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ABOUT THE ACCURACY OF IDENTIFYING ENERGY EXPENDITURE WITH THE WEARABLE ACTIVITY TRACKER POLAR

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Annotation. An important factor in the training of an athlete is the preparation of a diet. Many athletes use chest straps to measure heart rate for the calculation of energy expenditure. The aim of the study was to compare exercise energy expenditure calculated using a Polar chest heart rate monitor with energy expenditure calculated by a metabolograph. On average, energy expenditure during exercise, according to the Polar chest strap, was 120±20 kcal. The average energy expenditure during exercise, according to the data of the metabolograph, was 108±20 kcal. The average difference was 12%, the difference ranged from 6% to 33%.
Keywords: sports, heart rate monitoring, wearable activity trackers, indirect calorimetry, nutrition.

Introduction Worldwide, lack of physical activity is a pressing public health problem. A recent World Health Organization (WHO) report showed that about 23% of adults and 81% of schoolchildren do not follow recommendations for physical activity [1].

Wearables hold great promise, especially as data collection tools for cutting-edge healthcare research, and demand has grown significantly over the past few years [2]. Consumer-grade non-invasive wearable devices are typically less expensive than gold standard research devices, comfortable to wear, and affordable for consumers [3-4]. In recent years, the quality and accuracy of wearable devices have improved, resulting in more clinically approved certifications [5].

In a recent review, Bunn et al noted the tendency of wearable devices to underestimate energy expenditure (EE), heart rate (HR), and step count [6]. Fitbit wearables were highly correlated with step count criteria during lab evaluation and had consistently high inter-device reliability for both step counting and EE [7]. However, some devices tend to underestimate EE, which is consistent with a separate Fitbit accuracy review [8] indicating that Fitbit wearables only provide accurate measurements in limited circumstances.

Calculating EE from heart rate is quite common among chest straps such as Polar, Garmin, etc. Athletes and fitness enthusiasts often use this method to calculate EE for a workout to adjust their diet.

Commercial wearable devices could allow populations to measure physical activity and large-scale behavioral changes. However, questions remain regarding their reliability and validity**.**

The aim of the study: to compare EE calculated with a chest heart rate sensor with indirect calorimetry.

Methods and organization. The study involved 6 men (average age 23±3), training experience – at least 2 years. All participants were instructed to abstain from exercise for 48 hours prior to the study, and for 12 hours to avoid taking any stimulants (caffeine, taurine, etc.). All participants also received dietary recommendations for food intake 3 hours before the start of the study. The subjects performed a stepwise test on a bicycle ergometer (the first stage was 80 W, the load increased by 15 W every minute), the criterion for stopping the test was the Borg scale: level 19. The subjects of the study recorded calorie consumption using the Polar H7 chest sensor (Finland) and the Polar beat app (Polar electro, Finland) every minute of the

test, and real expenditure was identified with the COSMED-QWARK metabolograph (Italy).

Results and discussion. All study participants successfully completed the loading protocol. The average EE during exercise, according to the Polar chest strap, was 120±20 kcal. The average EE during exercise, according to the data of the metabolograph, was 108±20 kcal. The average difference was 12%, the difference ranged from 6% to 33%.

As a result of the study, the Polar chest heart rate monitor increased EE from the actual by an average of 12%, ranging from 6% to 33%. We assume that this depends, on the one hand, on the training of the subject, and on the other hand, on the pulse cost of the session, which has yet to be determined in future works. Such discrepancies can mislead users of these devices and lead to inaccurate calculation of the daily EE for both athletes and other physically active people. Further research should be aimed at developing predictive equations in order to avoid the error of determining the consumption of EE and the error of calculating the caloric content of the diet.

Conclusion. In this work, we have determined that users who use a Polar chest heart rate monitor to measure energy expenditure may significantly overestimate their diet in terms of kilocalories, which can adversely affect body composition. In the future, more research is required on the influence of various devices, the purpose of which is to calculate energy expenditure.

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REFERENCES

1. World Health Organization Global recommendations on physical activity for health. World Health Organization. Available at: https://www.who.int/publications/i/item/9789241599979 (accessed 21.06.2022).
2. Henriksen A., Haugen Mikalsen M., Woldaregay A.Z., Muzny M., Hartvigsen G., Hopstock L.A., Grimsgaard S. Using fitness trackers and smartwatches to measure physical activity in research: analysis of consumer wrist-worn wearables. *J Med Internet Res*, 2018, no. 20(3), pp. e110. DOI: 10.2196/jmir.9157.
3. Carpenter A, Frontera A. Smart-watches: a potential challenger to the implantable loop recorder. *Europace*. 2016, no. 18(6), pp. 791-793. DOI: 10.1093/europace/euv427.euv427.
4. Hickey A.M, Freedson P.S. Utility of consumer physical activity trackers as an intervention tool in cardiovascular disease prevention and treatment. Prog Cardiovasc Dis, 2016, no. 58(6), pp. 613-619. DOI: 10.1016/j.pcad.2016.02.006.S0033-0620(16)30016-0.
5. Dunn J., Runge R., Snyder M. Wearables and the medical revolution. *Per Med*, 2018, no. 15(5), pp. 429-448. DOI: 10.2217/pme-2018-0044.
6. Bunn J.A., Navalta J.W., Fountaine C.J., Reece J.D. Current State of Commercial Wearable Technology in Physical Activity Monitoring 2015-2017. *Int J Exerc Sci*, 2018, no. 11(7), pp. 503-515.
7. Feehan L.M., Geldman J., Sayre E.C., Park C., Ezzat A.M., Yoo J.Y., Hamilton C.B., Li L.C. Accuracy of Fitbit Devices: Systematic Review and Narrative Syntheses of Quantitative Data. *JMIR Mhealth Uhealth*, 2018, no 6(8), pp. e10527. DOI: 10.2196/10527.
8. Moher D., Shamseer L., Clarke M., Ghersi D., Liberati A., Petticrew M., Shekelle P., Stewart L.A., PRISMA-P Group Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev*, 2015, no 4:1. DOI: 10.1186/2046-4053-4-1.

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PHYSICAL ACTIVITY AND SOMATOTROPIC HORMONE

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Annotation. Growth hormone or somatotropic hormone attracts researchers who study its anabolic activity in terms of increasing muscle strength and mass. First of all, this is of interest to coaches, athletes and scientists who are trying to explain the anabolic effect of somatotropin in various variants of the training process. The theoretical analysis carried out demonstrated that at present there is still no logical large-scale picture of the relationships and effects of somatotropic hormone on various functions of the body of athletes, or simply people engaged in physical exercises. There are practically no studies of the relationship and interdependence of the volume and nature of human motor activity and the production of somatotropic hormone. These studies are of fundamental and practical interest, as they will reveal deeper mechanisms of adaptation to motor activity, as well as its influence on the patterns of growth and development of the human body.
Key words: pituitary hormones, somatotropic hormone, physical exercises, motor activity.

Introduction. The endocrine system has a complex co-subordinate organization. This can be seen in any hormonal relationship. All systems are regulated with the help of negative and positive feedbacks [1]. At the same time, each of them (thyroid, hypothalamic-pituitary, etc.) are interconnected with each other. In addition, there are many mechanisms of interaction between the hormonal, nervous and immune systems. There is even a field of knowledge – neuroimmunoendocrinology, which shows the relationship of these three regulatory systems, which accompany the action of their hormones, neurohormones, peptides, any body function (digestion, growth, pregnancy, motor activity, etc.) [2-3]. Intense muscle activity increases the activity of body functions, primarily their neuro-humoral regulation. In this connection, the influence of intense physical activity on the characteristics of hormone production, which determines the growth and development of the body, is of interest.

The aim of the work: theoretical analysis of the mechanisms of influence of physical activity on the production of somatotropic hormone.

Methods and organization. The research work presents the results of a content analysis of research papers by domestic and foreign authors, presented in peer-reviewed scientific publications, on the problem of the influence of physical activity on the production of somatotropic hormone. The mechanisms of hormone production and factors influencing this process were analyzed.

Results and discussion. Nervous regulation of endocrine functions is carried out by several mechanisms. One of them is neurosecretion, i.e. release of hormones from the neuron into the blood. Another mechanism is the direct autonomous innervation of endocrine tissues, which couples nerve signals from the central nervous system with the secretion of hormones, and hormones, in turn, affect the nervous system. Switching of nerve signals to endocrine ones occurs mainly in the functional hypothalamic-pituitary system, which regulates the functional activity of peripheral endocrine glands and other body functions [4-6].

Hypothalamic hormones entering the anterior pituitary gland regulate the secretion of pituitary hormones. Those hormones that stimulate this process are hypothalamic hormones – releasing hormones (RH) or liberins, these include thyrotropin-releasing hormone, gonadotropin-releasing hormone, corticotropin-releasing hormone, somatoliberin (somatotropin-releasing hormone) and others, inhibitory hormones or statins – somatostatin and dopamine

In addition to specialized hormones, the hypothalamus produces neurotransmitters (biologically active amines – dopamine, adrenaline, norepinephrine, serotonin, acetylcholine, gamma-aminobutyric acid (GABA), histamine), neuropeptides (vasoactive intestinal peptide (VIP), neurotensin, components of the renin-angiotensin system (RAS), cholecystokinin (CCK), endothelin, neuropeptide Y). All these substances have a diverse effect on the anterior and posterior lobes of the pituitary gland and the central nervous system (CNS) [7-10].

The secretion of pituitary hormones, in addition to hypothalamic and peripheral hormones that come with the blood, is influenced by external factors such as stress, nutrition, disease, etc. Stress stimulates the secretion of adrenocorticotropic hormone (ACTH), growth hormone (GH), and prolactin (PRL). The secretion of PRL and GH differs from others: it is not regulated by classical feedback. The main regulators of these hormones are hypothalamic liberins and statins. In the regulation of PRL secretion, inhibitory influences play the main role, while stimulating ones have an impact on the growth hormone secretion [11-12].

GH is a protein hormone consisting of 191 amino acid residues with a molecular weight of 21,500 kDa. It is synthesized and secreted by the somatotrophs of the anterior pituitary gland. The main function of GH is to stimulate the linear growth of a person. This stimulation is mediated by insulin-like growth factor-1 (IGF-1) [13-14]. GH affects all types of metabolism: carbohydrate – reduces the absorption of glucose by extrahepatic tissues, increases the production of glucose by the liver, together with glucocorticoids and insulin – glycogen stores in the liver, the level of glucose and ketone bodies in blood plasma; lipid – increases lipolysis in adipocytes, the level of ketone bodies in plasma; protein metabolism – increases the absorption of amino acids and protein synthesis through the action of IGF-1 [15].

The half-life of GH in plasma fluctuates between 20-50 minutes. In the early morning hours, the concentration of growth hormone does not reach 2 ng/ml (90 pmol/mL). The level of IGF-1 in plasma is identified mainly by the radioimmunological method, the determination of its concentration as a mediator of the action of growth hormone allows a more accurate assessment of the biological activity of the latter [16].

The secretion of GH is regulated by two hypothalamic hormones – somatotropin-releasing hormone and somatostatin. Physiological factors that stimulate the secretion of GH are the following: sleep, physical activity, physical or psychological stress, hypoglycemia; pathological – reduced protein levels and starvation, anorexia nervosa, chronic renal failure, acromegaly, obesity, hypothyroidism, hyperthyroidism, etc., there are many pharmacological stimulants. Nervous factors also affect the secretion of GH, for example, increased impulse secretion of GH during sleep is due to nerve impulses. The maximum level of GH is found 1-4 hours after falling asleep in children and decreases with age. Pulsed episodic secretion is typical for all studied pituitary hormones [15].

Disturbances in the secretion and synthesis of growth hormone have a severe effect on the development of the child, manifesting as pituitary dwarfism or vice versa gigantism. But HG is also necessary for adults, because it regulates metabolism, influences mental health and preserves youth, activates the synthesis of RNA and DNA nucleic acids, accelerates wound healing, counteracts aging of the body and the development of obesity [17-21].

Due to the anabolic effect of growth hormone, i.e. its ability to stimulate the formation of proteins, muscle mass is increased, the skeleton of the body is strengthened. STH improves the absorption of calcium and phosphorus by bone tissue, maintaining its density, and promotes fat burning. GH activates vitamin D in the kidneys, which affects the absorption of calcium and phosphorus, prevents their loss in the urine and helps strengthen bones [22-23].

With age, the level of GH decreases, and this is one of the causes of senile sarcopenia (decrease in muscle mass). To improve the situation, it is necessary to create conditions in your body so that GH is produced in the body as long as possible in a natural way. To do this, you need to sleep better, as it helps to stimulate

the production of GH, exercise, eat healthy foods with enough protein, limit simple carbohydrates and foods containing a large amount of cholesterol, since they do not contribute to the synthesis of GH. The importance of physical activity is indicated by the fact that under strict bed rest, bone resorption prevails over bone formation and a negative calcium balance develops rapidly in healthy people.

Skeletal muscles account for about 50% of body mass. They are able to change their energy needs by 20 or more times. During physical activity, a person increases the functional activity of not only skeletal muscles, but also the heart and respiratory muscles, which ensures the delivery of the required amount of oxygenated blood to meet the increased needs of working muscles. Different types of physical activity affect muscle tissue in different ways, in terms of stimulating anabolic processes by changing the concentration of GH.

The influence of strength exercises on the change in the GH concentration was studied. In strength training, a variety of training programs are used in which the choice of programming elements occurs and their interaction can play an important role in identifying the magnitude of the change in the GH level [24-25]. It has been proven that among the external factors that play a certain role in the ability to stimulate an increase in GH are the volume of muscles involved, the magnitude of the load during exercise, its volume and the duration of the rest intervals between the stages of exercise. Despite the large number of combinations of these factors, studies conducted by W.J. Kraemer et al. (1990, 1993) revealed that when comparing training programs, three factors can be distinguished that have the greatest stimulating effect on GH in men and women: this a combination of a large amount of work performed, a short duration of rest intervals (1 minute) and the use of an average weight of 10 RM [25-27]. Further studies have shown that the revealed dependences of the effect of strength exercises on GH stimulation depend on changes in the acid-base balance (increased lactate response) under the influence of these exercises [28]. Blood samples taken from people who performed strength exercises at night showed that the GH concentration in the first half of the night was lower compared to the control group, and in the second half it was higher than in the control samples. The researchers suggested that the observed changes could be the result of the influence of somatostatin or other metabolic or hormonal signals, such as somatoliberin or ghrelin [29-30]. These assumptions are waiting for their researchers.

Experimental data obtained on animals indicate the importance of the influence of physical activity for the GH secretion, which in turn stimulates somatic growth and muscle hypertrophy. Under the influence of an increased wave-like basal level of GH during exercise, an increase in the length of skeletal elements in animals, an increase in body mass and a decrease in adipose tissue were observed compared to control animals in a passive state [31].

When doing aerobic exercises, acute and chronic changes in GH are noted. Stimulation of GH secretion is observed as early as 15 minutes after the start of aerobic exercise. There is a linear dose relationship between the intensity of exercise and the level of GH secretion. In women of all ages, the GH level is noted to be higher than in men of comparable age, and they have a less pronounced undulating nature of secretion. The increase in GH secretion in response to physical activity in young people is higher than in older people. Aging in men leads to a weakening of the effectiveness of physical activity in terms of increased secretion of growth hormone by 3.9 times [32]. It is suggested that possible reasons for the decrease in GH secretion in older people may be an imbalance in the secretion of hormones that regulate the level of GH (somatostatin and somatoliberin or ghrelin)

The intensity and duration of aerobic exercise, the level of physical fitness, gender and age affect the degree of changes in GH in response to physical exercise. Age and obesity lead to a noticeable decrease in the secretory response due to changes in metabolic signals in the regulatory system and the effects of its main components [32]. The gender of a person determines the features of GH secretion in response

to physical activity, regardless of age. Circadian rhythms practically do not affect the effect of physical activity. No dependence of GH changes on the time of workout sessions during the day was found. A decrease in the physiological level of GH secretion in people leading a sedentary lifestyle, obese, elderly people is one of the reasons for the increase in fat deposits in the abdominal region, the occurrence of dyslipidemia, relative insulin insensitivity (insulin resistance), reduction in the mass of muscle and bone tissue (sarcopenia) and a decrease in the quality of life.

Conclusion. Thus, physical activity stimulates the secretion of growth hormone. GH production also depends on factors such as gender, age, lifestyle, obesity, etc. The presented data do not provide a logical large-scale picture of the relationships and effects of GH on various functions of the body of athletes, or simply people engaged in physical exercises. There are practically no studies of interrelations and interdependencies of the volume and nature of human motor activity and GH production. These studies are of fundamental and practical interest, as they will reveal deeper mechanisms of adaptation to motor activity, as well as patterns of growth and development of the human body.

REFERENCES

1. Goodman H.M. Basic Medical Endocrinology, 2nd ed. Raven Press, New York, 1994. 344 p.
2. Akmaev I.G. Neuroimmunoendocrinology: evidence and hypothesis. Problems of Endocrinology, 1997, no. 1, pp. 3-9. (In Russ.)
3. Savino W. Immunoneuroendocrine connectivity: the paradigm of the thymus-hypothalamus/pituitary axis. *Neuroimmunomodulation*, 1999, vol. 6, p. 126.
4. Diseases of the endocrine system organs. Ed. by I.I. Dedov. Moscow: Meditsina, 2000. 1946 p. (In Russ.)
5. Volevoda N.N. The growth hormone and the cardiovascular system. Problems of Endocrinology, 2011, vol. 57, no. 4, pp. 37-47. (In Russ.)
6. Spiegel A.M., Carter-Su C., Taylor S., Kulkarni R. Mechanisms of Action of Hormones That Act at the Cell Surface. In: Williams Textbook of Endocrinology, 10th ed. Saunders, 2002. 1820 p.
7. Anderson J.R. Neurology of the pituitary gland. *J Neurology Neurosurg Psychiatry*, 1999, vol. 66, p. 703.
8. Art E. Pathophysiological role of the cytokine network in the anterior pituitary gland. *Front Neuroendocrinol*, 1999, vol. 20, p.71.
9. Art E. Gp, Clin J 130 cytokine signaling in the pituitary gland: a paradigm for cytokine-neurotndocrine pathways. *Invest*, 2001, vol.108, p. 1729.
10.Ben-Jonathan N. Dopamin as a prolactin (PRL) inhibitor. *Endocr Rev*, 2001, vol. 22, p. 724.
11.Jansson, C. Growth hormone (GH) assay characteristic, and GH binding protein. *Clin Chem*, 1997, vol. 43, p. 950.
12.Chen C. Growth hormone secretagogue action on the pituitary gland: multiple receptor for multiple ligands? *Clin Exp Pharmacol Physiol*, 2000, vol. 27, p. 323.
13.Le Roith D., Bondy C, Yakar S., Liu J.L., Butler A. The somatomedin hypothesis. *Endocr Rev*, 2001, no. 22, p. 53.
14.Clark R.G. Robinson ICAF: UP and Down the growth hormone cascade. *Cytokine Growth Factor Rev*, 1996, no. 7, p. 65.
15.Vorotnikova S.Yu., Pigarova E.A., Dzeranova L.K. Metabolic effects of the growth hormone. Obesity and Metabolism, 2011, no. 4, pp. 55-60. (In Russ.)
16.Thorner M.O. The anterior pituitary. In: Williams textbook of endocrinology. 9th ed. Philadeiphia: Wb Saunders, 1988. 1819 p.
17.Dedov I.I., Tyul'pakov A.N., Petrakova V.A. Somatotropic insufficiency. Moscow: Indeks Print, 312 p. (In Russ.)
18.Thorner M.O. Manifestations of anterior pituitary hormone deficiency. In: Williams textbook of endocrinology. 9th ed. Philadeiphia: Wb Saunders, 1988. 1819 p.
19.Salomon F. The Effects of treatment with recombinant human growth hormone on body composition and metabolism in adults with growth hormone deficiency. *N Engl J Med*, 1989, vol. 321, pp. 1979-1803.
20.Espinosa de los Monteros A.L., Sosa F., Cheng S., Ochoa R., Sandoval C., Guinto G., Mendoza V., Hernández I., Molina M., Mercado M. Biochemical evaluation of disease activity after pituitary surgery in acromegaly: a critical analysis of patients who spontaneously change disease status. *Clin. Endocrin*, 2006, no. 64, pp. 245-249.
21.Nielsen E.H., Lindholm J., Bjerre V. Hagen C., Juul S., Jørgensen J., Kruse A., Laurberg P.

Frequent occurrence of pituitary apoplexy in patients with non-functioning pituitary adenoma. *Clin. Endocrin*, 2006, no. 64, pp. 319-322.
22.Whitehead H.M., Boreham C., Mcllrath E.M., Sheridan B., Kennedy L., Atkinson A.B., Hadden D.R. Growth hormone treatment of adults with growth hormone deficiency: Results of a 13 month placebo-controlled crossover study. *Clinical Endocrinology*, 1992, vol. 36, pp. 45-52.
23.Arwert L.I., Roosr C., Lips P., Twisk J.W.R., Manoliu R.A., Drent M.L. Effects of 10 years of growth hormone (GH) replacement therapy in adult GH deficient men. *Clin. Endocrin*, 2005, no. 63, pp. 310-316.
24.Fleck S.J., Kraemer W.J. Designing Resistance Training Programs, 3rd ed. Human Kinetics, Champaign, IL, 2004. 392 p.
25.Kraemer W.J., Dudley G.A., Tesch P.A. The influence of muscle action on the acute growth hormone response to resistance exercise and short-term detraining. *Growth hormone and IGF Research*, 2001, vol. 11, pp. 75-83.
26.Kraemer W.J., Marchitelli L., Gordon S.E. Normonal and growth factor responses to heavy resistance exercise protocols. *Journal of Applied Physiology*, 1990, vol. 69, pp. 1442-1450.
27.Kraemer W.J., Fleck S.J., Dziados J.E. Changes in hormonal concentrations after different heavy-resistance exercise protocols in women. *Journal of Applied Physiology*, 1993, vol. 75, pp. 594-604.
28.Gordon S.E., Kraemer W.J., Vos N.H. Effect of acid-base balance on the growth hormone response to acute high-intensity cycle exercise. *Journal of Applied Physioloqy*, 1994, vol. 76, pp. 821-829.
29.Fujisawa I. Magnetic resonance imaging of the hypothalamic-neurophyseal system. *Neuroendocrinol*, 2004, no. 16, p. 297.
30.Nindl B.C., Hymer W.C., Deaver D.R., Kraemer W.J. Growth hormone pulsatility profile characteristics following acute heavy resistance exercise. *Journal of Applied Physiology*, 2001, vol. 91, pp. 163-172.
31. Borer K.T. The effects of exercise on growth. *Sports Medicine (Auckland, NZ)*, 1995, vol. 20(6), pp. 375-397.
32.Weltman A., Pritzlaff, C.P., Wideman, L., Weltman, J.Y., Abbott, R., Gutgesell, M., Veldhuis, J.D., Hartman, M.L. The relationship between exercise intensity and growth hormone (GH) release is attenuated in older men. Paper presented at the Fourth International Conference of The Growth Hormone Research Society, Gothenberg, Sweden, 2000(b).

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STUDY OF THE REACTIVE ABILITY OF THE NEUROMUSCULAR SYSTEM OF ATHLETES DURING INTERACTION BETWEEN THE REGULATORY AND EXECUTIVE PARTS

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Annotation. We have studied the reactive ability of athletes in the sensorimotor tests of various difficulty in connection with the main rhythms of the brain, examined interaction between the regulating and executing parts of the neuromuscular system of athletes. This interaction was rated by the strength and direction of the connections identified with the Spearman correlation analysis. The results are presented in positive connections of the average strength between the main rhythms of the brain (alpha, beta, theta rhythms, and the theta/beta rhythms ratio), the mimic muscle electromyography with the results of sensorimotor tests of various difficulty, showing different structural and functional levels of the brain engaged in the motor response support. Developing fatigue of the regulating and executing parts greatly correlates with a number of erroneous motor responses and an absence of motor responses with beta and theta rhythms, stress of the mimic muscles, decrease in strength of interaction with alpha rhythm of an athlete's brain.
Keywords: brain rhythms, neuromuscular system, reactive ability, athletes.

Introduction. The regulation of the purposeful motor activity of a person that contributes the adaptation of an athlete's body to the professional activity depends on the functional state of the motor system [1-4] and the ability to adapt morphofunctional changes of all level of body function to the specifics of sports activity. The reactive ability of the neuromuscular system in the form of motor response reflects plasticity and functionality of the muscular apparatus as the executive part. The state of the regulating part of the reactive ability demonstrates the functional state of neuron structures that support movement. The conclusion on the functional state of the neuromuscular system and the adaptive changes occurred during the professional activity would allow us to study the consistency of the interaction between the regulatory and executive parts| of athletes in the study of the reactive ability [5].

Methods and organization. The state of the neuromuscular system's regulatory part in athletes was assessed by the main rhythms of the brain (alpha, beta, theta rhythms, the theta/beta rhythms ratio, Hz, %) on the "BOSLAB" software and hardware complex (the BI-2 version, made in Novosibirsk). We have made the 10-minute recording with the subject's eyes open, in the Cz-Fz lead (according to the "10-20" International Classification, the indifferent electrode was placed on the earlobe). The electromyographic (EMG) stress of the mimic muscles was registered with the sensors placed on the forehead.

According to the reactive ability of the muscle and motor response of athletes, we have also examined the function of the executive part of the neuromuscular system on for stimuli of various difficulty using computer software [6]. We have studied the simple sensorimotor reaction (SSR), complex sensorimotor reaction (CSSR), average response time (ms) (SSR, CSSR), erroneous responses of the CSSR (total, number), and response absence of the CSSR (total, number).

The study of the registered indicators' interrelation with the Spearman correlation analysis has allowed us to identify the interaction between the regulatory and executive parts of the neuromuscular system (we considered values of the average correlation coefficient ($r=\pm0.3$ to ±0.699) and high interaction strength

(r=±0.7 to ±1≥0.99)).

Interaction between the regulatory and executive parts in the sensorimotor tests of various difficulty demonstrate the total level of the central nervous system's function, its performance and activity, the dynamics of nervous processes, the speed of athletes switching to different types of activities [7].

Results and discussion. When analyzing the SSR's average time, correlated with macro movements and provided by the pyramidal level of movement organization [7], we have found the average degree of interaction with the studied brain rhythms (Hz): with alpha rhythm (r=0.4), beta rhythm (r=0.51), theta rhythm (r=0.44), and beta rhythm (%) (r=0.45).

The analysis of the CSSR's average time that reflects the CNS's selective activity with the distinction of the presented signals and the choice of behavioral response methods [8], which is regulated exclusively by the cortical level of the CNS [10], has demonstrated an increase in the strength of interaction with the brain rhythms: with alpha rhythm (r=0.5), beta rhythm (r=0.65), theta rhythm (r=0.5), as well as decreased interaction with EMG (r=0.38). These dynamics may reflect the redistribution of excitation processes, the shift of stress from the executive (motor) part to the regulatory (CNS) part of the neuromuscular system of athletes when providing a more complex motor response.

The occurrence of fatigue processes shows the occurrence of erroneous responses and the motor response absence in the CSSR, which was demonstrated in the interaction of the number of erroneous responses with the brain rhythms: with alpha rhythm (r=0.4), beta rhythm (r=0.4), theta rhythm (r=0.52) and the stress of the mimic muscles (EMG, r=0.4). The absence of responses to the signal significantly interacts with the beta (r=0.75) and theta rhythms (r=0.8), as well as with EMG (r=0.8), decreasing in the alpha rhythm (r=0.5). This, in whole, shows the occurrence of overstrain and fatigue in the neuromuscular system of athletes of both the regulatory (CNS) and the executive (muscular) parts, depending on the nature of local or generalized fatigue.

Conclusion. The analysis of the neuromuscular system's function based on the study of the interaction between the regulatory and executive parts during the examination of the reactive ability of athletes makes it possible to diagnose, control and predict the likely onset of negative psychophysiological processes, including fatigue associated with professional activity, affecting its efficiency [5, 6, 10-14]. Identifying the degree of interrelation between the regulatory and executive parts allows a reasonable approach to the choice of preventive and restorative means of the neuromuscular system of athletes during their professional activity.

REFERENCES

1. Bezrukikh M.M., Son'kin V.D., Farber D.A. Developmental physiology: (physiology of child development): a textbook for students of higher educational pedagogical organization. Moscow: Publishing Center "Akademia", 2003. 416 p. (in Russ.)
2. Flynn K.E., Piña I.L., Whellan D.J., Lin L., Blumenthal J.A., Ellis S.J., Fine L.J., Howlett J.G., Keteyian S.J., Kitzman D.W., Kraus W.E., Miller N.H., Schulman K.A., Spertus J.A., O'Connor C.M., Weinfurt K.P. Effects of exercise training on health status in patients with chronic heart failure: HF-ACTION randomized controlled trial. *HF-ACTION Investigators. JAMA*, April 8, 2009, vol. 301(14), pp.1451-1459.
3. Son'kin V.D., Tambovtseva R.V. Development of muscle energy and performance in ontogenesis. URSS, 2011. 368 p. (in Russ.)
4. Roschcina L.V., Chelnokov A.A. Effect of percutaneous electrical stimulation of spinal cord on human motor system functionality. *Theory and Practice of Physical Culture*, 2020, no. 4. (in Russ.)
5. Lunina N.V., Koryagina Yu.V. Interrelations of the regulatory and executive apparatus of the neuromuscular system of athletes in the study of reactivity. *Modern Issues of Biomedicine*, 2022, vol. 6, no. 1. DOI: 10.51871/2588-0500_2022_06_01_13. (in Russ.)

6. Koryagina Yu V., Nopin S.V., Ter-Akopov G.N. Development of hardware and software complex of express evaluation and analysis of athlete psychofunctional status "Sports diagnostics". *Resort Medicine*, 2019, no. 4, pp. 54-58. (in Russ.)
7. Khorzhunskij A.A. Methods of testing and analyzing psychomotor abilities of 11-13 year old judokas. *Physical Culture and Sports: Education, Training*, 2017, no. 4, pp. 34-36. (in Russ.)
8. Shutova S.V., Murav'eva I.V. Sensorimotor reactions as characteristics of functional state of CNS. *Bulletin of the Tambov State University*, 2013, no. 5, pp. 2831-2840. (in Russ.)
9. Matveev S.S., Shayakhmetova E.S., Matveeva L.M., Dubovitskaya T.D. Study of performance and fatigue of students with different profiles of functional interhemispheric asymmetry. *Online scientific and educational journal "Health and Education Millennium"*, 2016, vol. 18(4), pp. 30-36. (in Russ.)
10.Ignatova Yu.P., Marakova I.I., Yakovleva K.N., Aksenova A.V. Visual-motor reactions as an indicator of the CNS's functional state. *Ul'yanovsk Medical and Biological Journal*, no. 3, 2019. pp. 38-51. (in Russ.)
11.Antipova E.I., Shibkova D.Z. Psychophysiological risks caused by working conditions of social work specialists. *Fundamental Research*, 2014, no. 9-7, pp. 1532-1537. (in Russ.)
12.Fink A.V. Study of the effect of the light level on the sensitivity of the retina and the hand-eye reaction time. *Izvestiya of Altai State University*, 2009, no. 3 (63), pp. 30-32. (in Russ.)
13.Kaptsov V.A., Sosunov N.N., Ishchenko I.I., Viktorov V.S., Tulushev V.N., Deinego V.N., Bukhareva E.A., Murashova M.A., Shishchenko A.A. Functional state of the visual analyzer in the conditions of the use of traditional and led light sources. Hygiene and Sanitation, 2014, no. 93(4), pp. 120-123. (in Russ.)
14.Gubareva L.I., Ponomareva T.Yu., Ermolova L.S. Central nervous system function in gas transportation system staff with various degree of adaptation to the professional environment. *Medical News of North Caucasus*, 2016, no. 11 (4), pp. 573-576. (in Russ.)

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RISK FACTORS FOR THE DEVELOPMENT AND PROGRESSION OF SCOLIOSIS IN ADOLESCENT ATHLETES IN RHYTHMIC GYMNASTICS: A LITERATURE REVIEW

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Annotation. The article deals with the problem of structural and functional changes in the spine in the form of scoliosis in athletes involved in rhythmic gymnastics. The results of a theoretical analysis of literary sources revealed that adolescence of 12-14 years among athletes specializing in rhythmic gymnastics, on the one hand, is the most vulnerable in terms of imbalance in various body systems under the influence of specific loads, considering morpho-anatomical and physiological parameters. On the other hand, it is extremely important when building the training process, since it is at this time that the development and improvement of physical qualities, artistic and aesthetic abilities and the formation of sportsmanship takes place. The data obtained made it possible to form a theoretical basis in identifying the risk factors of scoliosis's development in adolescent athletes specializing in rhythmic gymnastics.
Keywords: scoliosis, rhythmic gymnastics, sports, health, musculoskeletal system, asymmetric loads.

Introduction. Since 1984, rhythmic gymnastics are an Olympic sport [1]. It is a complex coordination, aesthetic sport, which is constantly developing and increasing requirements to the technical complexity of performed elements. Despite this fact, it is one of the most popular sports among girls.

Frequently, young athletes have to endure extreme loads in order to achieve mastery in this field. However, the training method is not always constructed taking into account the age, anatomical and physiological features of a growing body. This also applies to the early specialization in gymnastics, which implies a large monotonous asymmetric physical load on the spine and ligamentous muscular apparatus of young athletes.

The training process in rhythmic gymnastics involves the implementation of complex coordinated elements that require athletes to have increased flexibility in the joints. Meanwhile, performance of asymmetric movements leads to the uneven work of the muscles and ligaments around the spine, which consequentially leads to disorders of statnamic characteristics in the spine of functional nature, then – to pathologically locked torsion changes of the spine in form of scoliosis. An increased injury rate in rhythmic gymnastics, developmental, anatomical and physiological features of a child's body that are a priority in sports selection are additional risk factors for the development and progression of scoliosis in young athletes.

The purpose of the study – theoretical analysis of risk factors for the development and progression of scoliosis in adolescent athletes in rhythmic gymnastics.

Methods and organization. We have used the content analysis of domestic and foreign scientific works, presented in peer-reviewed scientific publications, Russian and foreign databases. Total of examined references – 32, we have selected 20 among them.

Results and discussion. Scoliosis is an orthopedic disease characterized by a complex three-plane deformation of the spine [2] accompanied by a disorder in organ and system function which is a reason for severe physical and mental suffering among children [3].

Most frequently, the problem of scoliosis is registered among 7-12 years old girls (in 75%) [4-5]. Occurrence and progression of scoliosis is most frequently seen in childhood and adolescence, and it's related with an active stage of children's growth [6] and the fact that during this exact period the spine is the most flexible and, accordingly, subject to deformation.

The highest peak of physical loads in rhythmic gymnastics is noted at the stage of sports specialization at the age of 11-14 years and at the stage of sports improvement and high sportsmanship from 14 years [7]. This age is considered as "critical": puberty occurs, development of the endocrine system functions continues, the neurohumoral regulation forms and rearranges [6]. During this period, intense physical loads that are put on the growing body can be a cause of disorders in the reproductive system accompanied by hormonal shifts that contribute to the development of changes in the bone system [8].

Specificity of rhythmic gymnastics as asymmetric sport, the sessions of which are carried out without considering developmental, anatomical and physiological features of a child's body and following methodological guidelines and recovery measures, is attributed to high risks of asymmetric disorders of the musculoskeletal systems [9]. For example, the structure of the competitive program mainly consists of asymmetric exercises: most of the elements are performed with the "dominating leg", performance of tossing elements and work with objects (jumping rope, hoop, ball, Indian clubs, ribbon) are most frequently done with one hand. In addition, in order to master the program, the gymnast also performs correction of mistakes independently between practice runs, which in terms of repeating asymmetric movements leads to changes and redistribution of the muscle tone. There is also a unilateral predominance of the strength of the back muscles in the lumbar region and an opposite strengthening of the muscles in the thoracic spine.

Other important factors of occurrence and development of scoliosis in gymnasts are the excessive mobility in joints and asymmetric loads on the spine [10-12].

It must be kept in mind that development of scoliosis and posture disorders in young athletes occurs due to asymmetric loads during the most intense body growth period, which also aggravates the pathogenic profile.

A great number of asymmetric elements connected to the spine bend to one side is deemed as the most dangerous. This is the reason why researchers [8, 10] recommend to increase a set of symmetrical physical exercises during training or to use a set of correcting exercises after training in order to level the negative impact of asymmetric loads on the musculoskeletal system.

Moreover, the repetitive impact, as well as extreme spinal extensions performed for a long period of time, lead to the development of spondylolytic stress reaction, fatigue injuries and different diseases of the musculoskeletal system (scoliosis, osteoporosis, spondylosis, spondylolisthesis et al) [8, 13].

When achieving high sportsmanship, rhythmic gymnasts already have typical pathological processes [14-18], such as the degenerative processes in intervertebral cartilages and joints [8]. Meanwhile, the incidence of spondylolisthesis is 4 times higher in gymnasts than in total population.

Another number of factors can influence the development and progression of scoliosis, such as deceleration of skeletal maturity and bone mineralization compared to peers, later closure of bone growth zones [19]. Early engagement in sports and rigid diets, occurrence of pain sensations, disorders in the state of the musculoskeletal system also lead to a decreased density of bone tissue [20]. The aforementioned fact also proves a need for careful sports selection [21-22], ongoing and stage-by-stage control in order to preserve the health of gymnasts and timely inclusion of preventive measures to correct emerging deviations.

Conclusion. On the one hand, adolescent age of 12-14 years among rhythmic gymnasts is the most vulnerable according to morphological, anatomical and physiological parameters in terms of balance disturbance in different sys-

tems of the body influenced by specific activities. On the other hand, it is extremely important when building the training process, because it is at this time that the development and improvement of physical qualities, artistic and aesthetic abilities and the formation of sportsmanship takes place. The literary data analysis has formed a theoretical basis in identifying the risk factors of scoliosis in adolescent rhythmic gymnasts. It will serve as a base for developing methodological guidelines and implementing recovery measures in order to level the negative influence of intense specific loads mainly of the asymmetric nature in the training process of adolescent rhythmic gymnasts.

REFERENCES

1. Viner-Usmanova I.A., Kryuchek E.S., Medvedeva E.N., Terekhina R.N. Theory and methods of rhythmic gymnastics. Artistry and ways of its formation. Moscow: Sport, 2015. 120 p. (in Russ.)
2. Dudin M.G. Pinchuk D.Yu. Idiopathic scoliosis: neurophysiology, neurochemistry. Saint Petersburg: Chelovek, 2013. 304 p. (in Russ.)
3. Efremov A.Yu., Danilushkina V.V. Psychophysiological features of the consequences of scoliosis. *Scientific Research: from Theory to Practice*, 2015, no. 2(3), pp. 456-458. (in Russ.)
4. Shabanova O.A. Medical and social aspects of disability and rehabilitation of patients with scoliosis: an author's abstract. Moscow, 2011. 26 p. (in Russ.)
5. Fadzan M, Bettany-Saltikov J. Etiological theories of adolescent idiopathic scoliosis: Past and Present. *The Open Orthopaedics Journal*, 2017, no. 11 (9), pp. 1466-1489.DOI:10.2174/187 4325001711 011466.
6. Arshin V.V, Chebykin A.V. Scoliosis: etiology, pathogenesis and a new method of correction. *Bulletin of Medical University "Reaviz": Rehabilitation, Doctor and Health*. 2015, no.1 (17), pp. 55-57. (In Russ.)
7. Viner I.A. Preparation of elite athletes in rhythmic gymnastics: an author's abstract. Saint Petersburg, 2003. 20 p. (in Russ.)
8. Bikchurin N.M., Takhavieva F.V. Injuries and illnesses of young athletes practicing rhythmic gymnastics. *Science and Sports: Modern Tendencies*, 2018, vol. 21, no. 4, pp. 6-10. (in Russ.)
9. Medvedeva E.N., Tsallagova R.B., Suprun A.A., Kotel'nikova E.B. Innovative approach to prevention of traumatism at mastering of jumps in rhythmic gymnastics. *Scientific Notes of the P.F. Lesgaft University*, 2016, no. 4 (134), pp. 160-163. (in Russ.)
10.Tanchev P.I., Dzherov A.D., Parushev A.D. Dikov D.M., Todorov M.B. Scoliosis in rhythmic gymnasts. *Spine*, 2000, vol. 25, no. 11, pp. 1367-1372.
11.Dudin M.G., Pinchuk D.Yu., Mikhajlovskij M.V. Scoliosis: questions and answers. Learning guide. Saint Petersburg: Publishing house of the Mechnikov North-West State Medical University, 2019. 124 p. (in Russ.)
12.Latalski M., Danielewicz-Bromberek A., Fatyga M., Latalska M., Kröber M., Zwolak P. Current insights into the aetiology of adolescent idiopathic scoliosis. *Arch Orthop Trauma Surg*, 2017, vol. 137, pp. 1327-1333. DOI: 10.1007/s00402-017-2756-1.
13.Roberts K. Spine injuries in rhythmic gymnastics. *Sport Health*, 2009, no. 3, pp. 27-29.
14.Cupisti A., D'alessandro C., Evangelisti I., Umbri C., Rossi M., Galetta F., Panicucci E., Lopes Pegna S., Piazza M. Injury survey in competitive sub-elite rhythmic gymnasts: results from a prospective controlled study. *J Sports Med Phys Fitness*, 2007, vol. 47, no. 2, pp. 203-207.
15.Hutchinson, M.R. Low back pain in elite rhythmic gymnasts. *MedSciSportsExerc*, 1999, vol. 31, no. 11, pp.1686-1688
16.Saraiva B.M.A., Araujo G.S., Sperandio E.F. [et al] Gotfryd A.O., Dourado V.Z., Vidotto M.C. Impact of Scoliosis Severity on Functional Capacity in Patients with Adolescent Idiopathic Scoliosis. *Pediatr. Exerc. Sci*, 2017, vol. 5, pp.1-24.
17.Kasimova G.T., Saliev M.M., Kholov Z.S. Kadyrov S.S., Ravshanov S.N. Neurological state features in children with severe idiopathic scoliosis. Journal of Theoretical and Clinical Medicine, 2016, no. 3, pp. 66-69. (in Russ.)
18.Dimitrova L. Petkova K. Modeling injury risk for pre-elite rhythmic gymnasts: Bayesian network approach. EIIC. The 2nd Electronic International Interdisciplinary Conference, 2013, vol. 2.
19.Geogopoulos N.A., Markou K.B., Theodoropoulou A. D. Benardot, Leglise M., Vagenakis A.G. Growth Retardation in Artistic Compared with Rhythmic Elite Female Gymnasts. *Journal of Clinical Endocrinology and Metabolism*, 2002, vol. 87(7), pp. 3169-3173.

20.Solov'eva I.O. Correction of structural and functional changes in bodies of girls, engages in rhythmic gymnastics: an author's abstract. Saint Petersburg, 2011. 23 p. (in Russ.)
21.Nopin S.V., Koryagina Yu.V., Ter-Akopov G.N. A method for assessing children's predisposition to rhythmic gymnastics. Patent for invention RF 2780158 C1, 2022. (in Russ.)
22.Nopin S.V., Koryagina Yu.V., Ter-Akopov G.N. Sports orientation of children for rhythmic gymnastics. Certificate of the computer program registration RF 2018612450, 2018. (in Russ.)

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IMPACT OF THE RECOVERY PROCEDURES COURSE ON THE FUNCTIONAL STATE OF THE MUSCULOSKELETAL SYSTEM OF LOWER LIMBS OF FIELD HOCKEY ATHLETES DURING TRAINING IN MIDDLE ALTITUDE

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Annotation. The purpose of this study was to evaluate impact of a set of physical therapy procedures on the functional state of the neuromuscular system and hemodynamics of lower limbs in female athletes in middle altitude conditions during training. The study involved 19 female field hockey players with the Candidate for Master of Sports and Master of Sports titles. They were randomly divided into two groups: the treatment group (had a set of physical therapy procedures, including magnet therapy, hydrotherapy and lymphatic drainage massage (pressure therapy)) and the control group (had no procedures). The analysis of the neuromuscular transmission parameters in the treatment group after the course has revealed an increased amplitude on the left in two stimulation points: head of fibula and popliteal fossa. When analyzing hemodynamic indicators, the treatment group has also demonstrated a significant decrease in the asymmetry coefficient in the "foot" segment of the left and right leg. When analyzing the microcirculation indicators, we have found a decrease in the diastolic index and the left ventricle filling pressure in the "calf" segment of the right leg. Considering the data obtained, we can conclude a positive impact of a set of procedures on the blood flow and the neuromuscular system of female field hockey players during training in middle altitude.

Keywords: field hockey, recovery, middle altitude, training activity, neuromuscular system, hemodynamics, magnet therapy, hydrotherapy, lymphatic drainage massage (pressure therapy).

Introduction. Field hockey is a contact and dynamic situational sport that is actively developing recently in Russia. It requires not only tactical skills, but also great physical impact and good overall endurance from players, since practicing this sport involves mainly aerobic loads. High intensity of physical activity in professional sports, along with the body adaptation to middle altitude conditions, can cause almost an almost marginal level of the body function of athletes and, as a result, create prerequisites for faster fatigue, overstrain and overtraining, thereby reducing the efficiency of training activity [1-4]. That is the reason why the use of effective recovery methods while training elite female athletes in middle altitude conditions is extremely important. During recovery of athletes, experts apply different measures of physical therapy, such as magnet therapy and lymphatic drainage massage (pressure therapy) [5-6]. However, there is no research dedicated to studying efficiency of a comprehensive implementation of physical therapy procedures that include magnet therapy, hydrotherapy and pressure therapy in case of recovering athletes in middle altitude conditions [7].

The purpose of the study was to rate the impact of magnet therapy, hydrotherapy and lymphatic drainage massage on the neuromuscular system and hemodynamics of the lower limbs of female field hockey players during training in middle altitude conditions.

Methods and organization. The study was conducted in the Center of biomedical technologies, FSBI "North-Caucasian Federal Research and Clinical Center of the Federal Medical and Biological Agency", at an altitude of 1240 m (Maloe Sedlo Mountain, Kislovodsk) during training camps in the FSUE "Yug sport". It involved 19 female field hockey players aged 16-31 years (Candidate for Master of Sports, Master of Sports titles), members of the Russian national team. All athletes had diagnosis of the functional state of the neuromuscular system and hemodynamics of the lower

limbs. The lower limb hemodynamics were studied with the rheograph (Rheograph Valenta, made by "Kompania Neo" LLC in Saint Petersburg). The Neuro-MVP 4-channel hardware and software complex was used for stimulation electroneuromyography ("Neurosoft", Ivanovo). We have also examined registration of motor responses (M-responses) from the extensor digitorum brevis muscle innervated by the peroneus nerve.

The athletes were divided into two groups – the treatment group and the control group, the divide was randomized. In the course of 7 days, the treatment group received a set of physical therapy procedures, including magnet therapy, hydrotherapy and lymphatic drainage massage (pressure therapy). The control group did not receive any procedures.

Magnet therapy was made with the Physiomed Mag-Expert device, 60 cm coil, impact area – knee and ankle joints, impact time – 15 minutes, magnetic flux density – 0.006 T, frequency – 25 Hz. Beka hospitec, the contrast 4-chamber bath for hands and feet, was used for hydrotherapy, time – 10 minutes, hot water temperature – 38 °C, cold water temperature – 14 °C, cyclicity – 45 s, flow – 220 l/min, pressure – 1 atm. For pressure therapy, we have used the BTL-6000 LYMPHASTIM 12 4-channel device in Physiological mode (physical therapy), procedure area – lower limbs, time – 30 minutes, cuff pressure – 60 mm of Hg.

After the course, both groups had diagnosis of the functional state of the neuromuscular system and hemodynamics of the lower limbs.

The statistical data processing was made with the Wilcoxon matched pair test and the Mann-Whitney U-test on the Statistica 6.0 software. The difference between values deemed significant if $p<0.05$.

Results and discussion. The results obtained from the analysis of the neuromuscular transmission at the beginning did not demonstrate statistically significant differences between groups. The similar data was received after the hemodynamic indicators analysis.

According to the results obtained after the physical therapy course, we can note the following. Analysis of the neuromuscular transmission in the treatment group has revealed an increase amplitude of M-response on the left in two stimulation points: head of fibula (before: 6.05±0.57 мV and after: 6.92±0.72 мV, $p\leq0.03$) and popliteal fossa (before: 6.09±0.51 mV, after: 6.99±0.70 mV, $p\leq0.03$). It allows us to make a conclusion about an increase amount of motor units engaged in contraction when stimulating motor nerve fibers with electric current (fig. 1).

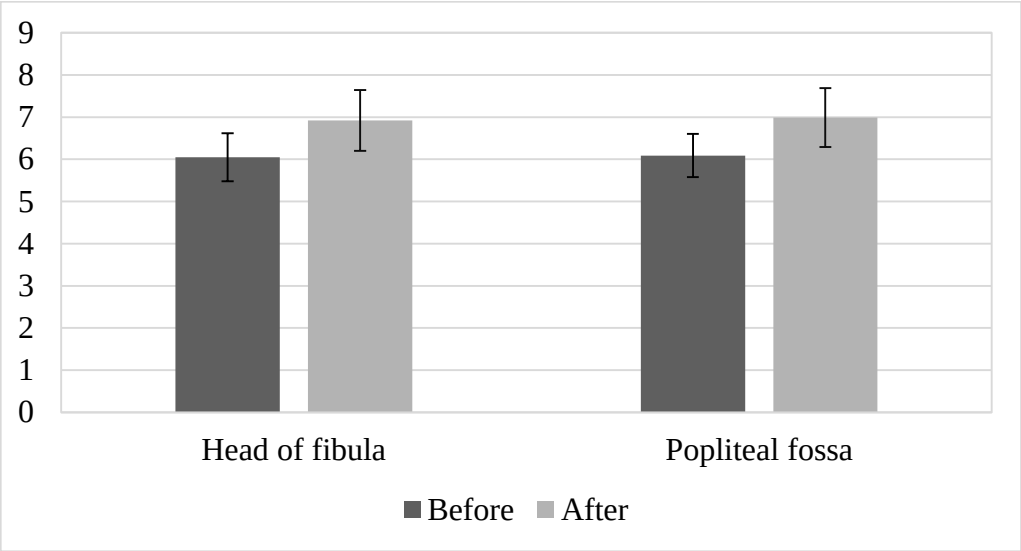

Fig. 1. Indicators of the M-response amplitude in the "head of fibula" and "popliteal fossa" stimulation points on the left in athletes before and after the procedures

The study has not revealed any other significant changes in the neuromuscular transmission in the treatment group. However, we can see that there is a tendency in all stimulation points of the right and left legs to increase following indicators: surface area and amplitude of M-response and nerve conduction velocity (NCV). There was also a decrease in M-response duration and residual latency (table 1).

Table 1

Comparative analysis of motor responses registered from the extensor digitorum brevis muscle, innervated by the peroneus nerve, in field hockey players of the treatment group before and after the procedures

Indicators	Treatment group		p	Standard
	Before	After		
Right tarsus				
Latency, ms	3.33±0.19	3.24±0.14	-	-
Amplitude, mV	6.12±0,51	6.35±0.53	-	≥3.5 mV
Surface area, mV×ms	19.1±1.55	20.6±1.71	-	-
Residual latency, ms	2.31±0.19	2.19±0.14	-	≤3 ms
Right head of fibula				
Latency, ms	10.1±0.34	9.97±0.31	-	-
Right popliteal fossa				
Surface area, mV×ms	19.7±1.70	20.3±1.38	-	-
Left tarsus				
Amplitude, mV	6.52±0.58	7.10±0.64	-	≥3.5 mV
Duration, ms	6.32±0.25	6.25±0.28	-	-
Surface area, mV×ms	20.8±1.43	22.6±1.72	-	-
Left head of fibula				
Surface area, mV×ms	20.3±1.62	23.0±1.92	-	-
Left popliteal fossa				
Duration, ms	6.59±0.30	6.55±0.31	-	-
Surface area, mV×ms	20.6±1.46	23,1±1,89	-	-
NCV, m/s	59.5±2.29	62.9±2.28	-	≥40 m/s

We can conclude that using physical therapy procedures on athletes of the treatment group has contributed to a higher engagement of motor units during the nerve stimulation, consequently – to an increase in muscle contraction surface area, as well to an increase of nerve conduction velocity, which is important for effective performance of movements requiring maximum muscle activation in a short period of time and for muscle coordination improvement.

When analyzing hemodynamic indicators of the treatment group, we have revealed a significant decrease in the asymmetry coefficient in the "foot" segment on the left (before: 47.9±5.79%, after: 23.0±4.52%, p≤0.003) and right (before: 47.9±5.79%, after: 30.4±8.90%, p≤0.04) (fig. 2).According to the microcirculation indicators, we have found decreased parameters of the diastolic index (before: 0.50±0.02 c.u., after: 0.41±0.03 c.u., p≤0.03) in the "calf" segment on the right. In the same segment on the left the aforementioned indicator has a tendency to decrease (before: 0.48±0.04 c.u., after: 0.44±0.03 c.u.) (fig. 3).

The "calf" segment has also demonstrated a significant decrease in the left ventricle filling pressure on the right (before: 24.3±0.52 mm of Hg, after: 21.8±0.76 mm of Hg, p≤0.02). There were no changes on the right, but there was a tendency for its decrease (before: 24.2±0.79 mm of Hg, after: 22.7±0.94 mm of Hg) (fig. 4).

In general, for hemodynamics of the lower limbs, a tendency to decrease in such indicators

as elastic modulus, diastolic index, left ventricle filling pressure was revealed. The indicators of venous outflow and the asymmetry coefficient decreased, which brought them closer to the standard values. However, no significant changes were detected for the listed indicators in the treatment group before and after the procedures (table 2).

Therefore, athletes of the treatment group have higher artery elasticity and normalized venous outflow, which indicates improved microcirculation.

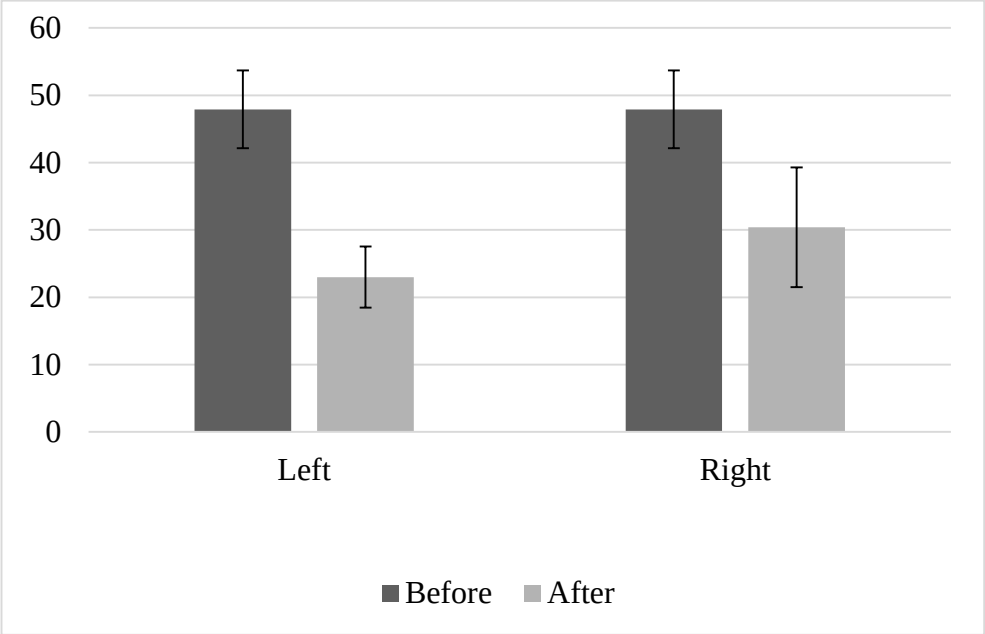

Fig. 2. The blood flow asymmetry coefficient indicators in the "foot" segment of the left and right legs in athletes before and after the procedures

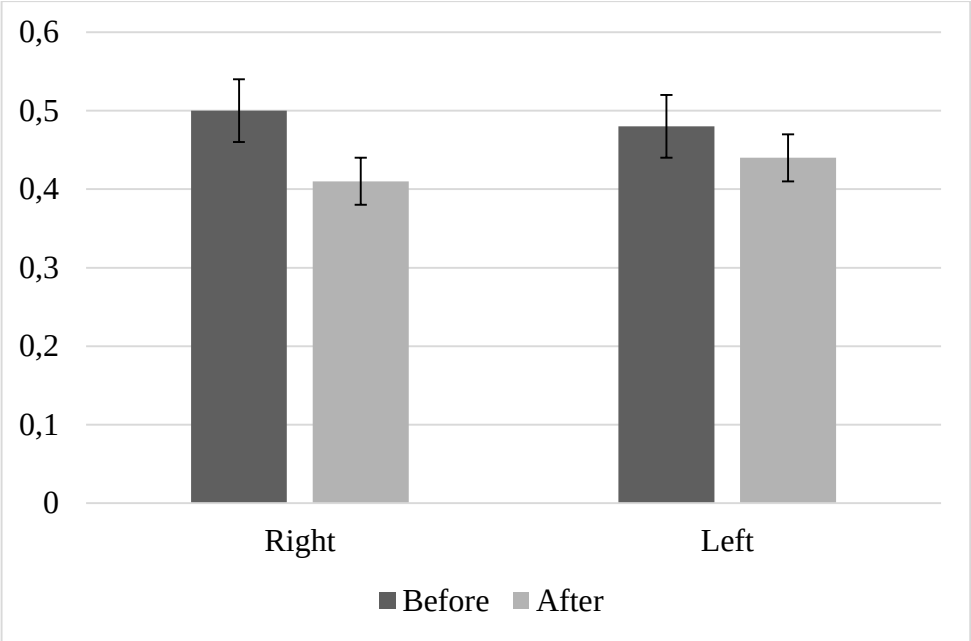

Fig. 3. The blood flow diastolic index indicators in the "calf" segment of the right and left legs in athletes before and after the procedures

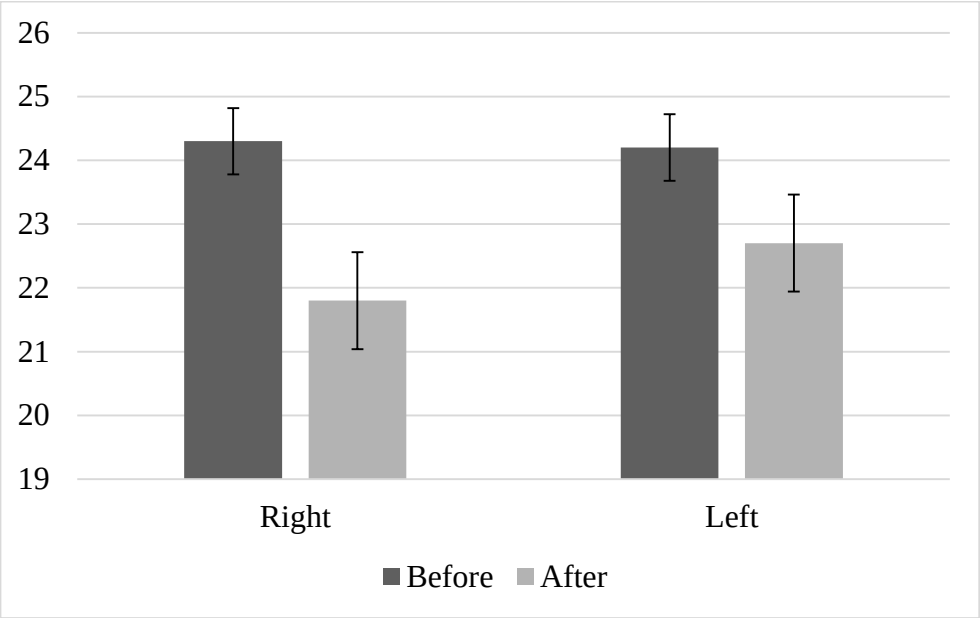

Fig. 4. Left ventricle filling pressure indicators in blood flow of the "calf" segment of the right and left legs in athletes before and after the procedures

Table 2

Comparative analysis of the lower limb rheovasography of female field hockey players before and after the procedures

Indicators	Treatment group		p	Standard
	Before	After		
Left foot				
Elastic modulus, %	15.6±1.71	13.9±1.09	-	11-16%
Diastolic index, c.u.	0.45±0.03	0.41±0.04	-	0.30-0.55
Left ventricle filling pressure, mm of Hg	23.0±0.89	21.7±0.98	-	-
Right foot				
Venous outflow, %	38.5±10.4	22.5±2.83	-	0-20%
Diastolic index, c.u.	0.43±0.03	0.39±0.02	-	0.30-0.55
Left ventricle filling pressure, mm of Hg	22.5±0.93	21.4±0.68	-	-
Left calf				
Diastolic index, c.u.	0.48±0.04	0.44±0.03	-	0.45-0.75
Asymmetry coefficient, %	22.2±4.25	14.8±2.97	-	0-20%
Left ventricle filling pressure, mm of Hg	24.2±0.79	22.7±0.94	-	-
Right calf				
Venous outflow, %	26.3±3.20	23.2±2.54	-	0-20%
Asymmetry coefficient, %	22.5±4.23	14.8±2.97	-	0-20%

Considering the fact that athletes of the main group have received the 7-day physical therapy procedure set, a tendency to normalize the peripheral blood flow indicators and improve the neuromuscular transmission parameters without any statistically significant changes can be explained by a need to receive a course cycle of physical therapy procedures during

training in middle altitude conditions. Thus, further studies are needed with subsequent observation of the functional state of the neuromuscular system and hemodynamics of the lower limbs of athletes.

Conclusion. The analysis of the data received has shown that using the physical therapy set that includes magnet therapy, hydrotherapy and lymphatic drainage massage (pressure therapy)) in the course of 7 days gave a positive effect on the blood flow and the neuromuscular system of female field hockey players during training in middle altitude. Indicators of the peripheral blood flow have returned to normal and the neuromuscular transmission parameters have improved.

REFERENCES

1. Kornyakova V.V., Badtieva V.A., Balandin M.Yu., Ashvits I.V. Physical fatigue in sports. *Human. Sport. Medicine*, 2020, no. 19(4), pp. 142-149. (in Russ.)
2. Vykhodets I.T., Didur M.D., Kargashina A.S., Lobov A.N., Miroshnikova Yu.V., Parastaev S.A., Plotnikov V.P., Polyaev B.A., Samojlov A.S., Feshchenko V.S. Clinical recommendations for the diagnosis and treatment of general and particular syndromes of overstrain of the central nervous system, cardiovascular system, musculoskeletal system, immune system and fatigue in elite athletes. Ed. by V.V. Ujba. Moscow: FMBA of Russia, 2018. 94 p. (in Russ.)
3. Makarova G.A., Loktev S.A., Porubajko L.N. Risk factors of overstrain syndrome in athletes. *Mezhdunarodnyj zhurnal eksperimental'nogo obrazovaniya*, 2014, no. 4(1), pp. 170-172. (in Russ.)
4. Ter-Akopov G.N. New technologies fort he rehabilitation of athletes on the training camp in the conditions of middle altitude. Modern Issues of Biomedicine, 2017, vol. 1(1). Available at: https://svbskfmba.ru/arkhiv-nomerov/2017-1/ter-akopov (accessed 23.09.2022)
5. Safonov L.V. Combined magnetic and pressure therapy for recovery improvement in elite athletes. *Sports Science Bulletin*, 2014, no. 1, pp. 47-50. (in Russ.)
6. Fudin N.A., Badtieva V.A., Kupeev R.V. On the use of acupressure in sports medicine. *Journal of New Medical Technologies, eEdition*, 2018, no. 2, pp. 160-164. (in Russ.)
7. Koryagina Yu.V., Nopin S.V., Ter-Akopov G.N., Roguleva L.G., Abutalimova S.M. Approval of complexes of restoration events developed for athletes on the federal basis of sports training in the conditions of middle heights. MCU Journal of Natural Sciences, 202, no. 1, pp. 25-34. (in Russ.)

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EFFICACY OF HYDROKINESIOTHERAPY IN INFANT CHILDREN WITH MUSCLE HYPOTENSION SYNDROME

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Annotation. This article presents the results of using hydrokinesiotherapy for infant children with muscle hypotension syndrome. The 6-month study was carried out in the "Eveksia" Medical Rehabilitation Center (Moscow). With parents' informed permission, it included children aged 1-2 years with muscle hypotension, who, according to the preliminary medical report, did not have any contraindications to hydrokinesiotherapy. The results have revealed the efficacy of hydrokinesiotherapy, which is demonstrated through the improvement of global motor and manual functions indicators: the babies under 2 years began to form walking skills, develop speed and volume of manual functions.
Keywords: hydrokinesiotherapy, muscular hypotension syndrome, young children, global muscle functions, manual functions.

Introduction. Muscle hypotension is a decrease in skeletal muscle tone (residual stress and muscle resistance to passive muscle pull) with the contractile function deterioration. This state is a symptom of a whole number of inherent and acquired pathologies that are attributed to neuromuscular disorders [1].

Total statistics of muscle hypotension syndrome in Russia is insufficiently represented. The world statistics, however, show that the incidence of the most common inherent neuromuscular disease – the Charcot-Marie-Tooth disease – is 1-3 cases per 10 thousand population [2]. According to some studies [3-4], one case of this pathology occurs per 9 thousand population in Japan, in Iceland – per 8.3 thousand, in Italy – per 5.7 thousand, in Spain – per 3.3 thousand. In addition, incidence of the inherent myasthenic syndrome is one case per 200 thousand of 1-year children, incidence of myofibrillar myopathy – one case per 50 thousand of newborns [5].

In the etiopathology of the hypotension occurrence and development, there are factors of damage to the nervous system occurring at any of its levels (brain and spinal cord, peripheral nerves, local neuromuscular connections) caused by dysfunctions of muscle or connective tissues and dependent on pathologies of metabolism or synthesis of individual enzymes [6]. The muscle tone decrease in children can be caused by anomalies of the neuromuscular junction, primary muscle diseases, endocrine pathologies et al. Infant muscle hypotension – congenital hypotension (P94.2 in ICD-10) – is mainly seen in prematurely-born babies (who were born under 37th week of pregnancy) with signs of general underdevelopment of organs and systems diagnosed at birth. Moreover, decrease in muscle tone in mature infants may indicate damage of functional or organic nature to the central nervous system (CNS), muscle or genetic disorders.

According to the literary data [7-8], muscle hypotension syndrome is registered in 12-17% of newborns during the residual period after any diseases. The progressive muscle dystrophy is a group of diseases, the main symptoms of which are weakness, skeletal muscle atrophy, disorders of the support movement function, muscle contractures. Muscle dystrophy progression entails a lag in the child's psychomotor development, which determines the search for methods to start rehabilitation measures adequate to the age, anatomical and physiological characteristics of young children as soon as possible.

Hydrokinesiotherapy is an appropriate rehabilitation measure for children with muscle hypotension syndrome. Exercises in water contribute to an optimal toning and strengthening of weakened muscles and the capsular ligament apparatus, improvement of blood supply and metabolic-nutritional processes, support formation of physiological volume of movement in joints. By decreasing static loads, the body water facilitates the verticalization of children with reduced muscle tone, promotes stimulation, formation and improvement of the supporting function, walking skills, performing manual movements [1, 2, 5]. In connection with the above, the use of hydrokinesiotherapy is relevant in the rehabilitation of children with muscular hypotension syndrome.

The purpose of the study – evaluation of the efficacy of hydrokinesiotherapy in infant children with muscle hypotension.

Methods and organization. Global motor functions of children with muscle hypotension was assessed with the GMFCS scale (Gross Motor Function Classification System), 5 points total [9]. Evaluation of the manual disorders was made with the MACS scale (Manual Ability Classification System for children with Cerebral Palsy), 5 points total [10].

The study was conducted in the "Eveksia" Medical Rehabilitation Center (Moscow), duration – 6 months. With parents' informed consent, the study involved children (n=8) aged 1-2 years with muscle hypotension, who, according to the preliminary medical report, did not have any contraindications to hydrokinesiotherapy.

The results obtained were processed with the mathematical statistics methods with calculation of average values and their standard deviation, the significance of differences was rated with the Wilcoxon T-test ($p \leq 0.05$).

Results and discussion. The 7-week hydrokinesiotherapy course was divided into 3 periods: introductory, main and final. During each one, we solved general and special tasks of health-improving and developmental nature. The tasks included the following: adaptation of a child's body to physical loads and being in an aquatic environment; normalization of the CNS function, normalization of the blood circulation system function; strengthening and increasing muscle tone; improving and stabilizing the background emotions of a child; general strengthening of the body; increasing immunity; coordination development; training and improvement of walking skills and manual functions.

Sessions were held in the presence of parents, in a shallow pool with a water temperature of 32-34 °C that contributes to an increase in muscle tone. The session time varied from 20 minutes at the beginning to 30 minutes at the course's end. The session structure included exercises for the development of all muscle groups performed in horizontal and vertical position of the trunk and head with supporting equipment. These exercises are aimed at the increase of muscle tone, activation of volitional movements of global and regional muscle groups of the higher and lower extremities, formation and improvement of the head and trunk verticalization skills, manual and walking skills. We have used passive, passive-active and active exercises. The directed activation of a child's volitional movements was made with the help of parents, using toys, equipment, word and visual-object accompaniment during each exercise. It supported its comprehensive development, the formation of a positive emotional response to the session, which in turn contributed to an additional increase in the overall tone of children with muscular hypotension syndrome.

The efficacy of hydrotherapy sessions was rated according to dynamics of the GMFCS (result – 1 to 5 points) and MACS (result – 1 to 5 points) indicators (table).

Values of global motor function according to the GMFCS scale improved by 50% and amounted to 1.25 ± 0.04 points ($T_{crit} \leq 0.05$), which corresponds to an approximation to the GMFCS I level, characterized by gait without restrictions. In children under 2 years of age, the formation of independent walking has also began.

Table

Dynamics of global and manual functions of infant children with muscle hypotension syndrome during the hydrokinesiotherapy course

Indicator	M±m		Dynamics		Reliabilty (Tcrit)
	Before the course	After the course	Absolute values (point)	Relative values (%)	
GMFCS, points	2.5±0.05	1.25±0.04	1.25	50	≤0.05
MACS, points	2.0±0.05	1.0±0.03	1.0	50	≤0.05

According to the manual function disorders evaluation in 1-2 years old children with muscle hypotension syndrome, we have noted improvement by 50% of the indicator, average values of which amounted to 1.0±0.03 points (Tcrit≤0.05). Changes were noted in a qualitative improvement of manual function in terms of increased speed and improved handgrip of objects with different diameter.

Conclusion. Significant differences of global and manual function indicators rated with the GMFCS and MACS scales prove the efficacy of using hydrokinesiotherapy in rehabilitation of children with muscle hypotension syndrome.

REFERENCES

1. Khachatryan L.G., Lyalina A.A., Zotova N.S., Kurenkov A.L., Akhadova L.Ya., Bykova O.V. Efficacy of Botulinum toxin type A in children with muscular dystonia. *Clinical Practice in Pediatrics*, 2019, no. 14(3), pp. 58-67. DOI: 10.20953/1817-7646-2019-3-58-67 (in Russ.)
2. Clinical recommendations of the All-Russian Society of Neurologists for the diagnosis and treatment of dystonia, 2014.26 p. (in Russ.)
3. Zalyalova Z.A. Current classifications of dystonies, treatment strategy. *Zhurnal Nevrologii i Psikhiatrii imeni S.S. Korsakova*, 2013, no. 3, pp. 85-89. (in Russ.)
4. Safronenko V.A. Hasanov M.Z. Physiotherapy and physioprophylaxis: methodological guidelines. Rostov-on-Don: Publishing house of the Rostov State Medical University, 2015. 107 p. (in Russ.)
5. Baranov V. A. Swimming, a technique for teaching children from an early age. Moscow, 2000. 69 p. (in Russ.)
6. Barkan A. Child development by months, what your baby should do. Moscow: Astrel', 2009. 254 p. (in Russ.)
7. Barashnev Yu.I. Perinatal neurology. Moscow: Triada-X, 2005. 672 p. (in Russ.)
8. Fenichel G.M. Clinical Pediatric Neurology: a Signs and Symptoms Approach. Translated from English. Moscow: Meditsina, 2004. 640 p. (in Russ.)
9. Zmanovskaya V.A. Popkov D.A. Monitoring program for children with cerebral palsy: methodological guidelines. Tyumen, 2015. 178 p. (in Russ.)
10.Eliasson A.-C., Krumlinde-Sundholm L., Rösblad B., Beckung E., Arner M., Öhrvall A.-M., Rosenbaum P. The Manual Ability Classification System (MACS) for children with Cerebral Palsy: scale development and evidence of validity and reliability. Developmental Medicine & Child Neurology, august 2006, no. 48(7), pp. 549-554. DOI: 10.1017/S0012162206001162.

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PATENT-PROTECTED TECHNOLOGIES FOR THE DIAGNOSIS AND REHABILITATION OF ATHLETES AFTER COVID-19

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Annotation. The research is devoted to the review of technological solutions created at the level of inventions protected by domestic and foreign patents in the field of technology development and scientific substantiation of methods for diagnosing the condition of athletes, their performance and recovery systems, rehabilitation after COVID-19 and other infections. The study made it possible to identify several subgroups of technical solutions and methods related to the prediction of the infection occurrence, the consequences associated with COVID-19 and the restoration of physical performance. In earlier patented methods, immunological tests are used to assess the prognosis of athletes' health, and during the epidemic of a new coronavirus infection, technical methods are proposed that detect the onset of conditions such as COVID-19 or other respiratory infections by monitoring respiratory rate and heart rate with automatic data processing. The section of recovery and rehabilitation of athletes is represented by documents in which several areas can be distinguished: physiotherapy, nutritional support for athletes, resort factors, hypoxic and cold loads, respiratory rehabilitation.
Keywords: patent, athletes, COVID-19, post-covid period, diagnosis, prognosis, physical performance, recovery, rehabilitation.

Introduction. Large-scale COVID-19 vaccination, which began in 2021, and an emergent tendency to decrease the incidence of a new coronavirus infection at the present time, confirmed by official data from the Rospotrebnadzor website [1], made it possible to reduce social restrictions and resume planned events, which is especially important for athletes whose lives are regulated by training and competition periods throughout the year, including those related to staying at the training camps in middle altitude [2-4]. However, the 3-year period of the SARS-CoV-2 pandemic, which covered all categories of the population, affected the established rules for the training of athletes infected with this viru**s.** All diagnostic, therapeutic and rehabilitation measures of people infected with COVID-19 are regulated by international and domestic clinical recommendations. In the field of sports medicine, criteria are additionally used that determine the gradual return of athletes to intense physical and professional activity after COVID-19 and other infections [5-7]. Nevertheless, the issues of the condition of athletes who have returned to training remain insufficiently covered, and an analysis of methodological approaches for their recovery after intensive physical activity exertion is also required. Therefore, it is relevant to evaluate existing materials on methods and technical solutions for medical control of athletes who have resumed training and have a history of infectious diseases, including COVID-19.

The aim of the study is to analyze the technical level and results of patent-protected technologies for diagnosis, physical performance, recovery and rehabilitation of athletes who had COVID-19 and other infections.

Methods and organization. The object of patent research was the problem of approaches to the diagnosis of conditions, recovery and rehabilitation of athletes who had COVID-19 and train in the middle altitude conditions. Individual keywords: diagnosis and prediction of health after COVID-19 and infectious diseases; methods for recovering patients and athletes after inflammatory diseases and coronavirus; respiratory rehabilitation; recovery of athletes by oxygen administration, hypoxia, middle altitude (in Russian and in English).

The patent information search was made in electronic patent databases of the Federal service for intellectual property (Rospatent, www.fips.ru), Yandex Patents, Google patents, search for patents and inventions of the Russian Federation and the USSR (http://www.findpatent.ru/), electronic databases of the European Patent Office (https://worlwide.espacenet.com), the United States Patent and Trademark Office, (https://globaldossier.uspto.gov/). The depth of the search was not limited, all the protection documents found for the search object under study were analyzed.

Results and discussion. The patent search was conducted in accordance with GOST P.15.011-96 "System for the development and production of products. Patent research. The content and procedure". According to the results of the search for methods, medical technologies and technical solutions, created at the level of inventions and protected by domestic and foreign patents, 89 security documents were found that meet the specified criteria for the subject: diagnosis and prognosis of health after COVID-19 and infectious diseases (in Russian) – 18; diagnosis and prognosis of health after COVID-19 and infectious diseases (in English) – 4; rehabilitation, recovery, performance of athletes after COVID-19 (in Russian) – 21; methods for recovering patients and athletes after inflammatory diseases and coronavirus (in English) – 8; respiratory rehabilitation (in Russian) – 11; respiratory rehabilitation (in English) – 2; recovery of athletes by oxygen administration, hypoxia, middle altitude (in Russian) – 13; recovery of athletes by oxygen administration, hypoxia, middle altitude (in English) – 12 (fig. 1).

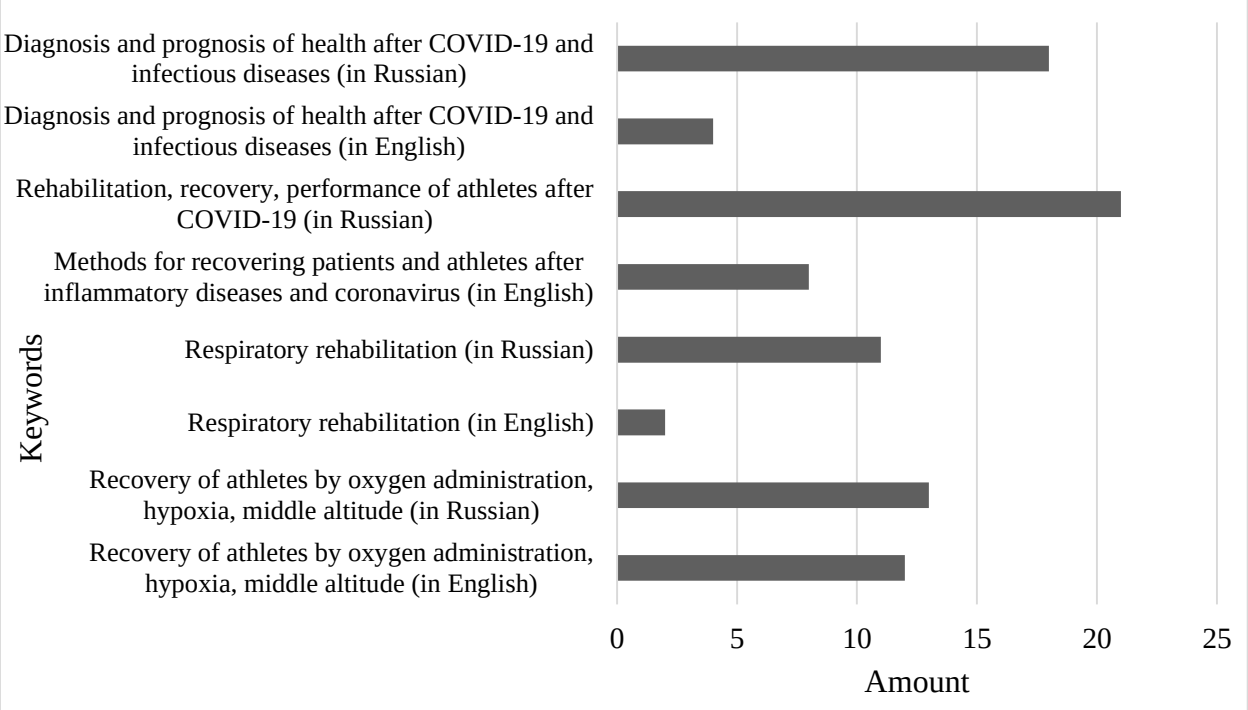

Fig. 1. Distribution of the number of patents by keywords (components) of the search object (keywords are shown in the figure on the Y axis)

The number of patents found for the keywords "rehabilitation", "recovery", "performance of athletes after COVID-19 and other infections", including the subsections "respiratory rehabilitation", "recovery of athletes by oxygen administration, hypoxia, middle altitude" in Russian and English prevails over the number of documents, related to the diagnosis of the condition of athletes. However, the choice of methods and approaches for assessing the condition of athletes who have resumed training,

their reactions to physical activity and performance will depend on the direction of new technologies and methods being developed for the recovery of athletes after COVID-19.

The documents found under the section "diagnosis and prognosis of health after COVID-19 and infectious diseases" (both in Russian and in English) (fig. 2) were distributed as follows, the earliest – 2, which occurred in 1998 and 1999, then – 6, published during the next 20 years and 12 – in the last two years.

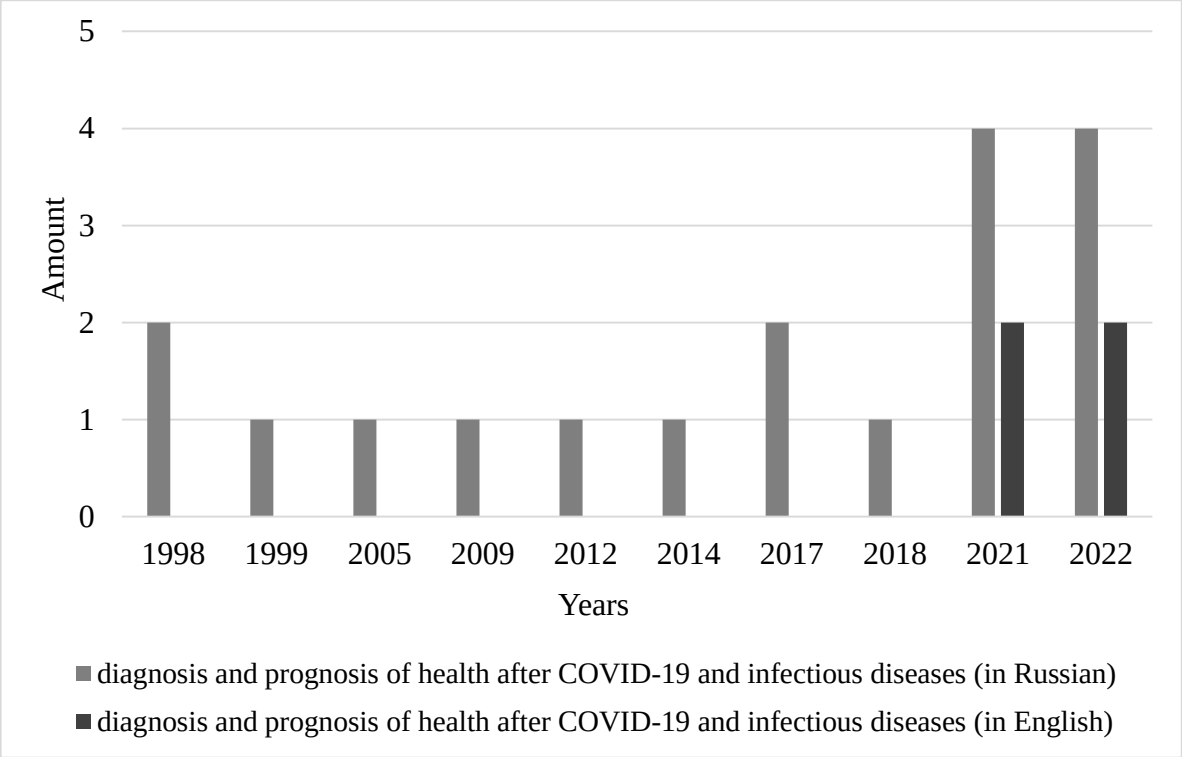

Fig. 2. Distribution of the number of patents by year by keywords "diagnosis and prognosis of health after COVID-19 and infectious diseases" (both in Russian and in English)

The greatest patent activity in this section was noted in 2021 and 2022 (12 patents out of 22). The patent holders are mainly legal entities in the Russian Federation and natural people from the USA and Europe.

An essential point in the diagnosis of athletes' health is the prediction of their condition during training in an epidemiologically unfavorable environment. Therefore, it is possible to distinguish several subgroups of technical solutions and methods related to the prediction of the occurrence of infections, the consequences associated with COVID-19 and the restoration of physical performance. In earlier patented methods, immunological tests are used to assess the prognosis of athletes' health [8], and during the epidemic of a new coronavirus infection, technical methods are proposed to detect the onset of conditions such as COVID-19 or other respiratory infections by monitoring respiratory rate and heart rate with automatic data processing [9]. In addition, there is a genetic screening, that includes the prognosis of the severity of an infectious disease, COVID-19 in particular [10], as well as the the prognosis of the condition of patients who had COVID-19, for example, by the level of volatile metabolites in exhaled air [11], by the control of endothelial markers [12] or indicators of the coagulation system [13].

Another subgroup of patent-protected documents includes load tests that determine the performance of athletes: according to the state of oxygen transport and oxygen-releasing systems with a given cyclic load of gradually increasing intensity in the zone of aerobic-anaerobic transition [14]; the conjugacy of cardiohemodynamics and external respiration with the

level of oxygen consumption is evaluated [15]; the body's resistance to hypoxia and hypercapnia is identified [16]; by comparing the external respiration and the capacity of the work performed during a bycicle ergometer test, the contribution of anaerobic glycolysis to the energy supply of the work is determined based on the assessment of the effectiveness of the athlete's physical performance [17]. The performance of athletes is determined by the metabolic profile after physical activity [18] or when the maximum load is reached on the bicycle ergometer [19]. Analyzing the list of published inventions over the past 5 years, it can be noted that research teams mainly offer automated non-invasive methods for diagnosing the condition of athletes using functional parameters of various organizational systems, or high-tech genetic tests for gene polymorphism are carried out, determining the functioning of systems both responsible for the immunological protection of the body, and related to the success of profiling sports activities.

The largest number of patents were found for the following keywords (both in Russian and in English): “methods for recovering patients and athletes after inflammatory diseases and coronavirus” (fig. 3). The earliest document was issued in 1994, the patent holder for it is the Russian Scientific Center for Rehabilitation and Physical Therapy. 12 documents were found for the period from 1996 to 2017. The greatest patent activity was noted starting from 2018 to the current time (2018 – 3 documents, 2020 – 2, 2021 – 6, 2022 – 5). Of the 29 patent holders, 10 are Russian legal entities, 11 are Russian natural people and 8 are foreign natural people. Among Russian and foreign copyright holders, there has been an increase in patent activity over the past 3 years, which is associated with the need to search for new methods of rehabilitation of various population groups, including athletes, given the appearance of SARS-CoV-2 in December 2019 and the following COVID-19 pandemic.

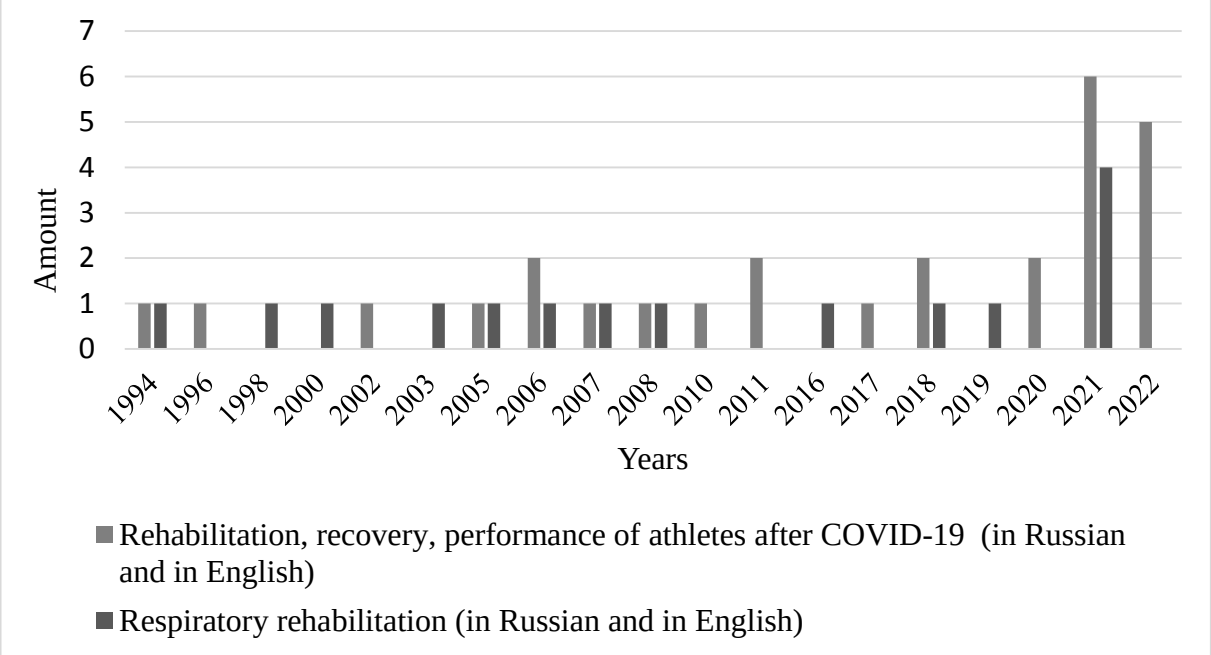

Fig. 3. Distribution of the number of patents by year according to the keywords “rehabilitation, recovery, performance of athletes after COVID-19”, “respiratory rehabilitation” (both in Russian and in English)

According to the search keywords "methods for recovering patients and athletes after inflammatory diseases and coronavirus", 8 documents were found, one each in 2005, 2008, 2017, in 2021 – 3 from the USA, 2018 – 1 international and 2021 – 1 from Great Britain, the patent holders of which are natural people. Separately, a search was made for the rehabilitation

subsection "respiratory rehabilitation" (in Russian and in English), which included 11 documents, 9 of them Russian and 2 foreign (1 from the USA and 1 from China).

This subsection is presented by documents, in which several directions can be identified that offer technical solutions for the recovery and rehabilitation of athletes. These are patents, where various methods of physical therapy are mainly used – 15, compositions for nutritional support of athletes – 6, resort factors – 2 and the effect of hypoxic and cold loads – 4, the latter are designed to increase physical performance and stress resistance. In the section of respiratory rehabilitation, the main ones are the methods with different techniques of respiratory gymnastics performed individually or in combination with kinesiotherapy and physical therapy. Over the past 3 years, the proposed methods of respiratory rehabilitation have been provided by automated control systems, for example, hardware methods of influencing the chest with biological feedback, combined with a certain breathing rhythm, are intended for complex rehabilitation after COVID-19 [20], as well as the intelligent breathing training systems for athletes [21]. Other methods of training and restoring respiration include methods of physical therapy: electric myostimulation of diaphragal respiration [22], a method using electrostimulation of areas of the vagus nerve [23].

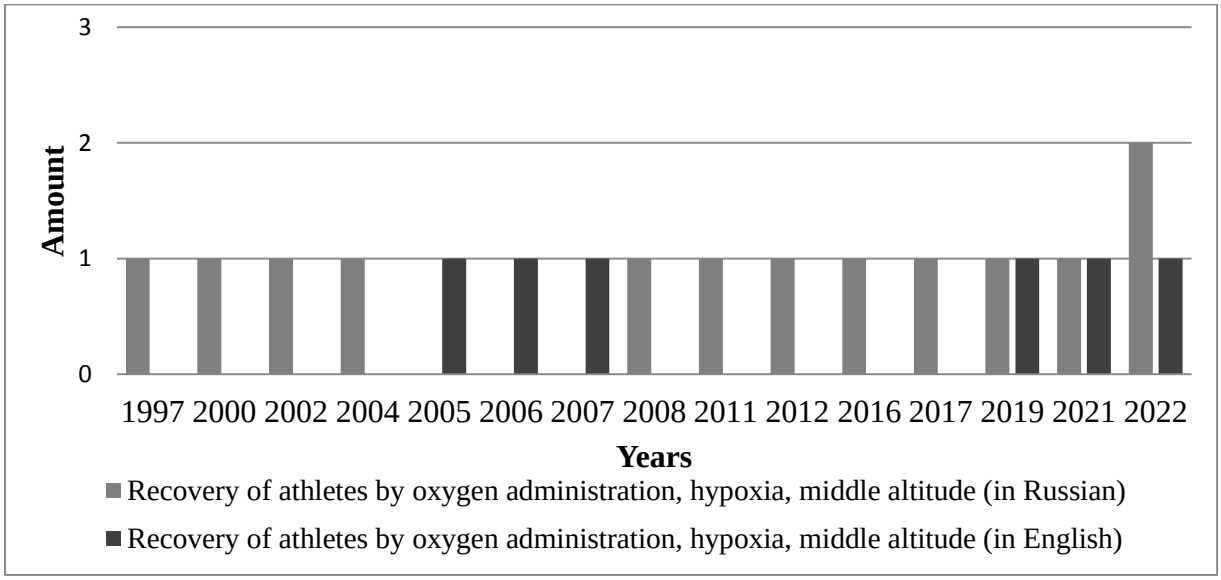

Fig. 4. Distribution of the number of patents by year by keywords "recovery of athletes by oxygen administration in middle altitude" (both in Russian and in English)

Conducting trainings in the middle altitude conditions implies the allocation of a separate section in the patent search, for which the following keywords were used: oxygen administration, hypoxia, middle altitude (both in Russian and in English) (fig. 4). 13 Russian documents were found, 7 of them dated 1997, 2000, 2002, 2004, 2008, 2011, 2012 years, 2 documents – 2016 and 2017, and 4 documents – from 2019 to 2022. Foreign patents are represented by American, European and Chinese natural people in 6 documents dated 2005, 2006, 2007, 2019, 2021 and 2022. The patent-protected documents present methods of oxygen therapy using various compositions of gas mixtures (xenon and oxygen, oxygen and helium, xenon with helium and oxygen), given in the proportions of normoxia or hyperoxia. Oxygen therapy is also carried out by the method of hyperbaric oxygenation. The feature of each of the methods is the control of physiological parameters by which dosing is carried out, duration and effectiveness of oxygen therapy is evaluated. [24]. Separately, it is possible to imagine the restorative effect of oxygen dissolved in water for oral administration [25] or in the form of water procedures [26].

Conclusion. The patent analysis demonstrated that scientists and experts are actively engaged in studying the issues that are the object of our research – the development of technologies for the recovery and rehabilitation of athletes after COVID-19.

There are several subgroups of technical solutions and methods related to the prediction of the occurrence of infections, the consequences associated with COVID-19 and the restoration of physical performance. In earlier patented methods, immunological tests are used to assess the prognosis of athletes' health, and during the outbreak of a new coronavirus infection, technical methods are proposed that reveal the onset of conditions such as COVID-19 or other respiratory infections for monitoring respiratory rate and heart rate with automatic data processing.

The section of recovery and rehabilitation of athletes is represented by documents in which several areas can be distinguished: physiotherapy, nutritional support for athletes, resort factors, hypoxic and cold loads. Respiratory rehabilitation is represented by various techniques of respiratory gymnastics, including in combination with kinesiotherapy and physical therapy.

REFERENCES

1. Report on the current situation in the fight against coronavirus. Communication Center of the Government of the Russian Federation, online statistics of coronavirus in the world according to WHO. Available at: stopcoronovirus.ru (accessed 07.06.2022) (in Russ.)

2. Fonarev D.V., Chernyaev A.A., Fonareva E.A. Analysis of training and competitive loads of marathon runners in the annual cycle during the precompetitive training. *Modern problems of science and education*, 2017, no. 6. Available at: https://science-education.ru/ru/article/view?id=27241 (accessed 07.06.2022) (in Russ.)

3. 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, pp. 4-16 (in Russ.)

4. Koryagina Yu.V., Ter-Akopov G.N., Nopin S.V. Modern technologies and effects of mountain and hypoxic athlete training. *Resort medicine*, 2017, no. 3, pp. 170-174. (in Russ.)

5. Nieß A.M., Bloch V., Friedmann-Bett B., Grim C., Halle M., Hirschmüller A., Kopp C., Meyer T., Niebauer J., Reinsberger C. et al. Position stand: return to sport in the current Coronavirus pandemic (SARS-CoV-2 / COVID-19). *DtschZ Sportmed*, 2020, vol. 71, no. 5, p. E1-E4.

6. Zelenkova I.E., Il'in S.D., Badtieva A.V. Return to training after coronavirus (SARS-CoV-2/COVID-19) infection. *Sports Medicine: Research and Practice*, 2020, vol. 10, no. 3, pp. 60-66. DOI: 10.47529/22232524.2020.3.60. (in Russ.)

7. Halle M., Bloch U., Nieß A.M. Predel H.-G., Reinsberger C., Scharhag J., Steinacker J., Wolfarth B. , Scherr J., Niebauer J. Exercise and sports after COVID-19 – Guidance from a clinical perspective. *Transl Sports Med*, 2021, vol. 4, no. 3, pp. 310-318. DOI: 10.1002/tsm2.247.

8. Dyatlov D.A., Dolgushin I.I., Vinantov V.V., Pushkarev E.D., Rybakov V.V. Method for predicting infectious diseases in athletes during the competition period. Patent for invention RU 2104541 C1, 1998. (in Russ.)

9. Capodilupo E.R., Capodilupo J.V. Wearable infection Monitor. Patent for invention N 2021252768, 2021.

10.Shkurnikov M. Yu., Nersisyan S.A., Tonevitskij A.G. Method for assessing the risk of developing severe COVID-19. Patent for invention RF 2751410 C1, 2021. (in Russ.)

11.Kruchinina M.V., Svetlova I.O. Gromov A.A., Logvinenko I.I., Belkovets A.V., Kashtanova E.V., Shramko V.S., Pushkina O.V. A way to identify the probability of liver fibrosis in patients who had COVID-19. Patent for invention RF 2764050 C1, 2022. (in Russ.)

12.Khavkina D.A., Chukhlyaev P.V., Ruzhentsova T.A. Method for determining the degree of risk of cardiovascular complications in COVID-19. Patent for invention RF 2768575 C1, 2022. (in Russ.)

13.Nekaeva E.S., Bolshakova A.E., Presnyakova M.V., Malysheva E.S., Galova E.A. Method of choosing the tactics of treatment of patients after the coronavirus infection (COVID-19) for the prevention of long-term thrombotic complications. Patent for invention RF 2770356 C1, 2022. (in Russ.)

14.Radchenko A.S. Method for identifying the functional state of the cardiovascular system under physical loads on the interaction of oxygen transport and oxygen-stabilizing systems of the human body. Patent for invention RF 2106108 C1, 1998. (in Russ.)

15.Labutin N.Yu., Gudkov A.B., Kubushka O.N., Neverova O.N. Method for assessing changes in the conjugacy of cardiodynamics and external respiration. Patent for invention RF 2254804 C1, 2005. (in Russ.)
16.Voronin R.M. Method for assessing the body's resistance to hypoxia and hypercapnia by the time of arbitrary breath holding on inspiration and vital capacity. Patent for invention RF 2359610 C1, 2005. (in Russ.)
17.Vashlyaev B.F., Vashlyaeva I.R., Sazonov I.Yu., Doronin A.I., Farafontov M.G., Shachkova T.A., Vishnev V.Yu. Method for identifying (evaluating) physical performance with the dynamics of the ratio of the respiratory minute volume to the power of the age load. Patent for invention RF 2449727 C1, 2012. (in Russ.)
18.Rakhmanov R.S., Belousko N.I., Strakhova L.A., Blinova T.V., Troshin V.V., Petrova I.A., Moiseeva E.V. A method for prenosological disgnosis of athlete's health. Patent for invention RF 2615872 C1, 2014. (in Russ.)
19.Chichkova M.A., Svetlichkina A.A. Method of comprehensive assessment of cardiovascular system indicators in athletes. Patent for invention RF 2652968 C1, 2018. (in Russ.)
20.Gerasimenko M.Yu., Frolov D.V., Kryukov E.V., Kostyuchenko O.M., Gevorgyan A.R. Method of rehabilitation of patients with bronchopulmonary pathology of infectious genesis. Patent for invention RF 2745697 C1, 2021. (in Russ.)
21.Hu B., Zhu X., Ruan D., Cui W. Intelligent breathing training system based on the cooperation of several monitoring units. Patent for invention N 212817922, 2021.
22.Artamonov A.A., Glukhov I.V., Kovalenko S.Yu. Method of electrical myostimulation of diaphragmatic respiration. Patent for invention RF 2760470 C1, 2021. (in Russ.)
23.Parnis S., Maskino S., Buras W., Guzman A. Cranial nerve stimulation for the treatment of pulmonary diseases. Patent for invention N 20070027496, 2007.
24.Boyu V., Xie G.O., Kuo C. Intelligent system of interval hypoxic and hyperoxic training based on algorithms and method, Patent for invention N 2021103856, 2019.
25.Guoin K.J. Compositions of water with a high oxygen content and corresponding methods and systems, Patent for invention N 10626036, 2020.
26.Guoin K.J. High oxygen spa system. Patent for invention N 10875803, 2020.

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METHODOLOGICAL FEATURES OF THE FLEXIBILITY DEVELOPMENT IN 7-8 YEARS OLD RHYTHMIC GYMNASTS

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Annotation. Rhythmic gymnastics is one of the most spectacular and beautiful sports. Flexibility as one of the main physical qualities, which is very important to develop in young gymnasts. The development of flexibility has been studied by many authors, but the use of weights, strength exercises for the development of flexibility with children aged 7-8 years has not been given due attention. The purpose of the study is to experimentally substantiate the effectiveness of using the method of combined development of flexibility and strength, aimed at developing flexibility in children aged 7-8 years engaged in rhythmic gymnastics. The results obtained in the course of the pedagogical experiment on the use of specially designed sets of exercises for the development of flexibility allow us to conclude that the use of the method of combined development of flexibility and strength in the training process, in addition to generally accepted exercises, improves the development of mobility in the joints and flexibility of the spinal column in 7-8 years old rhythmic gymnasts.

Keywords: training process, rhythmic gymnastics, flexibility, strength, the method of combined development of flexibility and strength.

Introduction. Rhythmic gymnastics is a popular sport among girls in Russia and the world. The competitive program includes more complex elements that require good physical and mental training of athletes. Success in rhythmic gymnastics in case of relatively equal level of physical, technical and psychological training of gymnasts will depend mainly on the development of flexibility. Flexibility must be developed continuously, gradually, in accordance with age features, volume and intensity of loads must be appropriately distributed.

Researchers, experts in physical culture and sports – Matveev L.P. [1, P. 273], Platonov B.M., Stepina K.N., Voropaeva V.V., in rhythmic gymnastics – Nazarova O.M., Kryuchek E.S., Medvedeva E.E., Suprun A.A., Viner-Usmanova I.A., Terekhina R.N. [2] confirm significance of developing flexibility as a necessary condition to master the technique of motor movements in different sports. Verkhoshanskij Yu.V. [3] examines some regularities that determine the qualitative development of physical qualities, flexibility in particular, in accordance with age and gender differences.

This topic is deemed relevant, since today sport becomes "younger", there are more requirements to children, and coaches face a difficult task: they have to search for such methods and ways so that students can easily and with positive emotions master new, complex elements in gymnastics, and in order to study them and perform them in the future, it is necessary to develop flexibility. The development of flexibility is comprehensive in the training process of rhythmic gymnastics classes with children aged 7-8 years. Proper, technically correct ("clear") performance of gymnastic elements depends directly on a gymnast's flexibility. It is important to know and apply appropriate methods to develop this quality [4-9].

For this study, we need to examine some features of flexibility. According to the L.P. Matveev's definition [1, P. 273], "flexibility", in terms of physical qualities of a human, is a property of elastic stretchability of bodily structures (mainly muscle and connective), which determines the limits of the amplitude of the body links' movement [1].

There are two types of flexibility – active and passive. Active flexibility is a maximum possible mobility in the joint, which a gymnast can demonstrate independently, using only their strength. Passive flexibility is a highest movement amplitude, which is usually achieved with the external help: with the help of a partner, a projectile or a weight. Active flexibility is more appreciated in gymnastics, since it supports natural freedom of movements and allows mastering correct technique of elements [1]. However, in order to achieve good joint mobility, you have to develop both types of flexibility.

There are also general and specific flexibility. Maximum amplitude in major joints is typical for general flexibility, while specific flexibility is connected to a performance of a certain motor action [1-2].

According to the analysis of special literature and author methods, we can present following features of developing flexibility for rhythmic gymnasts.

Sequence of performing flexibility exercises: 1) exercises for higher limb joints and shoulder girdle, 2) trunk, 3) lower limb joints.

A training session starts with warm-up exercises [4], then, at the end, performance of stretching exercises is obligatory. The load increases gradually by increasing the number of the exercise's repetitions, intensity or number of sets.

There is a great number of hard exercises, which must be studied for a very long time and carefully, for example, turns, cartwheels, bending back from various positions, etc. These complicated exercises require an individual approach to a child. When learning hard elements and exercises, a coach has to show mistakes, ensure safety and help to prevent injuries [2, 4, 9].

Success of developing physical qualities of young gymnasts is defined in many cases by some methodological techniques that are used by a coach during sessions: exercises with unusual names, e.g. "froggy", "little birch", "little boat", "kitty" – the task is perceived by ear very easily and raises the mood [4]. Sessions in form of games: various relay races, outdoor games and tasks cause gymnasts to feel the ease when performing gymnastic elements, and some exercises (combinations) are learned better if they are used in a game [1-2]. The girls are required to show initiative, courage, assertiveness, ability to work in a team – those are the features of the playing activity. It has a very positive impact on the training process.

L.P. Matveev [1] identifies such methods of flexibility development as the method of combined flexibility and strength development, the method of multiple stretching, the method of static stretching (static-active stretching, static-passive stretching, isometric stretching).

The researcher also notes [1, P. 275] that "development of flexibility is tightly connected to the development of muscle strength".

Now, let's look at the method of combined flexibility and strength development. In case of applying this method, one should pay attention to stretching muscles and ligaments, when strength exercises are performed, and consider possible negative effect on flexibility. To avoid this effect, one should use following methodological techniques: consistently use strength and flexibility exercises [1]:

- direct sequence – "strength + flexibility";
- reverse sequence – "flexibility + strength".

The reverse sequence is more convenient if one needs to perform strength exercises with the maximum movement amplitude. In this case, however, one needs to understand that strength capabilities will decrease [1].

In terms of the direct sequence, due to the fact that strength exercises are also present, the joint mobility will decrease approximately by 18-25%. After a set of stretching exercises, flexibility will increase by 55-75%.

With the method of alternate application of strength and flexibility exercises for, i.e. flexibility + strength + flexibility + ... (during one training session), there is a step-shaped change in the mobility of the links of the body that are engaged. Flexibility begins to decrease each time after performing a strength exercise, but immediately after stretching, flexibility increases with a general tendency, and by the end of the training – to 30-35% of the initial level [1].

Therefore, an appropriate result of frequency development will be achieved if the work-up that includes static exercises for stretching is applied.

The purpose of this study was to experimentally substantiate the effectiveness of using the method of combined flexibility and strength development, aimed at developing flexibility in children aged 7-8 years engaged in rhythmic gymnastics.

As a hypothesis, we have suggested that using the method of combined flexibility and strength development during training for 7-8 years old gymnasts would have a positive effect on flexibility development.

Methods and organization. We have used following methods: analysis of scientific and methodological literature, pedagogical experiment, math-and-stats methods, pedagogical observation and control tests.

The study included three stages (from August 2021 to January 2022).

The first stage (August-September 2021) included analysis of specific literature, definition of purpose, tasks, object and subject of research, hypothesis, selection of diagnostic material. We have defined exercises in the rhythmic gymnastics program and constructed a set of exercises for developing flexibility, selected control exercises (tests) for identifying a level of flexibility in students: “Inlocation” (cm), “Mobility in knee joints” (cm), “Cross split” (cm), “Forward lean” (cm), “Bridge” (cm), “Arching” (cm) [2, P. 278]. In the “NEW STARTS” Sports Training Center, located in Petrozavodsk, we have selected two groups 10 people each for the control (CG) and experimental groups (EG) [7].

The second stage (September-December 2021) included first testing on both groups. The sessions were held three times a week for 90 minutes according to the experiment program. Girls from the experimental group performed a set of exercises according to the method of combined flexibility and strength development. Sessions for the control group were based on a traditional method. During the study, based on methodological learning guides by Karpenko L.A. and Lisitskaya T.V. [4-5], we have created sets of exercises for classes with the experimental group. This stage also included repeated (final) testing.

The third stage (January 2022) included data processing, analysis and comparison of the obtained results, conclusions were made based on the results of the study, the effectiveness of using the method of combined flexibility and strength development in rhythmic gymnastics classes for children aged 7-8 years was identified; the results of the study were formalized.

The data were processed using Excel tables. We have also calculated significance of differences between two groups of results with the Student test.

Results and discussion. The training for girls of both groups used exercises for developing joint mobility and spine flexibility. On the same sessions, the EG had special sets of physical exercises.

Table 1 presents sets of exercises according to the method of combined flexibility and strength development, which were used for the EG.

According to the experiment results, the indicators have improved in all exercises (tests). Table 2 presents the indicators of flexibility development in the control (CG) and experimental groups in the course of the experiment.

Table 1

Sets of exercises with weights (for the experimental group

Set of exercises №1 Dynamic exercises for developing flexibility with leg weights (to 100 g)	Set of exercises №2 Exercises on wall bars with special rubber bands on legs	Set of exercises №3 Exercises for developing flexibility in knee and hip joints with leg weights (to 100 g)
1. Demi-pointe walking, with inlocation	1. Face the wall and alternate “releve” and “releve with plie”, repeat 4 times	1. Demi-pointe walking 2. Walking with forward swings

Table 1 (continued)

2. Uphill walk, with inlocation 3. Walking on the outside on the foot 4. Walking on the inside on the foot 5. Walking with forward swings and grasps 6. Walking with swings and grasps to the side 7. Walking with swings and the position of body arched touching the head with one leg 8. Bridge walks 9. The "Devil fish" ("Karakatitsa") run 10. Alternation of stomach rolls and front handsprings with elbows on knees 11. Alternation of cartwheels with hands, with elbows on knees, with chest on knees 12. Demi-pointe walking, with inlocation 13. Uphill walk, with inlocation 14. Splits: on the right, left leg, a cross split on gymnastic benches. Time for performance of the exercises – 3 minute for each split	2. Face the wall: 1 – "releve", 2 – bend knees, 3 – kneel down, heels are raised high, 4-5 – hold the position, press on the half-toes, 6-7 – get up from the floor, 8 – lower the heels down, repeat 4 times. 3. Like the second exercise, but uphill 4. Face the wall, legs apart, right hand on the rail, left raised. 1-3 – lean forward with touching the floor, 4 – rise up and change the hand, 5-8 – repeat with right hand. 5. Stand with one back to the wall, legs together, grab the rail near the hips, press the chest to the knees, repeat 8 times 6. Stand with your back to the wall, legs together, bent at the knees, hands hold the rail with a grip from above, 1-2 – stretch your arms, stand in the bridge, with your hands as if walking down, stretch your knees, 3-4 – hold the bridge, 5-8 – go back up, repeat 6 times 7. Face the wall, sit on the floor, legs apart, put your feet on 1 rail and hold 1 rail with hands, 1-4 – lean forward and touch the floor with your chest, 5-8 – return. Repeat 6 times 8. Stand with left side to the support, bend right leg at the knee and put it on the demi-pointe in front, and shift the center of gravity to the right leg, raise right hand up 1-4 – bend backwards, grasp the leg, 5-6 – keep this position, 7-8 – return to the	3. Walking with backward swings 4. Walking with lunges 5. Walking with bending forward and backwards 6. Bridge walks 7. Walking with toe touch bending 8. Handsprings sideways with elbows 9. Turning on the side in a split 10. Handsprints from the main position, then make a cross split, legs apart (spread straight legs in one line) and then return to the main position 11. Splits: on the right, left leg, a cross split on gymnastic benches. Time for performance of the exercises – 3 minute for each

Table 1 (continued)

	initial position. Repeat 4 times. Repeat with the left leg 9. Swings forward, to the side, backwards and into the position of body arched touching the head with one leg –10 times each with the rubber band 10. Face the wall, the left leg must be placed with the inside side close to the rail, the hands should be held on the wall. 1-4 – the right leg on the rail is stretched, fix in a split position, bend in the back and touch the head of the leg, 5-8 – return to the initial position. Repeat with the left leg. 11. Splits: on the right, left leg, a cross split on gymnastic benches. Time for performance of the exercises – 3 minute for each split	

Table 2

Flexibility indicators in the CG and EG at the beginning and the end of the experiment (M±σ)

Type of control exercises (test)	Control group (n=10)		Experimental group (n=10)	
	beginning of the experiment	end of the experiment	beginning of the experiment	end of the experiment
"Inlocation" (cm)	41.8±3.52	36.1±3.84	39.8±2.51	33.9±2.64
"Knee joint mobility" (cm)	4.6±2.63	5.5±2.54	4.3±2.66	6.4±1.95
"Forward lean" (cm)	8.1±3.41	10.8±2.89	8.0±5.39	12.5±4.08
"Bridge" (cm)	9.5±3.50	7.6±2.31	9.5±3.95	4.2±1.13
"Cross split" (cm)	10.2±6.21	7.8±6.79	10.2±6.62	4.6±4.52
"Arching" (cm)	7.8±5.11	5.3±2.35	8.7±4.94	4.4±0.96

Analysis of the results shows that before the experiments students of both groups had almost the same level of flexibility. The indicators are the same in the "Bridge" and "Cross split" exercises. There is an insignificant lag in the "Knee joint mobility" and "Forward lean" exercises, by 0.3 cm and 0.1 cm respectively. Girls from the EG had better initial indicators in the exercises "Inlocation" – by 1 cm, and "Arching" – by 1.1 cm.

At the end of the experiment, these is a positive dynamic in all indicators in both groups. At the age of 7-8, flexibility actively develops in children. Such exercises as the "Knee joint mobility", "Forward lean", "Cross split" have improved results. It must be kept in mind that at

the end of the experiment two girls from the control group sat in a split, the experimental group had much better results. This element is considered as one of the most complicated. The indicators have significantly increased in exercises that reflect the flexibility of the spine: "Forward lean", "Bridge", "Arching". However, not all students have improved their results in separate exercises. Five girls from the EG and six girls from the CG have demonstrated the same results as those in the initial test.

In total, the results obtained in both groups have significantly improved. In our opinion, the increase rate in the EG is connected to the purposeful impact of physical exercises with weights on flexibility. The suggested sets of exercises, performed according to the method of combined flexibility and strength development, had a positive effect on developing flexibility in 7-8 years old rhythmic gymnasts.

Conclusion. Therefore, considering the results of the conducted study, we would like to note that flexibility is a one of the leading physical qualities for rhythmic gymnasts. It is the foundation for learning the technique of separate and complicated gymnastic elements. The age of 7-8 years is a favorable period for developing flexibility, since it is advisable to include exercises with weights in addition to the generally accepted exercises for developing flexibility. It has been proven experimentally that inclusion of the exercises that are based on the method of combined strength and flexibility development contributes to an increase in the movement amplitude, joint mobility and comprehensive development of flexibility.

REFERENCES

1. Matveev L.P. Theory and methods of physical culture. 3rd ed., revised. and add. Moscow: Fizicheskaya Kul'tura i Sport: SportAcademPress, 2008. 542 p. Available at: https://clck.ru/sKksa (accessed 19.07.2022) (in Russ.)
2. Viner-Usmanova I.A., Kryuchek E.S., Medvedeva E.N. Rhythmic gymnastics: history, state and development prospects: a learning guide. Moscow: Chelovek, 2014. 200 p. Available at: https://clck.ru/sKjkN (accessed: 19.07.2022) (in Russ.)
3. Verkhoshanskij Yu.V. Fundamentals of special physical training of athletes. Sovetskij Sport, 2021. 332 p. Available at: https://clck.ru/sKjmM (accessed: 19.07.2022) (in Russ.)
4. Karpenko L.A. Rhythmic gymnastics. Moscow: 2003. 381 p. (in Russ.)
5. Lisitskaya T.S. Choreography in gymnastics. Moscow: Fizicheskaya Kul'tura i Sport, 2000. 133 p. (in Russ.)
6. Control over the development of flexibility in physical education. Available at: https://clck.ru/sKsjo (accessed 20.04.2022) (in Russ.)
7. CSP "NEW STARS" Rhythmic gymnastics. Available at: https://vk.com/newstars_gymnastics (accessed 19.09.2021) (in Russ.)
8. Zheleznyak Yu.D., Petrov P.K. Fundamentals of scientific and methodological activities in physical culture and sports. Available at: https://clck.ru/sKqjD (accessed 20.04.2022). (in Russ.)
9. Ivanov V.D., Bardina M.Yu. Effectiveness of statodynamic gymnastic exercises program in the development of flexibility in elementary school students. *Physical Culture. Sport. Tourism. Motor Recreation*, 2021, no. 6(3), pp. 25-34. Available at https://fkis74.ru/index.php/fkstdr/article/view/626. (accessed 26.09.2022**).** (in Russ.)

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