulder joint. Mean value of EMG at the end of the first set is lower by 14-22%. Analysis of the data from the last set shows us that with a comparable amount of work performed, the EMG values in the cluster scheme are 8-13% higher than in the traditional one, indicating more stable muscle activation with an equal amount of work. The study shows that the use of cluster training methods contributes to a higher activity of muscle fibers. This, in turn, can help increase muscle volume and strength in systematic training.

Conclusion. The conducted pilot study has allowed to comprehensively assess influence of work-to-rest ratio when using cluster sets and traditional training on speed-strength indicators of Greko-Roman wrestlers. The comparative analysis performed using kinematic characteristics of the barbell movement, EMG activity of the key muscle groups and subjective fatigue evaluation has revealed a number of significant tendencies.

1. The kinematic analysis has revealed that when performing CS exercises the athletes usually achieve higher values of acceleration compared with that of TRT. However, there were no statistically significant differences at the significance level $p \leq 0.05$. We have found different individual strategies of emphasis distribution in movement, which may show features of motor control and degree of fatigue.

2. The regression modelling of the Borg scale has shown that in cluster sets fatigue

increases more evenly and is subjectively perceived as less stressful when performing the same amount of work. This indicates the potential effectiveness of the cluster scheme in load management and reducing the severity of fatigue in the training process.

3. The EMG data demonstrate a much higher degree of muscle activation in performing exercises according to the cluster scheme, especially in final sets. The elevated bioelectric activity of the pectoralis major, anterior deltoid and triceps muscles of the shoulder in CS can contribute to a more significant training stimulus while maintaining the volume of work. Special attention should be paid to the increased role of the anterior deltoid and triceps muscles, which confirms the need to revise the emphasis in the bench press technique as an exercise.

Therefore, introduction of cluster sets with equal work-to-rest ratio may be considered as a promising alternative of the traditional method in developing speed-strength capabilities of wrestlers. Application of this scheme contributes to decreased fatigue, increased level of muscle activation and kinematic characteristics variability, which together can provide a more stable and effective adaptation to training activity. The results of this study require validation on broader samples, but already at this stage they confirm the expediency of using cluster training as a tool for individualizing and optimizing the training process in sports with a high proportion of speed and strength training.

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

REFERENCES

1. Li G., Wang Z., Hao Y. et al. Consensus statement of Chinese experts on exercise prescription (2023). *Sports Med Health Sci*, 2024, vol. 6(2), pp. 200-203. DOI: 10.1016/j.smhs.2024.02.003.
2. Mcleod J.C., Currier B.S., Lowisz C.V., Phillips S.M. The influence of resistance exercise training prescription variables on skeletal muscle mass, strength, and physical function in healthy adults: An umbrella review. *J Sport Health Sci*, 2024, vol. 13(1), pp. 47-60. DOI: 10.1016/j.jshs.2023.06.005.
3. Santos C.S., Pinto J.R., Scoz R.D. et al. What is the traditional method of resistance training: a systematic review. *J Sports Med Phys Fitness*, 2022, vol. 62(9), pp. 1191-1198. DOI: 10.23736/S0022-4707.21.12112-7.
4. Tufano J.J., Brown L.E., Haff G.G. Theoretical and Practical Aspects of Different Cluster Set Structures: A Systematic Review. *J Strength Cond Res*, 2017, vol. 31(3), pp. 848-867. DOI: 10.1519/JSC.0000000000001581.
5. Singer A., Wolf M., Generoso L. et al. Give it a rest: a systematic review with Bayesian meta-analysis on the effect of inter-set rest interval duration on muscle hypertrophy. *Front Sports Act Living*, 2024, vol. 6, pp. 1429789. DOI: 10.3389/fspor.2024.1429789.
6. Cui J., Yu Y., Xu Y., Wu H. Effectiveness of long-term cluster training and traditional resistance training in enhancing maximum strength in young adults: a systematic review and meta-analysis. *Front Physiol*, 2025, vol. 16, p. 1568247. DOI: 10.3389/fphys.2025.1568247.
7. Taber C.B., Murphy J., Shah J. et al. Changes in Bench Press Velocity and Power After 8 Weeks of High-Load Cluster or Traditional Set Structure: A Replication Study. *Communications in Kinesiology*, 2025, vol. 1(7). DOI: 10.51224/cik.2025.75.
8. Vargas-Molina S., García-Sillero M., Maroto-Izquierdo S. et al. Cluster sets and traditional sets elicit similar muscular hypertrophy: a volume and effort-matched study in resistance-trained individuals. *Eur J Appl Physiol*, 2025, vol. 125, pp 1725-1734. DOI: 10.1007/s00421-025-05712-6.
9. Latella C., Peddle-McIntyre C., Marcotte L. et al. Strengthening the Case for Cluster Set Resistance Training in Aged and Clinical Settings: Emerging Evidence, Proposed Benefits and Suggestions. *Sports Med*, 2021, vol. 51(7), pp. 1335-1351. DOI: 10.1007/s40279-021-01455-4.

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IMPROVING PSYCHOFUNCTIONAL STATE AND QUALITY OF LIFE WITH PHYSICAL REHABILITATION AFTER TRAUMATIC BRAIN INJURY COMBINED WITH SPASTIC HEMIPARESIS

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Abstract. ***Introduction.*** The article presents a study on increasing the activity of life, self-care skills and psychofunctional state in men with traumatic brain injury combined with spastic hemiparesis by physical rehabilitation means. ***Methods.*** The study involved seven men with traumatic brain injury, age – 25-35 years. Activities of daily living and self-care skills were estimated with the Barthel index and the modified Rivermead mobility index. Severity of pain syndrome was assessed with the visual analogue scale, functional state of the musculoskeletal system – with the Ashworth scale and Motricity index. ***Results.*** The positive effect is represented by reliable improvements in the Barthel, Rivermead and Motricity indices, in the results of the Ashworth scale, the visual analogue scale, the Berg balance scale, the Wakefield questionnaire, the Standing balance test and the Functional categories of walking test. ***Conclusion.*** The physical rehabilitation course after traumatic brain injury combined with spastic hemiparesis has significantly improved activities of daily living and supported the recovery of self-care skills and psychofunctional state.

Keywords: traumatic brain injury, spastic hemiparesis, activities of daily living, self-care, psychofunctional state, physical rehabilitation, motor activity.

Introduction. Modern data show that brain injuries are one of the main causes of disability and mortality of the population [1]. Each year, 1.5 million die from traumatic brain injury (TBI), 2.4 million become disabled. The incidence of TBI is 3-4 per 1000 population on average [1, 2]. In Russia, the leading causes of TBI are home accidents, car incidents and military injuries. In terms of gender, there are 2.5 times more men than women, who suffer from TBI [2]. According to the data from the Sklifosovsky Institute for Emergency Medicine, the number of hospitalized patients with TBI in Moscow is 10 000 to 13 000 per year, average age – up to 43 years [3]. Frequently, the received brain injury is complicated by changes in muscle tone and worsened mental state, which limit rehabilitation potential of the patients [4].

The importance of physical rehabilitation after TBI is due to a necessity to restore the functions lost after the injury: limb mobility, movement coordination, self-care skills, walking and other social skills [4, 5], in some cases professional skills as well, which demonstrates the relevance and timeliness of this research. Moreover, success of rehabilitation is significantly regulated by terms and volume of those rehabilitation measures that take into account clinical signs and rehabilitation potential of the patients.

Objective of the study: to estimate changes in activities of daily living, self-care skills and psychofunctional state of men with TBI combined with spastic hemiparesis after the physical rehabilitation course.

Methods and organization. The study included men with TBI (n=7). The inclusion criteria: gender – male; age – 25-35 years; diagnosis – TBI; severity – moderate (according to the L.B. Likhterman); motor disorders – spastic hemiparesis; recovery period – interim; voluntary consent to participate in the study.

Activities of daily living and self-care skills were estimated with the Barthel index (points) and the modified Rivermead mobility index (mRMI-ICU, points). Severity of pain syndrome was assessed with the visual analogue scale (VAS, points). Functional state of the musculoskeletal system was estimated with the modified Ashworth spasticity scale (points) and the Motricity index (motor tests for higher and lower limbs, points). Balance was assessed with the standing balance test (points) and the Berg

balance scale (points), motor behavior – with the Functional categories of walking test (level), psychophysiological state – with the Wakefield questionnaire (points).

The results were processed in the Statistica 13 software package. We calculated the mean (M) and the standard deviation (σ). The distribution normality was estimated with the Shapiro-Wilk test, reliability of differences in the studied indices before and after physical rehabilitation was identified with the Wilcoxon's signed-rank test, $p \leq 0.05$.

Physical rehabilitation measures were applied in a course that lasted 12 weeks. The following measures and forms were used: morning hygienic gymnastics (MHG) with calisthenic routine (CR), static and dynamic breathing (BE) exercises (everyday, 7-10 minutes in the initial position of lying on the back); therapeutic gymnastics (5 times a week, 20 minutes), including: CR (for all muscles of healthy limbs), BE (static and dynamic), special exercises (SE): passive, active-passive exercises for injured limbs, exercises for the back, pelvic and abdominal muscles, isometric contraction in the muscles of the injured limbs, stretching exercises, exercises for the vestibular system, verticalization therapy for a patient while sitting, then standing, verticalization training while sitting, balance exercises while sitting. The exercises were performed in the initial position of lying on the back, lying on the side and sitting. The active-passive exercises were carried out with the help of an instructor. Then, classes were held not only in the ward, but also in the physical therapy cabinet in the initial position of lying on the back, lying on the stomach, sitting, standing, standing at the wall bars in a knee pad. We included balance exercises in the sitting and standing positions, trained support for the injured limbs, taught walking recovery skills, followed by its training with the help of the instructor. To relax the spastic muscles, positioning (laying) was used (2-3 times a day for 20 minutes) and paraffin applications to the injured limbs (10 procedures every other day, 15-20 minutes each) in alternation with magnet therapy (10 procedures, 15 minutes each). Mechanotherapy was applied (the Motomed training device, Imitron): passive, active-passive movements of the legs and arms (daily, for 20 minutes). Therapeutic massage (10 procedures, 5 days a week, 15-20 minutes each) was implemented in alternation with acupuncture (10 procedures, 20 minutes each). Later, we included independent classes (active, active-passive exercises) aimed at restoring walking and household skills. As the walking skills with auxiliary equipment (walker, cane) were mastered, walking was prescribed daily with a gradual increase in time to 20 minutes. To train the correct walking pattern, treadmill exercises were also included (every other day, for 20 minutes, at a slow pace).

Results and discussion. After the physical rehabilitation course for patients with TBI combined with spastic hemiparesis, we have discovered an improvement in activities of daily living and level of independence in everyday life estimated by the Barthel index. At the beginning of the course, the Barthel index scored 6.86±2.98 points, showing dependence on external support in everyday life. At the end of the course, the index has increased by 75%, reaching 12±2.57 points and showing moderate degree of dependence on external support. The mobility level (the Rivermead mobility index, mRMI-ICU) has increased by 124% from moderate (3±0.86 points) to mild (6.71±0.49 points) degree.

We have also revealed reduced pain syndrome (VAS): in the higher limb – by 48% from moderate (3.29±1.18 points) to mild (2.14±1.84 points) degree; in the lower limb – by 47%, from 2.14±1.84 points to 1.14±1.02 points. According to the Ashworth's scale, the muscle spasticity of the higher (by 40%, from 2.14±0.24 to 1.29±0.41 points) and lower limbs (by 42%, from 1.71±0.41 to 1.00±0.29 points) has also reduced.

In terms of the most motor functions estimated by the Motricity index, movements in joints and muscle strength in the injured limbs have reliably improved ($p<0.05$): pinch-grasp – by 81%; elbow flexion – by 70%; shoulder abduction – 47%; ankle dorsiflexion – by 75%; knee extension – by 47%; hip flexion – by 34% (table).

Balance function have also significantly improved: in the Berg balance scale – from 2.29±0.41 to 3.57±0.49 points; in the standing balance test – from 0.43±0.61 to 2.57±0.65 points. In the Functional categories of walking test, the results increased from 0.71±1.02 to 3.57±0.77 points.

Recovery and improvement of the lost motor functions due to the injury have positively influenced psychoemotional state of the patients after the physical rehabilitation course. The initial score of the Wakefield questionnaire indicated its presence (19±2.57 points), then it has reduced to 11.43±2.78 points showing no signs of depression among the patients.

Table

Changes in the Motricity index before and after the physical rehabilitation course after traumatic brain injury combined with spastic hemiparesis, M±σ, points

Indices	Before	After	P<
Pinch-grasp	10.57±6.04	19.14±4.73	0.05
Elbow flexion	12.71±4.69	21.57±2.94	0.05
Shoulder abduction	10.57±3.92	15.57±2.69	–
Ankle dorsiflexion	8.43±2.41	14.71±2.45	0.05
Knee extension	12.57±3.06	18.43±2.53	0.05
Hip flexion	15.43±3.06	20.71±2.45	0.05

Conclusion. The physical rehabilitation course after traumatic brain injury combined with spastic hemiparesis has significantly improved activities of daily living and supported the recovery of self-care skills and psychofunctional state. The positive effect is represented by the reliable improvements of the Barthel, Rivermead and Motricity index, in scores of the Ashworth scale, VAS, the Berg balance scale and the Wakefield questionnaire, in the results of the standing balance test and the Functional categories of walking test.

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

REFERENCES

1. Poshataev K.E. Epidemiological and clinical aspects of the craniocerebral trauma. *Far East Medical Journal*, 2010, no. 4. Available at: https://cyberleninka.ru/article/n/epidemiologicheskie-i-klinicheskie-aspekty-cherepno-mozgovoy-travmy (accessed 07.08.2025). (in Russ.)

2. Sabirov D.M., Rosstalnaya A.L., Makhmudov M.A. Epidemiological features of cranial injury traumatism. *Bulletin of Emergency Medicine*, 2019, no. 2. Available at: https://cyberleninka.ru/article/n/epidemiologicheskie-osobennosti-cherepno-mozgovogo-travmatizma (accessed 07.08.2025). (in Russ.)

3. Surgery of severe traumatic brain injury. Krylov V.V. ed. Moscow: ABV-press, 2019. 859 p. (in Russ.)

4. Filatova O.A., Lunina N.V. Increasing the functional independence and psychoemotional state of persons with spinal cord injury in the course of physical rehabilitation. *Russian Journal of Sports Science: Medicine, Physiology, Training*, 2025, vol. 4, no. 2(14). DOI: 10.24412/2782-6570-2025_04_02_5.

5. Lunina N.V., Trofimova P.D. Effects of physical rehabilitation in cervical spinal cord injury. *Russian Journal of Sports Science: Medicine, Physiology, Training*, 2024, vol. 3, no. 2. DOI: 10.24412/2782-6570-2024_03_02_5.

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DEVELOPING THE METHOD OF READAPTATION AND RECOVERY OF THE TORSO MUSCLES OF ASTRONAUTS USING MECHANOTHERAPY ON THE CENTAUR COMPLEX

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Abstract. ***Introduction.*** The results of many years of research have established the negative influence of space flight factors on the functional state of the musculoskeletal of astronauts, including the torso muscles. Therefore, there is a need to develop efficient methods for their restoration and strengthening. Objective – to develop a method of robot-assisted mechanotherapy on the Centaur complex for post-flight rehabilitation of the astronauts' musculoskeletal system. ***Methods.*** The study involved 7 male astronauts and the control group (healthy men). The study of the torso muscles' force was carried out on the Centaur complex (diagnosis and training of the autochthonous torso muscles). ***Results.*** Taking into account the data of theoretical analysis and diagnosis of the force parameters of the torso muscles of astronauts and male volunteers, a method of robot-assisted mechanotherapy on the Centaur complex for the post-flight rehabilitation of the musculoskeletal system was developed. The technique consists in rotating the patient around their own axis with preset parameters to strengthen various muscle groups of the torso and differs depending on the diagnosed parameters of muscle balance. ***Conclusion.*** The developed technique is aimed at optimizing the balance of the autochthonous torso muscles, eliminating the deficit and restoring the force parameters of the muscles, centralizing movement and load along the main anatomical axes.
Keywords: astronauts, post-flight rehabilitation, musculoskeletal system, torso muscles, robot-assisted mechanotherapy.

Introduction. The work of astronauts on orbit is considered as an extremely complicated activity associated with substantial physical loads against the background of constant influence of specific spaceflight (SF) factors, such as zero gravity, overloading, radiation, vibration and physical inactivity. All of it lead to substantial morphological and functional changes, which should be considered as adaptive. Microgravity in SF conditions affects almost all functional systems of a human body [1-4]. Musculoskeletal system (MSS) is the most vulnerable. Zero gravity or microgravity, excluding physiological axial loading on MSS and joints as a basis of amortization in case of vertical movement in space, shift of the center of gravity and disturbance of adequate muscle stimulus and balance of calcium and other microelements cause significant changes in the function of support and movement organs of astronauts. A decrease in muscle tone leads to a reduced muscle mass, a redistribution of the volume of circulating blood and body fluids, demineralization of bone tissue, which, in turn, leads to impaired posture, displacement of internal organs and other negative changes [5-6].

It was established that at earlier stage of readaptation after support unloading, lumbar enlargement reduction is not compensated, the volume of white and gray matter remains reduced, which is accompanied by a decrease in the average sizes of motor neurons [7].

The lack of influence of body weight in microgravity entails a cascade of disorders, primarily related to the axial loading on the supporting skeleton, joints and muscular system. The absence of gravitational stimuli blocks antigravitational reactions from the musculoskeletal system. The idea of a chain of pathological disorders, first expressed as a hypothesis based on theoretical assumptions, was subsequently confirmed during flights and post-flight reactions. A decrease in afferent impulses in microgravity forms a violation of the responses of all physiological functions. An analysis of the features of the readaptation process in astronauts, as well as observations made during prolonged inactivity, indicate changes in general reactivity, regulation of autonomic and motor functions. The imperfection of reverse afferentation can be explained by violations of coordination of movements in statics and dynamics after the end of space flights [8].

Lack of compression effects on the musculoskeletal system alters exposure on the

external vascular tone and blood circulation. Functional muscle stiffness in microgravitation is a triggering mechanism that reduces anti-gravity muscle tone, their resistance and their working response. Microgravity reduces the tone of the muscles that ensure the vertical position of the body and the extensor muscles with the development of atrophic/atonic processes, which, in turn, reduces the resistance of the vascular wall with the development of dilation effects [9].

Metabolism disturbance in bone and muscle structure are also the consequence of reduced load on MSS. Moreover, protein catabolism intensifies, calcium deficit in muscle tissue, as well as endocrine status imbalance occur [8].

It has been shown that chronic decrease of motor activity causes large-scale changes in the transcriptome (several thousand mRNAs), as well as in the skeletal muscle proteome. These changes are primarily associated with the activation of the inflammatory response and the extracellular matrix restructuring, as well as with a decrease in the expression of genes encoding various mitochondrial enzymes [10].

Reduced tissue respiration and oxidative phosphorylation with the development of a dis-proportion of demand and energy consumption indicates the possibility of increased O_2 consumption and oxygenation deficiency [11].

A ten-year experience of observing the state of astronauts generalized complicated shifts that occur in the macro- and microelement base. Microgravity inevitably followed by adaptive clinical-biochemical, hormonal and metabolic processes of MSS relate to bone and muscle tissue. If there is no gravitational stimulus, a disturbance of macro- and microelement balance with the leaching of sodium, water, potassium, chlorine, and iron ions occurs. At the same time, negative nitrogen balance develops, which, together with the loss of water, leads to a decrease in body weight due to the loss of fluid, muscle mass, and mineral composition with the development of new correlations of chemical elements in biological environments [12].

The studies conducted on aging muscles demonstrated reduced synthesis of the main contractile proteins – heavy chains of myosin, which correlates with a decrease in muscle force, the content of insulin-like growth factor, dehydroepiandrosterone sulfate, and free testosterone. In turn, reduced protein synthesis in muscles can be explained by their decreased sensitivity to insulin and amino acids [13].

Therefore, results of long-term study proved negative effect of SF factors on the functional state of MSS of astronauts, including the torso muscles. Therefore, there is a need to develop effective methods for their restoration and strengthening. Mechanotherapy on robot-assisted biomechanical complexes, such as the Centaur complex, which are successfully implemented in restorative and sports medicine, may be used as one of these methods [14-17].

Objective – to develop a method of robot-assisted mechanotherapy on the Centaur complex for post-flight rehabilitation of the astronauts' MSS.

Methods and organization. The study took place in the North-Caucasian Federal Research-Clinical Center. The study involved 7 male astronauts (Me [Q1; Q3]), age – 55 [52; 57] years, height – 176 [172; 178] cm, weight – 89 [82; 102] kg and the control group (CG) – healthy men, coaches of different sports. All the participants gave an informed consent in accordance with the Declaration of Helsinki developed by the World Medical Association, as well as permission for personal data processing. The study was approved by the local Ethics Committee for biomedical research examination of the North-Caucasian Federal Research-Clinical Center (protocols No. 2 dated 26.01.2021, No. 2 dated 14.05.2024).

The study of the torso muscles was carried out on the Centaur complex (diagnosis and training of the autochthonous torso muscles) (BFMS, Germany) (fig.).

Statistical data processing was performed in the Statistica 13.0 software. We calculated standard indicators of descriptive statistics (median, first and third quartiles). Distribution normality was identified with the Shapiro-Wilk test. Comparison of the indices was done using the non-parametric Mann-Whitney test.

Results and discussion. A comparison of force of the autochthonous muscles of the torso in astronauts and CG showed that the total index of the maximum force of the torso muscles applied to maintain body position when changing the adjusted rotational angles during testing, as well as the indices of the maximum force applied to maintain body position when the training complex is tilted to the left and right, is statistically substantially higher in astronauts than that in CG.

Consequently, the astronauts put the highest possible effort to maintain their body position during rotation, compared to CG, apparently due to their greater weight. They had less relative

force applied. It should also be noted that the study was conducted in conditions of gravity. In general, it is possible to indicate higher force indicators and better coordination of the autochthonous deep-lying muscles of the astronauts' torso, which may be due to the adaptation of their work in conditions of gravity and zero gravity.

Fig. Study of the functional state of the musculoskeletal system of an astronaut on the Centaur complex

Table

Indicators of the muscular force applied to maintain body position when changing the adjusted rotational angles during the dynamometric testing on the Centaur complex for astronauts and CG, Me [Q1; Q3]

Indices	Astronauts (n=7)	CG (n=54)	P<
MMF, Nm	241 [240; 247]	167.3 [137.9; 214.2]	0.03
RMF, %	100 [94.9; 100]	218.53 [179.19; 309.61]	-
MMFL, Nm	226 [217.2; 240]	159.8 [132.6; 206.8]	0.05
RMFL, %	89 [88; 100]	100 [100; 100]	-
MMFR, Nm	240 [224.4; 242]	160.7 [132.6; 206.8]	0.04
RMFR, %	94.9 [90.9; 100]	100 [99.9; 100]	-
Imbalance, Nm	4.1 [0; 8.2]	0 [0; 0.75]	-

Note: CG – control group; MMF – maximum muscle force; RMF – relative muscle force; MMFL – maximum muscle force applied to maintain body position when the training complex is tilted to the left during testing; RMMFL – relative muscle force applied to maintain body position when the training complex is tilted to the left during testing; MMFR – maximum muscle force applied to maintain body position when the training complex is tilted to the right during testing; RMMFR – relative muscle force applied to maintain body position when the training complex is tilted to the right during testing; Imbalance – differences between the parameters of maximum muscle force on the right and on the left applied to maintain body position when the training complex is tilted during testing.

As a result of diagnosing the initial level of the torso muscle force, we have identified the program of post-flight rehabilitation of MMS of astronauts:

1) Enhancing and increasing the force of the upper and lower limbs' muscle groups, optimizing the balance of force of the muscles of the right and left half of the body.

2) Maintaining force of the torso muscles.

In order to maintain force of the torso muscles and optimize their balance we have developed a specialized method with the Centaur complex.

The method of restoring the functional state of the autochthonous stabilizing spine muscles includes application of the Centaur complex in the "Rotation in space" mode: the patient rotates

around their own axis with adjusted parameters to strengthen various torso muscle groups. This technique differs in the diagnosis of muscle imbalance in different parts of the spine.

Program for muscle imbalance in the thoracic spine:

1. Inactivity of the muscle group on the left:

- rotation angle (tilt) – adjusted individually, taking into account the diagnosis protocol, in the range of 0 to 90°;
- number of sets – 5;
- number of repetitions for one set – adjusted individually, depending on a number of preset tilt angles in a set (the diagnosis protocol);
- movement time – 5 s;
- tilt duration – 5-6 s;
- number of pauses – 4;
- pause duration – 7 s.

2. Physical inactivity of the muscle groups on the right:

- rotation angle (tilt) – adjusted individually, taking into account the diagnosis protocol, in the range of 0 to -90°;
- number of sets – 5;
- number of repetitions for one set – adjusted individually, depending on a number of preset tilt angles in a set (the diagnosis protocol);
- movement time – 5 s;
- tilt duration – 5-6 s;
- number of pauses – 4;
- pause duration – 7 s.

Program for muscle imbalance in the lumbar spine:

1. Physical inactivity of the muscle group on the left:

- rotation angle (tilt) – adjusted individually, taking into account the diagnosis protocol, in the range of 90 to 179°;
- number of sets – 5;
- number of repetitions for one set – adjusted individually, depending on a number of preset tilt angles in a set (the diagnosis protocol);
- movement time – 5 s;
- tilt duration – 5-6 s;
- number of pauses – 4;
- pause duration – 7 s.

2. Physical inactivity of the muscle groups on the right:

- rotation angle (tilt) – adjusted individually, taking into account the diagnosis protocol, in the range of -90 to -180°;
- number of sets – 5;
- number of repetitions for one set – adjusted individually, depending on a number of preset tilt angles in a set (the diagnosis protocol);
- movement time – 5 s;
- tilt duration – 5-6 s;
- number of pauses – 4;
- pause duration – 7 s.

The physiological mechanism of action is to optimize the balance of the autochthonous torso muscles, to eliminate the deficit of the supporting muscles. The musculoskeletal feeling is optimized, the force parameters of the torso muscles are restored, movement and load are centralized along the main anatomical axes.

Expected effects of the application. Improving the function of the musculoskeletal system by restoring the muscular balance of the torso and improving neuromuscular coordination. Acceleration of neuromuscular system recovery.

Indications: post-SF condition, degenerative diseases of the spine, functional back pain, weakness and imbalance of the back muscles, the need to increase the functional capabilities of MMS, insufficient level of development of separate muscle groups.

Contraindications to the method's application: acute injuries, diseases accompanied by acute pain syndrome, fever.

Conclusion. Taking into account on the data from theoretical analysis and diagnosis of force indicators of the torso muscles of astronauts and male volunteers, we have developed the method of robot-assisted mechanotherapy on the Centaur complex for post-flight rehabilitation of the MSS of astronauts.

The technique of restoring the functional state of the autochthonous stabilizing spine muscles is implemented using the Centaur complex in the "Rotation in space" mode: rotation of the patient around their own axis with adjusted parameters to strengthen various muscle groups of the torso. This technique differs depending on the preset parameters of muscle balance in different parts of the spine.

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

REFERENCES

1. Trappe S., Costill D., Gallagher P. et al. Exercise in space: human skeletal muscle after 6 months aboard the International Space Station. *Journal of applied physiology*, 2009, vol. 106(4), pp. 1159-1168. DOI: 10.1152/japplphysiol.91578.2008.

2. Nicogossia A.E., Williams R.S., Huntoon C.L. Space physiology and medicine: from evidence to

practice. NY: Springer, 2016, p. 509. DOI: 10.1007/978-1-4939-6652-3.
3. Ivanov V.A., Shansky Y.D., Prusakov K.A. et al. Prospective directions in human health monitoring during long-term spaceflights. *Extreme Medicine*, 2024, vol. 26(4), pp. 114-122. DOI: 10.47183/mes.2024-26-4-114-122. (in Russ.)
4. Zwart S.R., Mulavara A.P., Williams T.J. et al. The role of nutrition in space exploration: Implications for sensorimotor, cognition, behavior and the cerebral changes due to the exposure to radiation, altered gravity, and isolation/confinement hazards of spaceflight. *Neuroscience & Biobehavioral Reviews*, 2021, no. 127, pp. 307-331. DOI: 10.1016/j.neubiorev.2021.10.008.
5. Gurovsky N.N., Grigoriev A.I., Egorov A.D. Main mechanisms of zero gravity influence. Space biology and medicine. Physiology manual. O.G. Gazenko, ed. Moscow: Nauka, 1987. pp. 49-59. (in Russ.)
6. Khromova I.V., Ulyankin I.M. Effect of sedentary lifestyle in zero-gravity conditions. Science. Industry. Defense. Materials of the All-Russian Scientific and Technical Conference for students, postgraduates and young scientists. 2017. pp. 308-310. (in Russ.)
7. Ujba V.V., Ushakov I.B., Sapetskij A.O. The medical and biological risks associated with operations in deep space missions. *Extreme Medicine*, 2017, no. 1, p. 45-66. (in Russ.)
8. Tyapkina O.V., Mustakimov S.R., Nurullin L.F. Morphological changes in the lumbar spine of rats after a week of support unloading are not compensated during the readaptation week. Abstracts of the XVIII Conference on Space Biology and aerospace medicine with International Participation. Earth – Orbit – Far Space (November 7-9th, 2023). 2013, p. 464. (in Russ.)
9. Grigor'ev A.I., Kozlovskaya I.B., Shenkman B.S. The role of support afferentation in the organization of the tonic muscular system. *Russian Journal of Physiology*, 2004, vol. 90, no. 5, pp. 508-521. (in Russ.)
10. Kurochkina N.S., Orlova M.A., Vigovskij M.A. et al. Effects of chronic decreased motor activity on the transcriptome and proteome of human skeletal muscle. Abstracts of the XVIII Conference on Space Biology and aerospace medicine with International Participation. Earth – Orbit – Far Space (November 7-9th, 2023). 2013. pp. 247-248. (in Russ.)
11. Buravkov S.V., Mailyan E.S., Buravkova L.B. et al. The effect of prolonged hypokinesia on the cyclic nucleotide content and bioenergetics of rat skeletal muscles. Cyclic nucleotides. Abstracts of the III All-Union Symposium. Kiev: Naukova dumka, 1980. pp. 73-74. (in Russ.)
12. Grigoriev A.I., Huntun K., Morukov B.I. et al. Studies of metabolism, the study of the interaction of the endocrine, renal system and circulatory factors in maintaining volumetric and electrolyte homeostasis in microgravity: a Russian-American project. The Mir Space Station. Space biology and medicine.Volume 2. Biomedical experiments. Moscow: Slovo, 2002. Chapter 3. pp. 69-85. (in Russ.)
13. Acarin L., Villapol S., Faiz M. et al. Caspase-3 activation in astrocytes following postnatal excitotoxic damage correlates with cytoskeletal remodeling but not with cell death or proliferation. *Glia*, 2007, vol. 55, no. 9, pp. 954-965.
14. Ter-Akopov G.N. New technologies for the rehabilitation of athletes on the training camp in the conditions of middle altitude. *Modern Issues of Biomedicine*, 2017, vol. 1, no. 1 (1), pp. 4-16. (in Russ.)
15. Dodonov S.V., Anisimov E.A., Karmazin V.V., Pavlova A.A. Visualization of the postural function of the back and abdominal muscles during rehabilitation activity. Collection of abstracts of the XIV International Scientific Conference on the state and prospects of development of medicine in elite sports "SPORTMED-2019". 2019. pp. 72-73. (in Russ.)
16. Kostyuk E.V., Koryagina Yu.V. The method of optimization of the neuro-muscular balance of the muscular corpset of the spine in athletes at the robotyzed system "Centaur". *Modern Issues of Biomedicine*, 2017, vol. 1, no. 1 (1), pp. 23-30. (in Russ.)
17. Koryagina Yu.V., Abutalimova S.M., Abutalimov A.Sh., Nopin S.V. Medical rehabilitation technologies for the musculoskeletal and nervous systems of astronauts in sanatorium-resort conditions. *Modern Issues of Biomedicine*, 2023, vol. 7, no. 2, pp. 248-256. (in Russ.)

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SYSTEMATIC REVIEW OF STUDIES PUBLISHED IN 2005-2025 ON THE ISSUES OF RUSSIAN COMBINED HERBAL PRODUCTS FOR IMPROVING PERFORMANCE

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Abstract. ***Introduction*.** Combined herbal preparations that include several standardized plant components and are positioned as means of multi-link action on fatigue and recovery processes are actively developing in Russia. Objective: to systematically summarize Russian studies from 2005-2025 on combined herbal preparations for improving performance. ***Methods.*** The studies on multi-component herbal compositions developed in Russia with indicators related to performance and endurance were included. The design, models, indicators and level of standardization were assessed. ***Results.*** The preclinical effects of the preparations "Tetrafiton", "Kardekaim", "Centafit", "Leveton-P", "Sport-Aktiv", "Energodarin" are most fully documented. The advantage of the combined approach over mono-component regimens is recorded. ***Conclusion*.** Russian combined herbal preparations demonstrate consistent preclinical efficacy in validated models associated with improving endurance. Priority is given to compositions of three to five components with full analytical control and clinical protocols.

Keywords: physical performance, endurance, combined herbal preparation, adaptogens.

Introduction. Physical performance (PP) is interpreted as the integral ability of the body to perform muscular work of a given power and duration while maintaining key homeostatic constants [1]. The need for safe, legally permissible pharmacological agents that increase PP is especially great in elite sports, military medicine, and professions associated with extreme physical exertion.

In the late 1990s and early 2000s, an approach to combined herbal preparations based on standardized plant extracts was institutionally consolidated in Russia: the methodological guidelines of the Ministry of Health of the Russian Federation No 2000/63 set the framework for the standardization of extracts and the approval of combined compositions, the guidelines No 2000/154 clarfied the terminology and scope of application of natural pharmacy in clinical practice. The earlier methodological guidelines of the Ministry of Health and Medical Industry of the Russian Federation dated 08.04.1994 on preclinical and clinical studies of natural preparations were also based on the regulatory framework, which created an evidence procedure for multicomponent compositions [2, 3].

The scientific argumentation of the synergism of components and the principles of designing a multicomponent herbal preparation (MHP) were reflected in the publications of Wagner and Ulrich-Merzenich (2016). MHP is described as a targeted strategy for increasing the effectiveness and sustainability of action [4].

Modern Russian reviews emphasize that rational combinations of standardized extracts provide a multi-targeted profile of action and require strict analytical control of quality and dose dependence. At the same time, excessive polycomponentity worsens analytical control and reproducibility of batches [5-20].

For the purposes of improving PP, MHP is formed through the technologically controlled standardization of raw materials and finished forms, coordination of pharmacodynamics (metabolic and stress-limiting modulation, neuromodulation, microhemodynamics) [1-3, 9-12, 15, 16].

The objective of the study is to systematize and summarize research of Russian scientists dedicated to the development and study of the action of combined herbal preparations aimed at improving performance.

Methods and organization. This study is a systematic review based on the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement. The methodological approach included the following key steps: formulation of the research question, development of the search and selection protocol, establishment of inclusion and exclusion criteria,

assessment of the quality of the selected publications, synthesis and interpretation of the obtained data.

The review included Russian publications published between January 1, 2005 and August 31, 2025. The following types of documents were examined: peer-reviewed articles, dissertations and abstracts, patents, and official reports of scientific institutions.

To search for publications, the following key words and combinations were used: “combined herbal preparation”, “multicomponent herbal remedy”, “actoprotective activity”, “antihypoxic activity”, “physical performance”, “endurance”, “forced swimming”.

The following types of publications were excluded from the review: studies on monoextracts of herbal preparations, publications without data on the relationship with physical performance, reports with insufficient detail of composition, doses, or results, secondary retellings or reviews without reference to the original source, materials not related to multicomponent herbal compositions.

The systematic review was based on a comparative analysis of data extracted from Russian repositories and archival materials of scientific journals on the platforms of scientific electronic libraries CyberLeninka and eLIBRARY.RU, as well as on the official websites of journals and ROSPATENT databases.

Due to the expected heterogeneity of models, doses and duration of courses, quantitative meta-aggregation was not planned. A structured descriptive synthesis with a matrix by objects and outcomes was used: (1) compositions with a disclosed composition and a full set of preclinical markers; (2) compositions with a qualitatively described increase in endurance and stress resistance; (3) lines with a dissertation-patent base and safety data; (4) applied reviews in sports practice; (5) technological contours of standardization. The validity of the methods (forced swimming test, treadmill) was separately taken into account as a reflection of physical performance in animals, which is consistent with the practice of domestic preclinical publications [1-3, 9-12, 15, 16].

Results and discussion. More than 26 Russian sources were analyzed in 2005-2025: peer-reviewed articles from the Higher Attestation Commission list – 16, dissertations and abstracts – 6, patents – 2, methodological standardization publications – 2.

Collection of the works from the reviewed time period demonstrates a stable direction of the effects of multicomponent phytocompositions aimed at improving physical performance. Regardless of the specific trade or laboratory name, we examined the combinations of plant components designed as agents with an actoprotective and antihypoxic, adaptogenic profile of action [1-26]. At the preclinical level, this was manifested primarily in an increase in the time to fatigue in the forced swimming test and, in some cases – in an increase in distance/power during load protocols on the treadmill.

The consistency of the effect’s direction is supported by biochemical and physiological markers: a decrease in lactate and pyruvic acid concentrations, a decrease in the activity of creatine phosphokinase (CPK) and lactate dehydrogenase (LDG), an increase in the activity of superoxide dismutase (SOD) and catalase, and an increase in tissue adenosine triphosphate (ATP). This combination of signs indicates suppression of the hypoxic component of fatigue, stabilization of energy metabolism, and limitation of oxidative stress.

Below (table) is a sequential interpretation of the data obtained within each line of development, with a detailed analysis of the parameters: type of study, model/protocol, performance indicators, associated markers and observations. This allows for a comprehensive and objective analysis of the results, which is critical for the formation of substantiated conclusions and recommendations in the context of further research and practical application of the obtained data.

Comparison of the “Tetrafiton”, “Kardekaim”, “Centafit” lines, compositions with leuzea and cranberry meal, “Astragalus” and the “Ginseng with Astragalus” combined product reveals a common design logic: targeted combination of ecdysteroids, saponins, phenolic antioxidants and triterpenoids to cover metabolic and stress-limiting links of fatigue aimed at improving physical performance. In most series, course administration (7-14 days) was accompanied by an increase in endurance relative to the control data, which allows us to speak about the reproducibility of the effect between independent developments. At the same time, intensity of the effect varied due to differences in dosage, duration of the course and depth of standardization of the extracts, incomplete description of the methods of randomization and blinding [6, 7, 14-16, 24, 25].

Table

Characteristics of the main lines of development of domestic multicomponent herbal preparations

Name of the drug	Type of research	Model or protocol	Performance indicator	Associated markers and observations	Sources
“Tetraphyton”	In vivo animal experiment	Rats, 7-day course, forced swimming test with an additional load	Increase in swimming duration relative to the control group	Increased adenosine triphosphate levels in skeletal muscle and myocardium; decreased lactic and pyruvic acids; increased catalase and superoxide dismutase; decreased activity of creatine phosphokinase and lactate dehydrogenase	[6, 7]
“Kardekaim”	In vivo animal experiment	Rats, forced swimming test; stress models	Increased physical endurance relative to the control group	Stress-protective activity in the immobilization stress model	[14-16]
“Centafit”	Dissertation complex of preclinical works	Models of intense exercise, hypoxia and stress	Increasing resistance to intensive loads (according to the text of the abstract)	Adaptogenic and antihypoxic effects; toxicological assessment presented	[9, 10, 18-19]
Composition of five plants (series of articles on actoprotection)	In vivo animal experiment	Rats, 7-day course, forced swimming test	Increase in swimming duration relative to the control group	Coordinated changes in energy and antioxidant markers	[7-9, 25]
Compositions “Adaptofit-28” and “Adapton-6”	Dissertations and abstracts	Models of physical and emotional stress	Increased overall resistance, including resistance to physical activity	Description of composition, doses and methods in dissertations	[26, 27]
Composition of leuzea extract and cranberry meal	In vivo animal experiment	Models of anabolic activity	Indirect relationship with performance through anabolic effect	Markers of anabolic action and their dynamics are described	[23, 24]
“Astragalus” and “Ginseng with Astragalus” (combined biologically active supplements)	In vivo animal experiment	Models of hypoxia and stress	Increasing resistance to hypoxia and stress	Antioxidant and adaptogenic effects	[27, 28]
“Energodarin”	In vivo animal experiment	Forced swimming test; comparison with individual components	The effectiveness of the combined approach is reported	Overall superiority over component monotherapies	[13, 25]

The demonstration of the advantages of combination over monotherapy deserves special attention: in a number of studies, a comparison of a complex formula with its separate components showed a more pronounced increase in the time to fatigue with an unchanged or better tolerability profile [13, 25]. This result is logically consistent with the concept of pharmacodynamic synergism and “kinetic cover”, which suggests mutual enhancement and stabilization of action due to points of application separated by the mechanism and mutual influence on absorption, distribution and metabolism.

The “SportActive” technological line illustrates the role of standardization as a prerequisite for pharmacological stability [10-12, 25]. The presence of validated high-performance liquid chromatography (HPLC) for several marker compounds, quantitative control of phytoecdysteroids and auxiliary substances,

demonstration of inter-batch comparability allow us to link analytical quality characteristics with the stability of the biological response [10, 25].

Uniform safety protocols for all compositions are not presented, which limits meta-aggregation of data and requires unification of approaches to assessing toxicological endpoints at subsequent stages.

Studies by L.N. Shantanova et al. were conducted on rats, the weekly course and the forced swimming test with an additional load were applied [14-16, 29]. The 2018 publications showed a statistically significant increase in the time to fatigue relative to the control data against the background of the combined formula of the herbal preparation [20]. In the abstract of dissertation by Dimitrov (2019), parallel anti-stress effects are described [17]: biochemical profile of an increase in ATP in skeletal muscle and myocardium, increase in SOD and catalase activity, decrease in lactate, pyruvate, CPK and LDG. Numerical effect sizes in open versions of articles are presented in a limited way. The authors' contribution is the formation of a stable test protocol, reproduction of the effect in independent series. Conclusion: a combination of four standardized components demonstrates actoprotection in a validated model with good physiological consistency of markers; extended numerical reporting and clinical verification are needed.

The research of E.A. Alekseeva et al. covers the forced swimming test and immobilization stress models [6, 14-16, 28-29]. An increase in endurance relative to the control data and pronounced stress-protective activity are documented. A number of publications present the dynamics of antioxidant indices and indirect signs of energy stabilization. In public domain versions, the numerical values of the effect at the level of time to fatigue/distance are often not disclosed. Scientific contribution – demonstration of the relationship between actoprotection and the anti-stress component and the transfer of results between models. Conclusion: the direction of the effect is proven; unified quantitative reports and a standardized analytical passport of the composition are required.

A number of dissertation studies by B.A. Muruev confirms the adaptogenic and antihypoxic properties of the dry extract "Centafit" on models of intense exercise and hypoxia, with the inclusion of a toxicological section [7-9]. The abstract indicates an increase in resistance to exercise, numerical data on the increase in time to fatigue in the public domain versions are limited [18]. The author's contribution is the validation of safety and tolerability in the studied doses, the formation of a basis for further standardization. Conclusion: technological fitness is above average due to the presence of toxicological sections; full-text quantitative results and comparable protocols of endurance tests are required.

Publications of 2018 (B.A. Muruev et al.) record an increase in swimming duration after a 7-day course in rats and consistent shifts in energy and antioxidant markers [6]. The contribution of the author groups is the demonstration of the reproducibility of the effect in parallel series and the linkage of *in vivo* results with biochemical panels. Conclusion: the actoprotective effect is confirmed in a validated model; accurate effect sizes and comparability of doses/schemes are required for interproject comparison.

Studies on the combination of leuzea extract with cranberry meal focus on the recovery and anabolic aspects [22, 23]. Preclinical data indicate positive dynamics of anabolic markers and acceleration of recovery after exercise; direct endurance tests in this line are limited. The authors' contribution is the expansion of the pharmacological base due to the anabolic circuit. Conclusion: development of comprehensive schemes of improving physical performance; the inclusion of validated endurance tests is required.

The line of phytocomplexes developed by Ya.I. Bilyach – "Energodarin" and "SportAktiv" – in a comparative experiment demonstrated the superiority of the combined formula over the monomodes of its components in the forced swimming test [10-13, 25]. The open access materials present the design and structure of the issue; detailed numerical tables are contained in the full text of the journal. Scientific contribution – empirical confirmation of the advantages of rational combination with equal duration of the course. Conclusion: the argument in favor of combination is confirmed; the next stage is clinical validation with objective metrics.

The technological and analytical series of works by Ya.I. Bilyach et al. formed a complete HPLC passport, provided quantitative control of phytoecdysteroids and potassium orotate and demonstrated inter-series comparability [10-13, 25]. In a preclinical model in rat swimmers, a 14-day course increased the time to complete fatigue

almost threefold relative to the control group data, which serves as a rare example of a rigid connection "quality → pharmacological response". The authors' contribution is the creation of a portable technological platform suitable for clinical translation. Conclusion: the standardization circuit is a necessary condition for the reproducibility and clinical verifiability of the actoprotective effect.

Analysis of the data set allows us to conclude that it is advisable to limit the number of components in the composition of drugs [5, 6, 13-25, 29]. Moderate compositions have a number of advantages, including a higher degree of standardization and better reproducibility of therapeutic effects. These properties are due to a smaller number of variables affecting the pharmacodynamics and pharmacokinetics of the drug, which contributes to more predictable and stable results when used in clinical practice.

Conclusion. Russian combined herbal preparations demonstrate consistent preclinical efficacy. Independent randomized studies with objective performance metrics and universal biomarker panels, as well as widespread standardization of the composition are required to confirm clinical significance. The developers should focus on compositions of three to five plants with full analytical control of marker compounds and stable technology. It is important for clinicians and sports physicians to interpret preclinical data taking into account the lack of randomized clinical trials and to avoid extrapolations without any evidence. It is advisable for regulators to stimulate the registration of clinical protocols and open access to primary data arrays.

Further research will focus on clinical trials and validation of the effectiveness of herbal preparations in real-life conditions of use.

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

REFERENCES

1. Sonkin V.D. The problem of assessing physical performance. *Bulletin of sport science*, 2010, vol. 2, pp. 37-42. (in Russ.)
2. Ministry of Health of the Russian Federation. Phytotherapy: Methodological recommendations No 2000/63, approved 26.04.2000. From the book: Karpeev A.A., Kiseleva T.L., eds. Phytotherapy: regulatory documents. Moscow: Publishing house of the Federal Scientific Clinical and Evaluation Center of the Russian Ministry of Health, 2006. pp. 9-42. (in Russ.)
3. Ministry of Health of the Russian Federation. Application of terms of naturotherapy and naturopharma in practical health care: Methodological guidelines No 2000/154, approved 01.11.2000. Moscow: Scientific and Production Center of TMG, Ministry of Health of the Russian Federation, 2000. 46 p. (in Russ.)
4. Wagner H., Ulrich-Merzenich G. Synergy research: creation of a new generation of herbal remedies. *RussianMedicalJournal*,2016,vol.3,pp.183-189.(inRuss.)
5. Sambukova T.V., Ovchinnikov B.V., Ganapolsky V.P., Yatmanov A.N., Shabanov P.D. Prospects for the use of herbal remedies in modern pharmacology. *Reviews of clinical pharmacology and drug therapy*, 2017, vol. 15, no. 2, pp. 56-63. DOI: 10.17816/RCF15256-63. (in Russ.)
6. Alekseeva E.A., Dimitrov O.G., Muruev B.A. et al. Effect of a multicomponent herbal remedy on physical endurance in the forced swimming test. *Acta Biomedica Scientifica*, 2018, vol. 3, no. 2, pp. 97-101. (in Russ.)
7. Muruev B.A., Mondodoev A.G., Matkhanov I.E. et al. Actoprotective activity of a complex herbal remedy. *Acta Biomedica Scientifica*, 2018, vol. 3, no. 4, pp. 120-124. (in Russ.)
8. Muruev B.A., Gulyaev S.M., Shantanova L.N., Mondodoev A.G. Anti-stress and antidepressant effect of a herbal remedy in chronic moderate stress. *Reviews of Clinical Pharmacology and Drug Therapy*, 2018, vol. 16, no. 2, pp. 69-73. (in Russ.)
9. Toropova A.A., Muruev B.A., Razuvaeva Ya.G. et al. Antioxidant activity of an adaptogenic herbal remedy in in vitro model systems. *Yakut Medical Journal*, 2019, vol. 1(65), pp. 20-23.
10. Kompantseva E.V., Kompantsev D.V., Bilyach Ya.I., Leonova V.N. Determination of phytoecdysteroid content in the drug "Sport-Active" by HPLC. *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences*, 2011, vol. 13, no. 1, pp. 842-845 (in Russ.)
11. Bilyach Ya.I., Kompantseva E.V., Kompantsev D.V. et al. Development of technology and qualitative analysis of the drug "Sport-Active". *Bashkir Chemical Journal*, 2009, vol. 16, no. 3, pp. 166-170. (in Russ.)
12. Kompantseva E.V., Kompantsev D.V., Bilyach Ya.I., Leonova V.N. Determination of potassium orotate content in the drug "Sport-Active". *Issues of biological, medical and pharmaceutical chemistry*, 2013, no. 1, pp. 19-23. (in Russ.)
13. Kompantsev V.A., Bilyach Ya.I., Kompantsev D.V. et al. Study of the pharmacological activity of the drug "Energodarin". *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences*, 2010, vol. 12, no. 1, pp. 2055-2057. (in Russ.)
14. Alekseeva E.A., Shantanova L.N., Nikolaev S.M. Adaptogenic action of the complex herbal remedy "Kardekaim". *Bulletin of the Buryat State University*, 2010, no. 12, pp. 29-64. (in Russ.)
15. Shantanova L.N., Alekseeva E.A., Osadchuk L.V. Pharmacocorrection of physical performance with the herbal remedy "Kardekaim". *Acta Biomedica Scientifica*, 2013, vol. 2(2), pp. 167-170. (in Russ.)
16. Shantanova L.N., Bazarova N.Yu., Dashieva O.V. Stress-protective activity of the complex herbal

remedy “Kardekaim” on the model of immobilization stress. *Experimental and clinical pharmacology*, 2015. Available at: https://www.ekf.folium.ru/index.php/ekf/article/view/1701/1643 (accessed 31.08.2025). (in Russ.)
17. Dimitrov O.G. Pharmacotherapeutic efficacy of “Tetrafiton” in experimental stress-induced conditions: an author’s abstract. Ulan-Ude, 2019. 24 p. (in Russ.)
18. Muruev B.A. Adaptogenic properties of dry extract “Centafit”: an author’s abstract. Ulan-Ude, 2019. 24 p. (in Russ.)
19. Razuvaeva Ya.G., Toropova A.A., Nikolaeva I.G. et al. Preclinical studies of the safety of an adaptogenic herbal remedy. *Reviews of Clinical Pharmacology and Drug Therapy*, 2021, vol. 19, no. 4. Available at: https://bmpcjournal.ru/sites/default/files/fulltext-pdf/25877313-2021-04-04.pdf (accessed 31.08.2025). (in Russ.)
20. Seyfulla R.D., Potupchik T.V., Poluboyarinov P.A. et al. Possibilities of using the combined adaptogen “Leveton P”. *Doctor*, 2018, vol. 29, no. 10, pp. 37-43. (in Russ.)
21. Potupchik T.V., Evert L., Ivanov A. Possibilities of using biologically active supplements in athletes with high training loads. *Doctor*, 2019, vol. 30, no. 10, pp. 24-31. (in Russ.)
22. Khalikova D.A., Ankov S.V., Meshkova Yu.V., Tolstikova T.G. Anabolic activity of the plant composition of leuzea extracts and cranberry meal. *Siberian Scientific Medical Journal*, 2021, vol. 41, no. 6, pp. 45-50. DOI: 10.18699/SSMJ20210604. (in Russ.)
23. Khalikova D.A., Ankov S.V., Meshkova J.V., Tolstikova T.G. The effect of the composition of leuzea and cranberry meal extracts on testosterone level in mice. *Medical academic journal*, 2021, vol. 21, no. 4, pp. 67-72. DOI: 10.17816/MAJ90692 (in Russ.)
24. Nikolaev S.M., Nikolaeva I.G., Shantanova L.N. et al. Method for obtaining a product with antihypoxic activity: Patent RU 2669365 C1, 2018. (in Russ.)
25. Bilyach Ya.I. Is study and standardization of a drug to improve physical performance: an author’s dissertation. Pyatigorsk, 2009. 153 p. (in Russ.)
26. Boldoguev V.M. Adaptogenic effect of the herbal remedy “Adaptofit-28”: an author’s abstract. Ulan-Ude, 2011. 22 p. (in Russ.)
27. Tulesonova A.S. Adaptogenic effect of the herbal remedy “Adapton-6”: dis. ... candidate of medical sciences. Ulan-Ude, 2011. 132 p. (in Russ.)
28. Alekseeva E.A. Molecular mechanisms of action of plant adaptogenes. *Bulletin of the Buryat State University. Medicine and Pharmacy*, 2021, no. 2, pp. 16-22. (in Russ.)
29. Nikolaev S.M., Nikolaeva I.G., Shantanova L.N. et al. Method for obtaining a product from rhizomes with roots of Leuzea, which has stress-protective and antihypoxic activity. Patent RU 2582282 C1, 2016. (in Russ.)

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EFFECT OF TRANSCRANIAL ELECTRICAL STIMULATION, PNEUMO- AND HYDROTHERAPY ON RECOVERY OF BOXERS AND KICKBOXERS IN MIDDLE ALTITUDE CONDITIONS

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Abstract. ***Introduction.*** The purpose of the study – to evaluate the effect of the course of transcranial electrical stimulation, pneumo- and hydrotherapy on recovery of boxers and kickboxers during training activity in middle altitude conditions. ***Methods.*** The study included 21 athletes (boxers and kickboxers, men), age – 17 to 27 years. At the beginning and final stage, we registered waves of electroencephalogram, heart rate variability, hemodynamics, electroneuromyography, and conducted psychophysiological tests. ***The results*** of the study have shown that after the course cerebral circulation has optimized, the functional state of the central nervous system and heart functioning efficiency have improved, as well as bioelectrical activity, muscle coordination and microcirculation. ***Conclusion.*** We have proven the effectiveness of the 7-day course of procedures for recovery of the functional state of boxers and kickboxers during training in middle altitude conditions.

Keywords: transcranial electrical stimulation, pressotherapy, underwater shower massage, psychofunctional state, bioelectrical brain activity, central and peripheral hemodynamics, neuromuscular system.

Introduction. Development of methods for the recovery of the functional state of athletes during intense physical activity, including conditions of middle altitude, where fatigue develops faster than that in normal environmental conditions, remains one of the important tasks of sports medicine. The neurohumoral system plays a crucial role in fatigue processes, which is the reason why physiotherapy methods that have a positive effect on its functioning, in particular transcranial electrical stimulation (TES), have recently been widely applied [1-3]. Literature sources contain studies showing that application of TES in middle altitude conditions supports an improvement of psychofunctional state and performance, an increase of intensity of recovery processes of athletes after physical activity [4, 5]. Earlier, studies were conducted examining a comprehensive effect of physio- and balneoprocedures on the psychofunctional state and recovery processes of cyclic sports athletes in middle altitude conditions [6]. However, there are no data on a combined effect of physio- and balneoprocedures on a body of situational sports athletes.

Objective of the study: to evaluate the effect of the course including TES, pneumo- and hydrotherapy on the recovery of the functional state of boxers and kickboxers.

Methods and organization. The study was conducted at the Center for Biomedical Technologies (North-Caucasian Federal Research-Clinical Center of Federal Medical and Biological Agency) at an altitude of 1240 m (Maloe Sedlo Mountain, Kislovodsk) during training camps physically based at the Yug Sport Rehabilitation Center. It included 21 qualified male athletes specializing in boxing and kickboxing, age – 17 to 27 years, all the athletes are members of the national teams of the Russian Federation. During the study period, the athletes continued training activity (they trained 2-3 times a day).

At the beginning and final stage, the athletes were monitored, which included the analysis of wave brain activity, heart rate variability (HRV), indices of the central and peripheral hemodynamics, neuromuscular system, and psychophysiological tests. The bioelectrical brain activity was registered at rest using the Neuron-Specter 5 complex (Neurosoft, Ivanovo). The study involved athletes, who did not have any EEG-signs of paroxysmal neuron activity: spikes, sharp waves, and fast wave – slow wave complexes.

The study of HRV, central hemodynamics and blood oxygen saturation indices was conducted using the ESTECK System Complex (LD Technology, USA). The study of lower limb and brain vessel hemodynamics was carried out on the rheograph (Rheograph Valenta, Company Neo LLC, Saint Petersburg) according to the following methods: RVG (rheovasography) and REG (rheoencephalography). The stimulation electroneuromyography (ENMG) was conducted

on the Neuro-MVP 4-channel complex (Neurosoft, Ivanovo). We registered motor responses (M-response) from the extensor digitorum brevis muscle innervated by n. Peroneus. The psychological tests were carried out on the "Sports psychophysiologist" complex [7].

At the next stage, the athletes were divided into two groups. The main group (MG) included 12 athletes: 7 boxers (qualification – 4 Candidates for Master of Sports, 1 Master of Sports, 2 Masters of Sports of International Class) and 5 kickboxers (qualification – 1 Candidate for Master of Sports, 2 Masters of Sports and 2 Masters of Sports of International Class). MG athletes went through the restorative course that included TES, device lymphatic drainage (pressotherapy) of the lower limbs and underwater shower massage. The control group (CG) included 9 boxers (qualification – 4 Candidates for Master of Sports, 5 Master of Sports). CG athletes received device lymphatic drainage (pressotherapy). All the athletes had no contraindications to the procedures.

We performed TES on the Transair-05 device (registration ID card No FSR 2010/07062, TES Center LLC, Saint Peterburg, Russia). Device lymphatic drainage (pressotherapy) of the lower limbs was conducted on the BTL – 6000 Lymphastim 12 device (BTL Industries Ltd., United Kingdom) in the "regeneration" mode. The underwater shower massage was performed on the BEKA hospitec UWM-100 device (Beka hospitec, Germany). A mode of action on the lymph flow and muscles was used – from the periphery to the center.

Statistical data processing was performed in the Statistica 13.0 software using non-parametric Wilcoxon signed-rank test. The difference in values was considered significant at $p<0.05$. The data is presented as medians and quartiles (Me [Q1; Q3]).

Results and discussion. *Effect of the restorative course on the functional state of the central nervous system of the athletes.* It is known that EEG results can be used to assess both the functional state of the brain and signs of fatigue and overtraining [8]. Elite athletes often have a decrease in alpha activity on EEG against the background of an increase in low-frequency beta activity, in some cases – theta and delta activity.

Analysis of bioelectrical activity parameters in MG athletes did not reveal reliable changes in the alpha wave amplitude. The representation of the alpha wave in the occipital and parietal leads remained within the normal range. A significant decrease in the delta wave amplitude in the right mid-temporal lead was revealed (before: 7.50 [3.50; 10.9] μV, after: 4.50 [1.40; 13.0] μV ($p<0.03$)) against the background of a significant increase in the alpha/theta ratio in the right frontal lead (before: 1.38 [1.14; 1.77] c.u., after: 1.68 [1.23; 4.70] c.u. ($p<0.04$)). At the same time, there was a tendency of the decreasing slow-wave and fast-wave activity amplitude in almost all leads.

The CG athletes also did not have any statistically significant changes in the alpha wave amplitude. At the same time, there was a significant increase in the amplitude of the theta wave in the right anterolateral lead (before: 8,70 [2.80; 17.5] μV, after: 19.90 [7.20; 23.40] μV ($p<0.01$)), theta/beta ratio (before: 1,05 [0,40; 1,78] c.u., after: 1,97 [1.05; 2.94] c.u. ($p<0.01$)), as well as the theta+alpha amplitude (before: 22.40 [20.40; 24.50] μV, after: 24.10 [20.60; 25.50] μV ($p<0.02$)) against the background of the tendency of the increasing mu wave (before: 13.00 [12.40; 14.20] μV, after: 14.00 [12.90; 16.20] μV). For the remaining leads, no significant changes were found in the dynamics for the studied values of slow-wave and fast-wave activity. Thus, the course contributed to the improvement of the functional state of the athletes' brains.

Optimal brain functioning of martial artists is the key to a successful match. The athlete's better perception of the opponent's distance, body position, and movement patterns makes it possible to perform the most advantageous motor actions faster in conditions of choice, when the time of making a decision is limited [9]. The study analyzed the effect of the course on simple and complex sensorimotor reactions, on mental performance, warming-up, and stability (Schulte test) of the athletes (table. 1).

The psychophysiological testing has shown that the sound reaction time significantly decreased in MG athletes after the course, a tendency of the decreasing time of sound reaction and choice reaction was revealed as well. At the same time, a significant improvement in the result for the work efficiency in the Schulte test was revealed against the background of a tendency to improve the result of the degree of warming-up and mental stability. There were no statistically significant changes in psychophysiological parameters of CG athletes, but there was a tendency of improving indices of simple sensorimotor responses and work

efficiency. Consequently, the course had a positive effect on mental performance and contributed to the improvement of sensorimotor reactions.

Effect of the course on HRV and central hemodynamics of the athletes. The analysis of HRV indices in all athletes has revealed a moderate stress of regulatory systems (table 2).

Table 1

Changes in psychophysiological parameters of boxers and kickboxers before and after the course in middle altitude conditions, Me [Q1; Q3]

Indices	Main group (n=12)		P<	Control group (n=9)		P<
	Before	After		Before	After	
Light reaction time, ms	272.2 [252.2; 290.2]	270.6 [231.2; 293.6]	-	286.4 [268.5; 291.5]	276.0 [249.8; 298.1]	-
Sound reaction time, ms	363.5 [332.2; 451.0]	336.9 [307.0; 386.0]	0.01	396,6 [366,5; 431,8]	383.3 [345.3; 413]	-
Choice reaction time, ms	365.9 [323; 405.20]	353,9 [306.0;376.6]	-	379,8 [353.4; 412.9]	378.2 [353.9; 417.8]	-
Work efficiency, s	39.69 [33.68; 43.12]	31.86 [28.53; 34.90]	0.004	39,31 [36.83; 45.36]	36.54 [32.33; 45.68]	-
Warming-up degree, c.u.	1.02 [0.87; 1.2]	0.98 [0.95; 1.09]	-	1,06 [0.97; 1.33]	0.95 [0.90; 1.16]	-
Mental stability (endurance), c.u.	1.10 [0.88; 1.16]	0.98 [0.95; 1.09]	-	0,90 [0.84; 1.01]	0.95 [0.90; 1.16]	-

Table 2

Dynamics of heart rate variability of boxers and kickboxers before and after the course in middle altitude conditions, Me [Q1; Q3]

Indices	Norm	Main group (n=12)		Control group (n=9)	
		Before	After	Before	After
HR, beats/min	60-80	79.4 [70.6; 91.1]	73.7 [66.3; 84.8]	73.5 [70.0; 83.4]	81.1 [71.4; 87.5]
SI, c.u.	50-200	118.6 [91.2; 167.8]	82.3 [46.9; 126,5]	102.0 [76.5; 177.5]	73.3 [63.7; 139.3]
MxDMn, ms	150-300	234.5 [171.0; 250.0]	257.5 [237.0; 331.0]	238.0 [192.0; 291.5]	273.0 [208.5; 319.0]
SDNN, ms	40-80	51.0 [43.0; 57.3]	61.3 [53.1; 81.3]	51.3 [40.2; 64.6]	56.1 [40.7; 70.4]
HF, %	22-34	29.7 [24.9; 36.1]	35.3 [31.9; 42.2]	30,7 [28.9; 36.8]	32.6 [23.8; 41.8]
LF, %	22-46	29.8 [23.8; 39.9]	31.9 [19.1; 40.0]	35.2 [27.4; 43.2]	31.9 [27.0; 38.9]
VLF, %	25-50	33.2 [24.3; 39.0]	35.5 [27.0; 38.7]	31.1 [20.1; 40.3]	33.9 [23.1; 37.0]
LF/HF, c.u.	0.5-2.0	1.0 [0.8; 1.5]	1.0 [0.5; 1.3]	0.9 [0.8; 1.8]	1.0 [0.8; 1.3]

Note: HR – heart rate; SI – stress index; MxDMn – variation range of cardiac intervals; SDNN – mean square deviation of cardiac intervals; HF – power of the high-frequency component of spectral frequency analysis (breathing waves): LF – power of the low-frequency component of spectral frequency analysis; VLF – power of the very-low-frequency component of spectral frequency analysis; LF/HF – autonomic balance indicator.

After the course MG athletes did not have any statistically significant changes. However, a positive trend of decreasing heart rate (HR) and stress index (SI) was identified. We have also registered a tendency towards an increase in the values of the mean square deviation of the cardio intervals and the power of high-frequency waves. The data obtained allow us to conclude that the autonomic regulation is enhanced and the effect of respiration on the heart rate of athletes is increasing. CG athletes also lacked statistically significant changes in HRV indicators. A tendency to an increase in the heart rate was revealed, while SI decreased.

The analysis of central hemodynamics and blood oxygen saturation has not reveal any statistically significant changes in all the athletes after the course. Before and after the course low values of saturation were registered, reflecting hypoxia: MG before: 95.0 [94.0; 96.0] %, after: 96.0 [95.0; 96.0] %, CG before: 95.0 [94.0; 97.0] %, after: 95.0 [94.5; 96.0] %. However, MG athletes had a tendency towards an increase of this indicator. After the course, all the athletes had a tendency towards a decrease of diastolic blood pressure (MG before: 67.5 [56.0; 71.0] mm of Hg, after: 65.5 [59.0; 70.0] mm of Hg; CG before: 71.0 [61.0; 72.5] mm of Hg, after: 65.0 [64.0; 70.0] mm of Hg) and peripheral resistance (MG before: 1113.5 [874.4; 1215,4] dyn*s/cm^2, after: 983.9 [927.6; 1057.4] dyn*s/cm^2; CG before: 1063.3 [1020.9; 1118.3] dyn*s/cm^2, after: 966.8 [869.3; 1163.0] dyn*s/cm^2. Thus, the course provided an enhancement of functional capabilities and heart functioning efficiency.

Effect of the course on the brain and lower limb vessels of the athletes. The analysis of hemodynamic parameters of carotid and vertebral artery systems in boxers and kickboxers was carried out. Significant differences were found only for the rheographic index parameters in the carotid artery system on the right in MG after the course (before: 1.37 [1.08; 1.55] c.u., after: 1.24 [0.99; 1.42] c.u. ($p<0.02$)) (fig.).

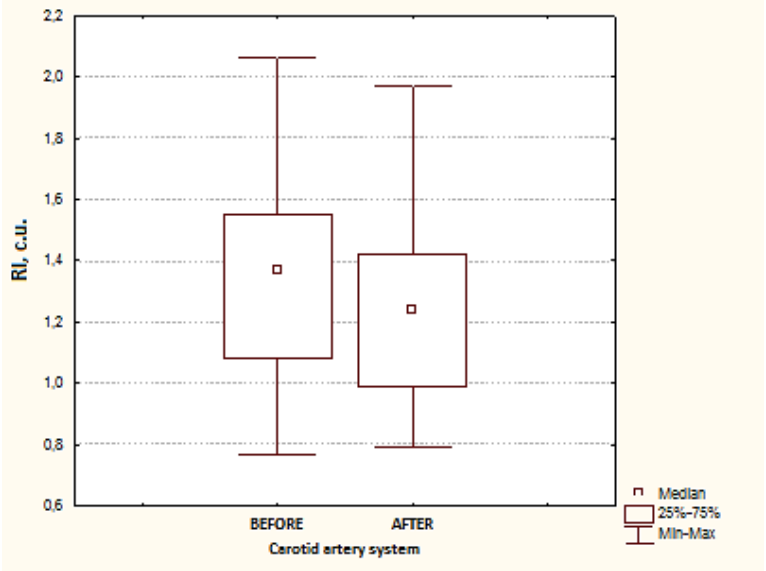

Fig. Parameters of the rheographic index (RI) in the carotid artery system on the right in athletes of the main group before and after the course in middle altitude conditions

A positive trend was found towards normalization of venous outflow parameters both in the carotid artery system (on the right before: 32.5 [28.5; 46.5] %, after: 30.0 [20.5; 46.0] %; on the left before: 30.0 [25.0; 42.5] %, after: 28,5 [19.5; 38.5] %), and in the vertebral artery system (on the right before: 36.5 [31.5; 43,5] %, after: 31.0 [27.5; 46.5] %; on the left before: 36.0 [28.0; 55.0] %, after: 32.5 [26.0; 41.5] %). Meanwhile, in the carotid artery system, there was a tendency of normalizing dicrotic (on the right before: 0,61 [0,53; 0,72] c.u., after: 0,53 [0,49; 0,69] c.u.; on the left before: 0,62 [0.53; 0.77] c.u., after: 0,58 [0,50; 0,68] c.u.) and diastolic indices (on the right before: 0.70 [0.61; 0.76] c.u., after: 0.64 [0.58; 0.79] c.u.; on the left before: 0.68 [0.63; 0.84] c.u., after: 0.66 [0.61; 0.69] c.u.), in the vertebral artery system – diastolic index on the right (before: 0.44 [0.39; 0.53] c.u., after: 0.51 [0.42; 0.66] c.u.).

The dynamics of CG athletes in the vertebral artery system showed a significant increase in the parameters of the slow vascular filling time on the left (before: 0.06 [0.06; 0.07] s, after: 0.12 [0.08; 0.17] s ($p<0.02$)), and elastic modulus (on the left before: 12.0 [11.0; 15.0] %, after: 24.0 [18.0; 27.0] % ($p<0.01$), on the right before: 12.0 [12.0; 13.0] %, after: 15.0 [13.0; 19.0] % ($p<0.03$)). As a result, the course contributed to normalization of cerebral artery tone and improvement of blood outflow from arteries to veins, which indicates improved blood supply to the brain.

The analysis of the lower limb vessel hemodynamics in MG athletes after the course has demonstrated no reliable differences. However, there was an increase (higher than normal values) of rheographic index and venous outflow parameters in the “foot” segment of the right leg, as well as in the “crus” segment of both legs. In addition, we have also registered a

decrease in the asymmetry coefficient between the right and left legs in the "crus" segment. Higher blood supply in the studied segments may be explained by an improvement in microcirculation in tissues after the course.

Analysis of peripheral hemodynamics parameters has identified a reliably significant decrease of rheographic index parameters in the "foot" segment of the right leg (before: 1.55 [1.28; 2.04] c.u., after: 1.18 [0.90; 1.25] c.u. ($p<0.02$)) against the background of the increasing asymmetry in the "foot" segment between the right and left legs (before: 13.0 [8.0; 22.0] %, after: 28.0 [24.0; 41.0] % ($p<0.02$)). In addition, a tendency was registered towards a decrease of venous outflow to the limits of normal values in the "foot" segment of the right (before: 35.0 [32.0; 38.0] %, after: 17.0 [14.0; 31.0] %) and left (before: 41.0 [23.0; 50.0] %, after: 17.0 [12.0; 29.0] %) legs, as well as venous outflow in the "crus" segment of the right leg (before: 25.0 [16.0; 41.0] %, after: 17.0 [12.0; 29.0] %). Consequently, the course supported the improvement of microcirculation in the lower limbs of the athletes.

Effect of the course on the neuromuscular system of the athletes. The ENMG data revealed a significant increase in the parameters of the amplitude and area of the M-response against the background of a tendency towards a decrease in latency and residual latency in the right leg of MG athletes. A significant increase in the M-response amplitude was also detected in the left limb in the "popliteal fossa" stimulation point. The rest of the parameters were not significantly influenced by the course.

The dynamics of CG athletes have significantly revealed an increase in the parameters of the M-response duration in the "head of fibula" stimulation point on the left (before: 6.0 [5.3; 6.4] ms, after: 6.3 [5.7; 7.1] ms ($p<0,03$)). The rest M-response parameters haven't changed much, though there was an increase in the parameters of area (before: 18.4 [17.7; 23.6] mV×ms, after: 20,5 [18.3; 26.8] mV×ms), amplitude (before: 5.8 [5.4; 8] mV, after: 7.6 [5.5; 8.3] mV) and nerve conduction velocity (before: 53.3 [52.6; 57.5] m/s, after: 55.0 [53.5; 56.5] m/s) of M-response in the "popliteal fossa" stimulation point of the right leg. Thus, the course contributed to an increase in the bioelectric activity of the muscles and improved muscle coordination.

Conclusion. Application the 7-day course aimed at restoring the functional state of athletes during intense physical activity in middle altitude conditions, combined with the effects of TES, device lymphatic drainage (pressotherapy) of the lower limbs and underwater shower massage for boxers and kickboxers had a positive effect on cerebral circulation, contributed to the improvement of the functional state of the central nervous system, manifested in optimizing the wave activity of the brain by reducing slow-wave activity, improving mental performance and sensorimotor responses. In addition, the functional capabilities and heart functioning efficiency have increased, and the autonomic regulation of heart rhythm has been enhanced. After the course, the bioelectric muscle activity, muscle coordination and microcirculation improved in the lower limbs of boxers and kickboxers.

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

REFERENCES

1. Roguleva L.G. Effect of transcranial electrical stimulation on the functional state of athletes engaged in wrestling and strength sports: an author's dissertation. Tomsk: Siberian State Medical University, 2015. 146 p. (in Russ.)

2. Friehs M.A., Whelan E., Güldenpenning I., Krause D., Weigelt M. Stimulating performance: A scoping review on transcranial electrical stimulation effects on Olympic sports. *Psychology of Sport and Exercise*, 2022, vol. 59, pp. 102-130.

3. Chinzara T.T., Buckingham G., Harris D.J. Transcranial direct current stimulation and sporting performance: A systematic review and meta-analysis of transcranial direct current stimulation effects on physical endurance, muscular strength and visuomotor skills. *European Journal of Neuroscience*, 2022, vol. 55, no. 2, pp. 468-486.

4. Koryagina Yu.V., Roguleva L.G., Nopin S.V., Ter-Akopov G.N. Effects of application of transcranial electrical stimulation in the training process at elite athletes of various sports. *Problems of Balneology, Physiotherapy and Exercise Therapy,* 2020, vol. 97, no. 5, pp. 70-79. (in Russ.)

5. Ter-Akopov G.N., Koryagina Yu.V., Nopin S.V. et al. The transcranial electrical stimulation course in recovery of karatekas in conditions of training in middle altitude. *Modern Issues of Biomedicine*, 2024, vol. 8, no. 2, pp. 259-266. (in Russ.)

6. Koryagina Yu.V., Abutalimova S.M., Roguleva L.G., Nopin S.V., Kopanev A.N. To the question of developing effective restoration strategies for athletes

during stay in the camp at federal bases of sports training. *Modern Issues of Biomedicine*, 2020, vol. 4, no. 1 (10), pp. 35-39. (in Russ.)
7. Koryagina Yu.V., Nopin S.V. Hardware and software complex "Sports psychophysiologist". *Programmy dlya EVM. Bazy dannykh. Topologii integral'nykh mikrosistem*, 2011, no. 1, p. 308. (in Russ.)
8. Sazonova E.A. Peculiarities of bioelectrical activity of the brain of athletes in some sports. Relevant Issues of Training and Health Preservation of Athletes: Materials of the All-Russian Scientific and Practical Conference with International Participation, dedicated to the 40th Anniversary of the Department of Sports Medicine and Physical Rehabilitation (Chelyabinsk, December 20th, 2013). Bykov E.V., ed. Chelyabinsk: UralSUPC, 2013. pp. 454-456. (in Russ.)
9. Cristofori I., Cohen-Zimerman S., Grafman J. Executive functions. *Handbook of clinical neurology*, 2019, vol. 163, pp. 197-219.

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AGE-RELATED FEATURES OF THE MOTOR ABILITIES DEVELOPMENT OF 8-17-YEAR-OLD SCHOOLCHILDREN WITH INTELLECTUAL DISABILITY

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Abstract. ***Introduction***. The process of developing motor abilities of students with intellectual disability is characterized by: lagging in the development of motor qualities from the "norm"; uneven development of motor abilities of children with intellectual disability; the specifics of the adaptive physical education methodology; the influence of sports for people with intellectual disability. ***Methods***. To investigate age-related peculiarities of motor skill development in 8-17-year-old children with intellectual disabilities we used the following methods: testing and estimation of motor skill development of the students, pedagogical experiment, and math-and-stats methods. ***Results***. We have identified positive age-related changes in the development of basic physical abilities of children and adolescents with intellectual disability. ***Conclusion***. The identified age-related patterns may serve as a base for the development of additional comprehensive programs for adaptive physical education, as well as sports training programs for adaptive sports disciplines in compliance with the requirements of the Federal Standard of sport for people with intellectual disability.
Keywords: schoolchildren with intellectual disability, motor abilities, physical qualities, motor tests, age-related features, grow rates.

Introduction. The process of long-term physical training of schoolchildren is due to a vast number of factor, one of which are specific features of the development of motor abilities. Knowledge and consideration of the general patterns of the development of motor abilities in schoolchildren from special (correctional) schools will allow the teacher of additional education, the trainer-teacher of adaptive physical education and sports to develop control standards, to determine the proper level of physical fitness of students at various stages of long-term training. These data will help to optimally select the ways and methods of pedagogical influence in the system of sports training in the disciplines of the sport for people with intellectual disability.

It was approved experimentally that chosen and directed pedagogical influences, coupled in time with the periods of accelerated age development of a certain motor physical quality, are accompanied with statistically reliable increase in growth rates of the indicators in tests used for its description and assessment. The long-term effect of these measures is manifested in the preservation of the achieved advantages over a two-year period and in higher rates of ontogenetic development of motor abilities [1].

The development of motor abilities of schoolchildren with intellectual disabilities is due to a number of interconnected factors. Among them the following are noted: lagging behind the "standard" in the indicators of motor qualities development [2-5]; uneven development of functional systems and motor abilities of children with intellectual disability [3-5]; influence of environmental and social factors [6-7]; features of the adaptive physical education methodology [8-9]; influence of sports activities of people with intellectual disability [9-11].

Aim of the study – to examine age-related features of the motor abilities development of 8-17-year-old children and adolescents with intellectual disability studying in a special (correctional) school.

Methods and organization. We used the following methods: testing and assessment of the level of development of motor abilities of hearing-impaired schoolchildren, pedagogical experiment, math-and-stats methods.

To identify the level of motor abilities development and physical fitness of children and adolescents with intellectual disabilities, we conducted a pedagogical testing of 8-17-year-old schoolchildren from the Special (Correctional) Private School No. 11 located in Shadrinsk (84 were examined in total).

When selecting testing methods, we were guided by the following criteria: the tests had to be reliable, accessible in terms of the content of motor tasks for students with intellectual

disability, and, especially, easy to apply in practice.

In order to solve the objective, we applied the following motor tests. To study the features of speed qualities development we used the "30-meter run" test. We also studied the features of the development of speed and strength qualities using the tests "sit-ups in 20 seconds", "standing long jump", "overhead shot of a 1-kilogram stuffed ball while sitting". Determination of the endurance development features was carried out with the "300-meter run" test – the time of passing the distance in seconds was measured. To assess flexibility, the subjects were also offered the "torso forward tilt while standing on an elevated surface" test.

The statistical data processing of the results was carried out in Microsoft Excel, Statistica 13.0 software packages. The reliability of differences in the results obtained was assessed with the Student's t-test, the normalcy of distribution – with the Shapiro-Wilk test. The growth rates of the indicators were calculated with the S. Brody's formula. For each of the studies indicators we calculated the arithmetic mean (M) and mean square deviation (σ). The statistical data processing of measurement results was carried out taking into account gender and age (for each of the following age groups: 8-9, 10-11, 12-13, 14-15, 16-17 years).

Results and discussion. In the course of the study, we have found that in most cases average values of the studied indices in boys and young men with intellectual disability improve visibly. The highest growth rate was registered in the "overhead shot" test – 94%. In the "sit-ups for 20 seconds", "standing long jump", "30-meter run", "300-meter run" tests, the growth rate amounted from 30 to 45%.

Analysis of the age-related changes in the growth rate of boys and young men with intellectual disability indicates an uneven development of indicators characterizing motor qualities. Thus, in the "300-meter run" test, which assesses the endurance development, the highest growth rates were recorded at the age of 9-10 years. In the tests characterizing the development of speed and strength qualities, the greatest increase was also found at the age of 9-10 years, although in the test with overhead shot the increase in results is almost the same in all age groups. In the "standing long jump" test ($p<0.05$), a significant increase in results was also identified at the age of 15-16 years. The endurance index has the greatest increase at the age of 9-10 and 15-16 years.

Table 1

Age-related dynamics of motor abilities development of 8-17-year-old boys and young men with intellectual disability, M±σ

Test	Age groups/indices				
	8-9 years	10-11 years	12-13 years	14-15 years	16-17 years
30-meter run, s	7.1±0.7*	6.1±0.7*	5.6±0.6*	5.4±0.4*	5.0±0.5*
Overhead throw while sitting, cm	200.2±51.0*	273.2±43.2*	357.3±67.3	425.0±101.9*	552.7±98.4*
Sit-ups for 20 s, number	9.6±2.9*	12.8±2.9*	14.9±3.2*	12.3±2.6	15.1±2.4*
Standing long jump, cm	118.8±21.9*	146.5±17.6*	161.6±19.2*	171.2±23.0*	200.2±23.0*
Forward tilt on an elevated surface, cm	1.4±6.0	2.7±5.3	1.9±7.7	3.1±8.2	4.1±4.9
300-meter run, s	90.6±16.2*	74.5±10.4*	69.2±9.0*	65.4±7.1*	58.8±7.2*

Note: * – reliability of differences ($p<0.05$)

For girls and young women with intellectual disability, most tests show a gradual improvement in scores, followed by a trend for scores to remain the same or to decline.

In the development of speed abilities relatively uniform growth of results continues up to 13 years of age, then stabilization and decrease of average values of the studied indicator is observed.

Growth rate of the results describing speed and strength abilities continues until the age of 15, although in the "sit-ups for 20 s" test the decrease of indices begins at the age of 14, and in the "standing long jump" test at the age of 13-14 there is only a slight increase (3%). The growth of endurance indices continues until the age of 13.

In terms of the age changes of motor qualities development in girls and young women with intellectual disability, it should be noted that the highest growth rates in almost all the tests occur at the age of 11-12 years. The exception is the sit-up test, in which the greatest increase in results is recorded at the age of 9-10 years.

It should be noted that in the flexibility test, both girls and boys with intellectual disability demonstrated a large variability of values ($3\sigma>X$), which did not allow us to identify any age trends in this test.

Table 2

Age-related dynamics of motor abilities development of 8-17-year-old girls and young women with intellectual disability, M±σ

Test	Age groups/indices				
	8-9 years	8-9 years	8-9 years	8-9 years	8-9 years
30-meter run, s	6.9±0.6*	6.6±0,8*	5.9±0.9*	5.9±0.6*	6.3±0.1*
Overhead throw while sitting, cm	196.3±31.3*	223.7±43.1*	331.5±70.0*	394.0±62.7*	368.3±71.4*
Sit-ups for 20 s, number	7.1±3.1*	10.3±2.8*	13.5±3.9*	12.3±2.6*	11.4±1.8*
Standing long jump, cm	112.6±15.8*	126.5±16.5*	153.1±20.9*	158.3±14.7*	149.8±23.8*
Forward tilt on an elevated surface, cm	3.5±5.4	3.3±6.5	7.1±5.4	6.5±8.0	5.9±5.5
300-meter run, s	83.2±17.4*	78.6±11.7*	70.9±12.9*	73.3±10.8*	74.8±14.5*

Note: * – reliability of differences ($p<0.05$)

Conclusion. The revealed patterns of motor abilities development of 8-17-year-old children and adolescents with intellectual disability can be the base for the development of additional comprehensive programs in the field of adaptive physical education and sport, as well as sports training programs for the disciplines of adaptive sport according to the requirements of the Federal Standard of sports for people with intellectual disability. It would also allow a more efficient construction of the educational and training process of students with intellectual disability in the disciplines of sport for the studied group.

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REFERENCES

1. Gorskaya I.Yu. Theoretical and methodological basics of mastering basic coordination abilities of schoolchildren in different states of health: an author's abstract. Omsk, 2001. 46 p. (in Russ.)
2. Ivinskij D.V. Development of motor abilities in schoolchildren with intellectual disabilities in conditions of a special (correctional) type VIII private school: an author's abstract. Tambov, 2007. 24 p. (in Russ.)
3. Litosh N.L. Age-related dynamics and factor structure of motor abilities of 8-17-year-old school-children with intellectual disability. Modern Issues of Education of Children and Studying Youth: materials of the International Scientific and Practical Conference. Ekaterinburg, 2021. pp. 305-309. (in Russ.)
4. Kulikova A.G., Sokolov A.V., Karpova N.V. Development of physical qualities of 11-13-year-old children with intellectual disability. Physical Culture and Sport in Inclusive Education of Children and Studying Youth: materials of the All-Russian Scientific and Practical Conference. Moscow, 2016. pp. 112-115. (in Russ.)
5. Evseeva O.E., Shelekhov A.A. Mastering motor abilities for people with intellectual disability by means of physical culture and sports. Materials of the Final Scientific and Practical Conference of the Faculty of the P.F. Lesgaft National State University of Physical Culture, Sports and Health, dedicated to the 120th Anniversary of the University. Saint Petersburg, 2016. pp. 104-105. (in Russ.)
6. Salimov M.I. Effect of physical culture on fitness for social adaptation of schoolchildren with mild intellectual disability: an author's abstract. Ekaterinburg, 2006. 25 p. (in Russ.)
7. Ol'khovaya T.I. Adaptive physical culture and adaptive sport as a base for mental stability of children and adolescents with intellectual disability. Children. Society. Future: article collection based on the materials of the III Congress "Mental health of the XX century man". Moscow, 2020. pp. 170-171. (in Russ.)
8. Kuropatkina N.A. Mastering the process of adaptive physical education of adolescents with intellectual disability. Modern Issues of Physical Education of the Growing Generation: Prospects and Way to Solve: Collection of materials of the All-Russian Scientific and Practical Conference with International Participation. 2017. pp. 185-189. (in Russ.)
9. Skrylnikova E.N. Features of the development of strength abilities in 8-10-year-old children visiting adaptive physical education classes and sports sections. Human in a World of Sports: abstracts of the Open Regional Interuniversity Conference of young scientists. Saint Petersburg, 2009. pp. 162-163. (in Russ.)
10. Ivinskij D.V. Actuality of experimental methodics of additional physical education of students of special (correctional) school of VIII type. *Tambov University Review. Series: Humanities*, 2015, no. 2(142), pp. 102-107. (in Russ.)
11. Artemenko E.P., Litosh N.L. Development of motor coordination abilities of children with intellectual disabilities engaged in table tennis. *Modern Issues of Biomedicine,* 2022, vol. 6, no. 4. DOI: 10.51871/2588-0500_2022_06_04_44 (in Russ.)

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