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BIOIMPEDANCE ANALYSIS OF THE BODY COMPOSITION OF FEMALE WRESTLERS AT TRAINING CAMPS IN THE MIDDLE ALTITUDE CONDITIONS

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Annotation. The aim of the work was to assess the dynamics of body composition indices of female wrestlers at training camps in the middle altitude conditions taking into account conditional weight groups. We examined the representatives of the Russian freestyle wrestling youth team during training camps in the middle altitude conditions of Kislovodsk. The age was 18.5±1.1 years, sports qualification – Candidate for Master of Sports and Master of Sports. Female athletes were divided into three conditional weight groups: light – 50-57 kg, medium – 59-65 kg and heavy – 68-76 kg. The results of the body composition study revealed significant differences in active cell mass among the female athletes in the heavy weight group. A comparative assessment of the body composition indices in terms of conditional weight groups has shown the lack of geometric similarity of the constitution of female athletes, which allows the coach to select the ways and methods of sports training, taking into account the weight categories.

Keywords: women's wrestling, female wrestlers, athletes, body composition, bioimpedance analysis.

Introduction. The competitive success of athletes is largely determined by the structure of body mass components [1]. There are no uniform standards of body composition in athletes, "they vary depending on the sport, specific specialization and level of fitness. However, it is known that reducing the proportion of fat mass to 5-6%, and musculoskeletal mass to 46% in the competitive period is undesirable and may indicate overfatigue in athletes" [2]. Experts have previously studied the relationship between athletic success and the features of body type of female wrestlers [3-5]. However, a content search of scientific publications devoted to the dynamics of changes in body constitution parameters during training camps in middle altitude conditions revealed an insufficient number studies.

Evaluation of body composition of female athletes at training camps allows the coach to quickly adjust the individual training taking into account the weight categories, and to plan the correction of body composition in a targeted manner (muscle gain and/or loss of fat mass), which can help to improve athletes' performance. This information will allow us to create an understanding of the variability of body composition values of female wrestlers with regard to weight categories during the training period, which can be used in practice to assess the current state of female athletes.

Aim of the study: to assess the dynamics of body composition indices of female wrestlers at training camps in middle altitude conditions taking into account conditional weight groups.

Methods and organization. Female wrestlers, representatives of the Russian youth team, were examined during the training camps in the middle altitude conditions of Kislovodsk. The average age was 18.5±1.1 years, sports qualification – Candidate for Master of Sports (85%) and Master of Sports (15%). Female athletes were divided into three conditional weight groups: light – 50-57 kg (n=7), medium – 59-65 kg (n=7) and heavy – 68-76 kg (n=9). Materials were collected in compliance with Bioethics rules and were depersonalized.

We measured body length (BL) and mass (BM). Bioimpedance analysis of body composition was made with the AVS-01 “Medass” analyser (“Medass” Scientific and Technical Center, Russia) using a standard wrist and ankle electrodes scheme in a supine position [6]. Following body composition indices were analyzed: body mass index (BMI, kg/m^2), fat (FM), lean (LM), active cell (ACM), musculoskeletal (MSM) mass in absolute and relative values, total body water (TBW, kg), extracellular (ECF, kg) and cellular fluid (CF, kg), basal metabolic rate (BMR, calories/day), and specific metabolic rate (SM, calories/day/m^2).

All participants gave informed consent to participate in the study in accordance with the Declaration of Helsinki of the World Medical Association, as well as permission to process personal data. For underage participants, consent was given by their legal representatives.

The Statistica software (version 12, StatSoft Inc., USA) was used for data processing. The hypothesis of normal distribution was tested with the Shapiro-Wilk test. To check the significance of differences in the values for the 2 dependent samples we used the nonparametric Wilcoxon signed-rank test and Mann-Whitney U test for unrelated groups, differences were considered statistically significant if $p \le 0.05$.

Results and discussion. The table shows the dynamics of average values of body composition indices of female wrestlers, taking into account conditional weight groups during the training camps in the middle altitude conditions (table).

Table

Dynamics of body composition indicators of female wrestlers during the training camps in the middle altitude conditions, taking into account the conditional weight groups

Indices	Conditional weight groups											
	Light (n=7)				Medium (n=7)				Heavy (n=9)			
	beginning		end		beginning		end		beginning		end	
	m	s	m	s	m	s	m	s	m	s	m	s
BL, cm	159.6^3	5.3	159.6	5.3	163.4	4.2	163.4	4.2	167.6	4.6	167.6	4.6
BM, kg	54.7^{2,3}	2.9	54.9	2.9	62.7^3	2.8	62.4	2.6	71.3	3.0	71.4	3.5
BMI, kg/^{m}	21.5^{2,3}	1.3	21.6	1.4	23.5^3	1.2	23.4	1.2	25.5	2.1	25.5	2.2
FM, kg	10.5^{2,3}	1.7	10.8	1.9	16.4^3	1.2	16.5	1.7	20.1	3.5	20.6	3.7
FM, %	19.2^{2,3}	2.7	19.7	3.0	26.2	2.0	26.5	2.4	28.1	4.1	28.7	3.9
LM, kg	44.2^3	2.2	44.1	2.6	46.3^3	2.9	45.9	2.4	51.3	2.5	50.8	2.1
ACM, kg	27.6^3	1.9	27.5	1.6	28.6^3	1.6	28.0	1.3	31.7	1.7	32.1	1.9
ACM %	62.6	2.9	62.4	1.4	61.9	1.6	61.0	1.8	**61.9***	1.7	**63.2***	2.2
MSM, kg	22.4^3	1.7	22.3	1.7	23.5^3	2.1	23.2	1.7	26.2	2.1	25.9	1.8
MSM, % of LM	50.6	1.9	50.5	1.5	50.6	1.5	50.5	1.4	51.1	1.8	50.8	1.7
TBW, kg	32.3^3	1.6	32.3	1.9	33.9^3	2.1	33.6	1.7	37.5	1.8	37.2	1.6
ECF, kg	13.5^3	0.7	13.4	0.8	14.3^3	1.0	14.3	0.8	16.0	0.9	15.7	0.8
CF, kg	18.9^3	0,9	18.9	1.1	19.6^3	1.2	19.4	0.9	21.6	1.0	21.5	0.9
BMR, calories/day	1489^3	59	1485	50	1520^3	51	1500	42	1618	52	1631	59
SMR, calories/day/m^2	966^3	49	963	40	915	21	905	31	905	32	911	34

Note: m – mean arithmetic; s – standard deviation; BL – body length; BM – body mass; BMI – body mass index; FM – fat mass; LM – lean mass; ACM – active cell mass; MSM – musculoskeletal mass; TBW – total body water; ECF – extracellular fluid; CF – cellular fluid; BMR – basal metabolic rate; SMR – specific metabolic rate; * – significant statistical differences in dynamics; ^{2} – significant statistical differences from the average weight group; ^{3} – significant statistical differences from the heavy weight group ($p \le 0.05$); beginning\end – beginning and end of the training camps

Analysis of the body composition values of female athletes at the beginning and at the end of the training camps, taking into account conditional weight groups, found statistically significant differences (p≤0.03) only in the index of active cell mass in % among representatives of the heavy weight group. Thus, the ACM% values changed upward by 1.02 times by the end of the camps. All the other indices of body composition showed no significant differences in all weight groups (table). Dynamics of the indices at the beginning and at the end of the training camps had insignificant changes up and down within the measurement error limits of the AVS-01 "Medass" body composition analyzer [6].

Comparison of estimates of the body composition indices with regard to conditional weight groups demonstrated that athletes of the light weight group have significant differences from the average group in terms of body mass (p≤0.002), BMI (p≤0.03) and fat mass (p≤0.002) in absolute and relative values and from the heavy group – for all indices except active cell mass in % and musculoskeletal mass in % of lean mass. Women in the medium weight group had significant differences from the heavier group in all absolute values of body composition, but no significant differences were found in the relative values of fat, active cell mass, musculoskeletal mass in % of lean mass and specific metabolic rate (table).

In female athletes with increasing weight category, all the body composition indices increase in absolute values, and the relative fat mass characterizes the lack of geometric similarity of body constitution. That is, the geometric similarity of the constitution manifested in the body composition indices of female athletes implies the similarity of their relative values regardless of weight category [1, 7]. The relative values of active cell mass in % and musculoskeletal mass in % of lean mass and specific metabolic rate regardless of weight group have similar values, indicating that female wrestlers are athletically fit [3].

Conclusion. The analysis of the dynamics in the body composition indices of female wrestlers revealed statistically significant differences only in ACM% in the heavy weight group. For a better assessment of the training camps' efficiency it is necessary to conduct functional tests in addition to the body composition evaluation. Based on the results of comprehensive studies, it is possible to carry out targeted correction of body composition and, in general, to construct and monitor the training process of female wrestlers.

A comparative assessment of the body composition indices in terms of conditional weight groups has shown that there is no geometric similarity in the constitution of female athletes, which allows the coach to choose the ways and methods of sports training, taking into account the weight categories.

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RISK FACTORS LEADING TO KNEE JOINT INJURIES IN BASKETBALL: A LITERATURE REVIEW

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Annotation. The article presents an overview of Russian and foreign studies that consider risk factors for injuries of the ligament system of the knee joint in basketball players. The results of a theoretical analysis of literary sources showed that anterior cruciate ligament rupture is the most common knee injury in an athlete, regardless of age or sports specialization. A high percentage of traumatization of the ligaments in the knee joint is explained by the specifics of activity in basketball: the movements typical of this sport, the pace of their implementation, the emotional load and involvement of the player during the training and competitive processes, the anatomical and physiological features of basketball players that are taken into account in sports selection. The data obtained made it possible to identify the main risk factors for traumatization of the ligament system of the knee joint in basketball players and determine the main directions for the prevention and rehabilitation of this type of injury.

Keywords: ligament system, knee joint, injury, basketball players, risk factors, prevention, rehabilitation.

Introduction. Basketball has long been one of the most popular team sports in Russia, which is developing rapidly every year. The Russian Men's Basketball Championship has been held since 1992 [1-2]. The structure of Russian men's basketball includes the following professional divisions: VTB United League – 12 clubs (8 Russian); Russian Basketball Super League 1 – 16 clubs; Russian Basketball Super League 2 – 12 clubs.

According to regulations, every club officially registered with the Russian Basketball Federation (RFB) is required to have a youth squad taking part in the Children's and Youth Basketball League (CYBL) championship, which determines the increasing number of young people engaged in professional basketball [1-3]. The transition from youth basketball to professional level, associated with increased physical and emotional stress of the training and competition process and a number of other factors, is often accompanied by an increase in injuries, Injuries are also a common cause of interruptions in sporting activities [4-6].

According to experts, approximately 17% of athletes participating in the training and competition process injure the knee joint during the season [6]. Taking into account the complexity and long-term rehabilitation after knee ligament system injuries, when restoring the athletic performance of basketball players, it is necessary to consider the specifics of these injuries [6-7], as well as risk factors for the prevention of re-traumatization of athletes.

The purpose of the study: a theoretical analysis of risk factors leading to ligament injuries of the knee joints in basketball.

Methods and organization. We used the method of content analysis of research papers of Russian and foreign authors, presented in peer-reviewed scientific journals, Russian and foreign databases. A total of 30 sources were analyzed and 26 were selected.

Results and discussion. According to data on injury rate in different sports, basketball is one of the ten most injury-prone team contact sports (fig. 1). Injury rate in this sport is very high and varied due to the specific movements of athletes during training and matches. The ankle, knee, wrist and shoulder joints are more susceptible to injuries, and the lumbar spine is often affected. The relevance of the research results is due to the high frequency of injuries of the knee joint, both in young and professional basketball players. Young players are at risk, especially during the period of transition to a professional team, when the load on the musculoskeletal system increases, often accompanied with little to no adaptation and lack of injury prevention measures [6-7].

Specificity of motor actions in basketball consists of realizing strong angular accelerations with a change in movement, tempo, combined with constant various jumps occurring in constant contact with the opponent, creating an extreme load on the knee joint and making it vulnerable to damage, macro and micro injuries [8].

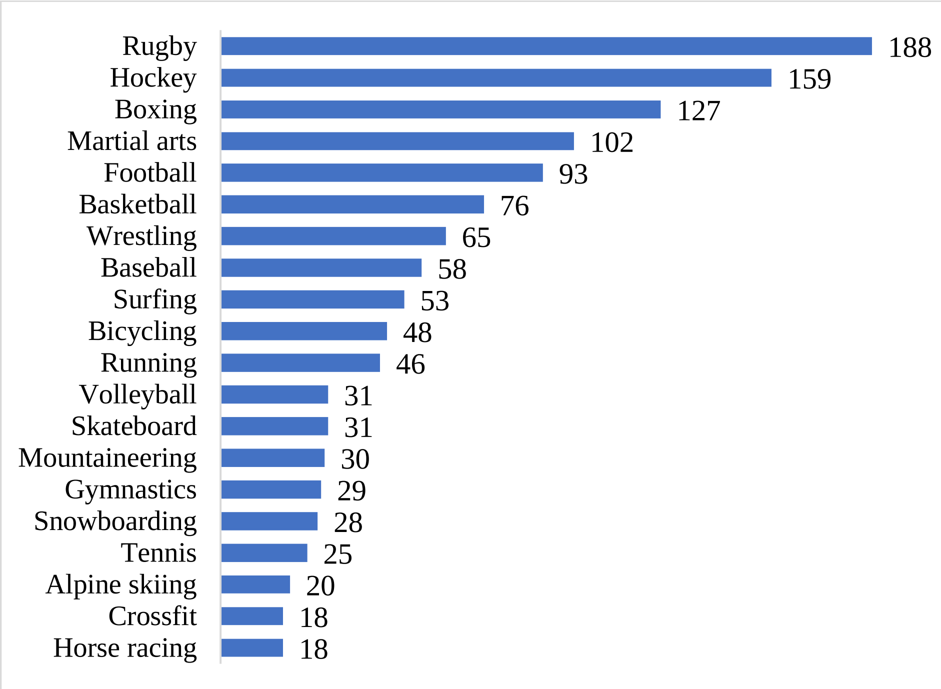

Fig. 1. Injury rate for every 1000 athletes in different sports (American Sports Data Press Release, 2003)

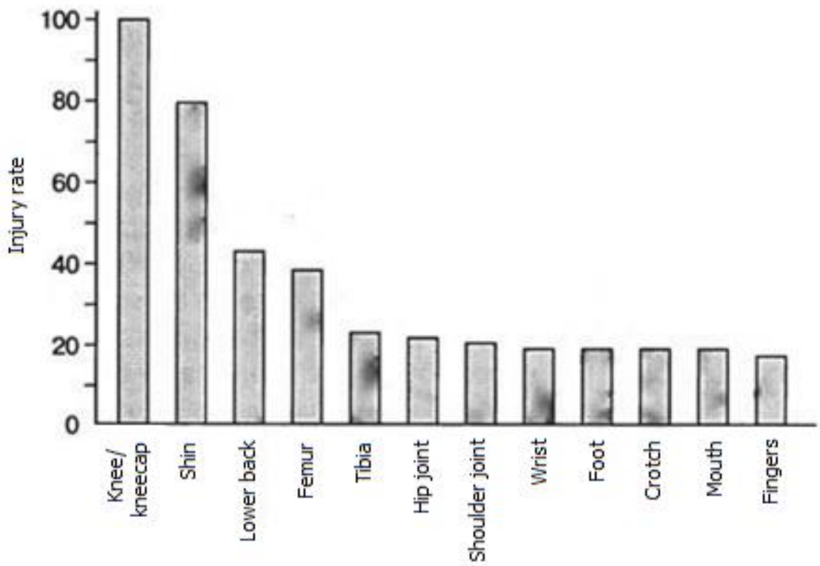

Fig. 2. Location of injuries typical for basketball [12]

Detailed statistics on basketball injuries (fig. 2) show the following distribution of joint injuries of the total number: the ankle joint – 30% and the knee joint – 18%. Of the 80% of injuries, 28% are ligamentous injuries, 21% are muscle injuries, 18% are bruises and 12% are tendinopathy [9-11].

Although the ankle joint accounts for the largest percentage of injuries in basketball, knee injuries are considered to be much more serious and complicated due to the length of recovery time. The recovery time from an ankle injury is easier and quicker, with an average of 4-8 weeks. The rehabilitation period for injuries to the knee joint can last up to a year. In some cases, after a serious knee injury, up to 8% of all players end their career [13-15].

The recovery time after a ligament injury in the knee joint is mostly defined by anatomic and physiological features.

The stability of the knee joint is due to the ligaments around it that hold the bones in position as they bend and straighten the knee. Compared to the hip joint, which is quite stable, the knee joint lacks the "depth" to maintain joint congruence during maximum amplitude movements and the ligament system of the knee joint is highly stressed to maintain it [16-19].

The collateral ligaments along the lateral surfaces of the knee joint (tibia and fibula) are elastically stretched when the knee joint is extended and loosen when it is flexed.

Tears of the tibial collateral ligaments and anterior cruciate ligaments can be caused by blows to the side of the knee [19-20], by maximal extension of the knee joint, by sudden thrusts when performing exercises with a overextended knee, such as deadlifts, forward bending with the barbell on the back, etc. Besides, anterior cruciate ligament is often torn as a result of the femur sliding backwards in relation to the tibia, which may be caused by running backwards (back to front) or kicking the hip. It is also injured when one player falls on other player lying and facing the ground, causing involuntary overextension of the knee joint.

One of the most common reasons for an early end of a basketball player's career is the knee joint's injury, mostly the anterior cruciate ligament ruptures with instability of the knee joint [22-24]

Two groups of risk factors are attributed with the injury: disruption of the ligament system of the knee joint and overexposure to the traumatic factor.

The main factors for the protection and prevention of knee injuries in athletes include: sufficient elasticity of the ligaments and joint tissues; adequate blood supply to the ligaments and joint tissues; the degree of development of the joint-strengthening muscles. Effective adaptation of the knee joint to physical loads is important for athletes.

A variety of damaging factors contribute to injury to the knee joint. In athletes participating in team sports, the following are distinguished: impaired biomechanics of the joint's movement; reduced level of the joint's fitness to perform a given amount of physical loads; mechanical impact made on the joint; congenital features of the joint's structure; effect of congenital connective tissue diseases (e.g. connective tissue dysplasia). These factors are not a reason for excluding a child from the sport. However, it will significantly increase the risk of musculoskeletal injuries. This issue is particularly relevant for young basketball players, since the selection criteria is a tall and asthenic body type, typical of athletes with connective tissue dysplasia [25-26].

Conclusion. High rate of the ligament injury in the knee joint in basketball is due to specificity of motor actions: fast and sudden movements on the court, significant number of contact movements with other players and different jumps (vertical, horizontal). During sports selection, morphological, anatomical and physiological features are taken into account as risk factors for injuries in basketball: tall stature, asthenic body type, often caused by dysplasia, which further increases the risk of musculoskeletal injuries. At the same time, the possibility of injury is greatly increased by high physical and emotional stress when levels of competition are changed, in the team due to the increased responsibility, tempo and complexity of the training process.

The literature analysis has formed a theoretical foundation of the role and significance of paying attention to main risks factors of the knee joint in basketball. In future, it would serve as a basis for developing methodological guidelines, comprehensive prevention and recovery measures for treating the knee joint's injury in basketball players.

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INFLUENCE MECHANISMS OF TRAINING WITH BLOOD FLOW RESTRICTION ON HYPERTROPHY OF WORKING MUSCLES: A SCOPING REVIEW

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Annotation. Although the hypertrophic effects of resistance training and blood flow restriction have been demonstrated by numerous studies, the underlying mechanisms responsible for these effects have not been elucidated. Objective: to conduct a scoping review of the available literature to analyze and summarize the mechanisms underlying muscle hypertrophy during training with blood flow restriction. The systematic search of publications in PubMed ended on 05.05.2023. This study was conducted in accordance with the statement of Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR). A total of 128 references were identified. As a result of selection, 6 reviews were analyzed and included in the study. Systematizing the data, we came to the conclusion that the increased level of metabolic stress is the main driving mechanism of muscle growth during blood flow restriction training.

Keywords: occlusion training, blood flow restriction training, muscle hypertrophy.

Introduction. Blood flow restriction (BFR) training was developed in Japan in the late 70s, where it was called the KAATSU training [1]. Although long-term benefits of the BFR exercises, including increase of muscle hypertrophy, strength and improved aerobic and anaerobic working capacity are clearly described in scientific literature, a discussion on underlying mechanisms responsible for adaptation is still going on.

In terms of muscle hypertrophy, the occurring hypertrophic effects of strength training with BFR are due to an increased level of metabolic stress (i.e. metabolite accumulation as a response to ischemic/hypoxic environment) [2], which in theory causes muscle growth, influencing other factors, such as HTMU's (high threshold motor units) recruitment [3-4], increased level of systemic hormones [5-6], cell edema [7] and increased production of ROS (reactive oxygen species) [8].

Since many researchers explained possible mechanisms underlying muscle growth after BFR training in different ways, and the data cannot be merged into either a systematic or umbrella review, we have set an objective of our study.

The objective: to conduct a scoping review of the available literature to analyze and summarize the mechanisms underlying muscle hypertrophy during training with blood flow restriction.

Methods and organization. The study took place in the Department of Sports Medicine (Russian State University of Physical Education, Sport, Youth and Tourism, Moscow). It was conducted in accordance with PRISMA-ScR requirements (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) [9]. The study's protocol was made before the search and did not change either during or after the research. Prior to the search, we have determined that the scoping review would only include reviews of the subject field that examine mechanisms underlying muscle hypertrophy during BFR training.

The literature search was made in the PubMed database. The following keywords are: "blood flow restriction training AND (muscle mass OR muscle strength OR skeletal muscle hypertrophy OR muscle protein synthesis OR muscle growth)"; "KAATSU AND (muscle mass OR muscle strength OR skeletal muscle hypertrophy OR muscle protein synthesis OR muscle growth)"; "occlusion training AND (muscle mass OR muscle strength OR skeletal muscle hypertrophy OR muscle protein synthesis OR muscle growth)". No time frames were set, but the last search was dated 05.05.2023.

In order for the research to be included, it must correspond with the inclusion criteria based on the PICOS system [10]. P (Population) – active and non-active participants, athletes, elite athletes (men and women) above 18; I (Intervention) – BFR training (strength training, training with weights); C (Comparison) – comparison with the control group or when the intervention starts; O (Outcomes) – mechanisms of BFR training's influence on hypertrophy of working muscles were studied; S (Study) – reviews of the subject field, systematic reviews and meta-analyses, in which the aforementioned mechanisms were studied.

Initially, two authors of the review (F.A. Koloskov, A.B. Miroshnikov) simultaneously and independently checked titles of the articles, their abstracts and, when needed, full texts in accordance with the criteria. Duplicates and articles that did not correspond were excluded. There was no language barrier. Since all the data were presented in a descriptive way, there was no statistical analysis.

Results and discussion. A total of 128 mentions were found. Then we exported the needed data; all duplicates and irrelevant articles were deleted manually. The figure below shows the PRISMA scheme describing the selection process. Only 6 reviews corresponded with the criteria [11-16].

Hwang et al [11] identify following mechanisms contributing to muscle growth during BFR training:

1) metabolic accumulations, which can stimulate anabolic growth factors;

2) increased muscle protein synthesis through specific intracellular signaling pathways;

3) muscle injury;

4) mechanotransduction;

5) HTMU's recruitment patterns;

6) increased activity of satellite cells;

7) ROS production;

6) increased anabolic hormones' (testosterone, growth hormone, insulin-like growth factor 1 – IGF1)) levels.

Moreover, the authors assume that mechanical load and metabolic stress can act synergistically to create suitable conditions for the greatest hypertrophic potential.

Loenneke et al [12] reveal 4 phases, in which BFR training is applied:

1) bed rest;

2) low-intensity walking;

3) low-intensity training with weights;

4) low-intensity exercises combined with high-intensity strength training.

During the first phase, the predominant mechanisms participating in support of skeletal muscle mass with BFR activate muscle cell edema and enhancement of signal transfer through β2-adrenergic receptors when there is no physical load. The predominant mechanisms that are identified during the 2nd phase are rapid increase in volume of muscle cells and increased cardiac output or blood volume. The predominant mechanisms in the following phases are:

1) HTMU's recruitment;

2) additional secretion of anabolic hormones.

Pearson et al [13] divide mechanisms, with the help of which BFR training stimulates muscle growth, into primary and secondary ones.

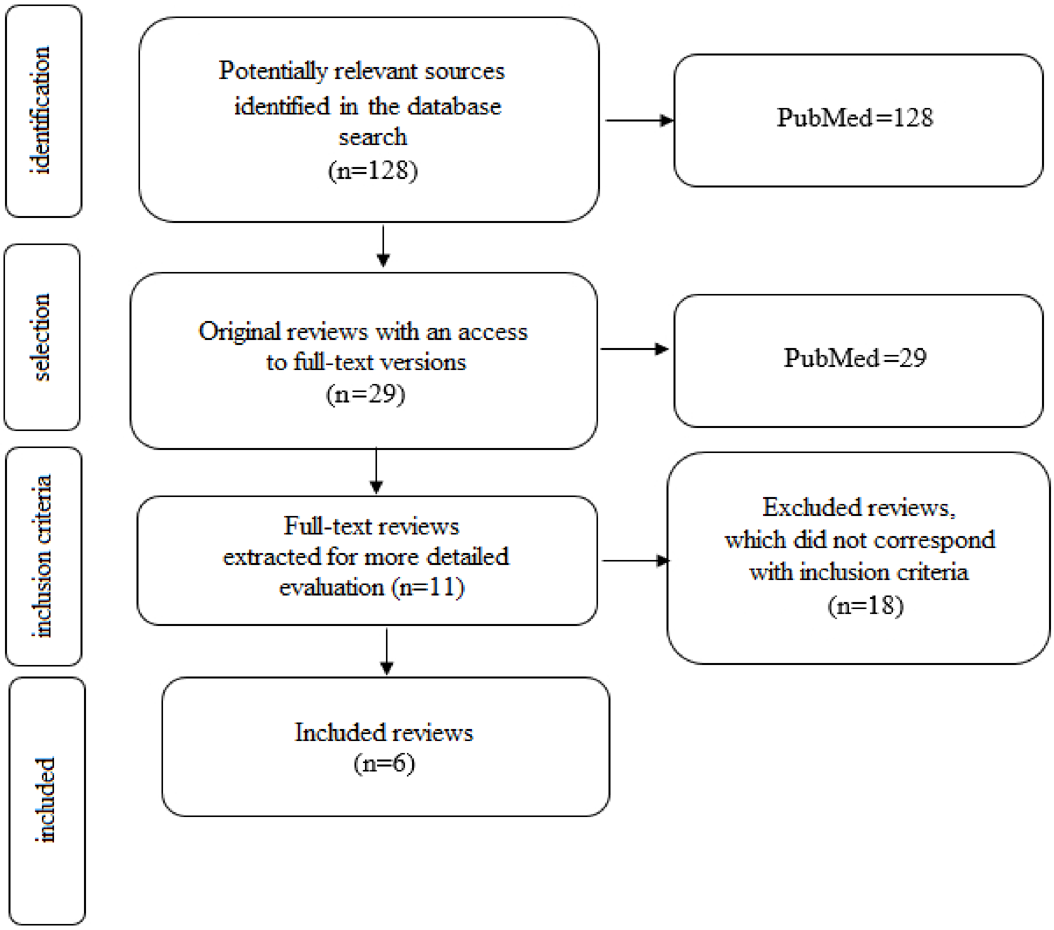

Fig. The PRISMA scheme

The main (primary) mechanisms are mechanical load and metabolic stress. The authors assume that the primary factors will effect a number of connected secondary mechanisms of the muscle growth induction, such as mechanotransduction, muscle injury caused by physical exercises, increased secretion of systemic and localized hormones, cell edema, increased ROS and nitrogen oxide production (which may also lead to production of heat shock proteins), as well as HTMU's recruitment. The authors also note potential autocrine (i.e. protein synthesis stimulation due to increase of anabolic and/or decrease of catabolic signaling pathways) and paracrine (i.e. increased activation, proliferation and fusion of satellite cells) mechanisms participating in hypertrophy caused by BFR training with weights.

Yuan et al [14] identify the following main mechanisms, with which BFT training stimulates skeletal muscle growth:

1) HTMU's recruitment;
2) activation of the protein synthesis signaling pathway;
3) metabolic stress;
4) anabolic hormones' secretion;
5) cell edema.

Freitas and his colleagues [15] name the following mechanisms:

1) metabolic stress;
2) HTMU's recruitment;
3) anabolic hormone secretion;
4) increased protein synthesis due to changes in biomolecular pathways, including the mammalian target of rapamycin complex 1 (mTORC1) and inhibition of such atrogenes as the Muscle RING Finger1 (MuRF1) and atrogin-1, as well as myostatin pathway inhibition.

Vopat et al claim that the suggested mechanisms are based on two main factors: metabolic and mechanical stress [16].

These factors act synergetistically, signaling about a number of secondary mechanisms including tissue hypoxia, metabolite accumulation and cell edema. At the end, it contributes to autocrine and paracrine signaling pathways leading to protein synthesis, HTMU's recruitment, local and systemic synthesis of anabolic hormones and myogenic stem cells' stimulation.

When integrating information about all mechanisms (table) mentioned in the works and included into the scoping review, we can conclude the following: 83.3% – metabolic stress, 33.3% – mechanical load, 33.3% – mechanotransduction, 33.3% – muscle injury caused by training, 50% – increase of the protein synthesis due to mTORC1 changes, 100% – HTMU's recruitment, 100% – increased anabolic hormones' levels, 33.3% – ROS production, 66.7% – muscle cell edema, 50% – increased satellite cell activity and 16.7% – myostatin pathway inhibition.

Table

Integration of information about all mechanisms, with which blood restriction training stimulate skeletal muscle growth

Mechanism	Reference
metabolic stress	[11,13,14,15,16]
mechanical load	[11,13]
mechanotransduction	[11,13]
muscle injury caused by training	[11,13]
increase of the protein synthesis due to mTORC1 changes	[11,13,14]
HTMU's recruitment	[11,12,13,14,15,16]
increased anabolic hormones' levels	[11,12,13,14,15,16]
ROS production	[11,13]
muscle cell edema	[12,13,14,16]
increased satellite cell activity	[11,13,16]
myostatin pathway inhibition	[15]

Note: HTMU's – high threshold motor units; ROS – reactive oxygen speciesa; mTORC1 – mammalian target of rapamycin complex 1

Considering the fact that the increased systemic hormones' level will not probably effect muscle growth [17-18], mechanical load and metabolic stress are apparently the main mechanisms of muscle growth. Moreover, metabolic accumulations that occur as a result of metabolic stress may provide the additional mechanism of HTMU's recruitment [19], which contributes to a creation of mechanical tension in these fibers. Eventually, almost the whole muscle growth process may be due to mechanical stress with slight influence of metabolic stress and possibly even harmful effect of muscle injury [20].

Conclusion. Although exercises with weights and BFR are indeed popular and effective, the mechanisms underlying hypertrophic adaptation have not yet been identified. While creating a data system, we have concluded that an increased metabolic stress level is the main stimulus in this process, which, as supposed, activates the other mechanisms (e.g. systemic hormone production, increased HRMU's recruitment), all of which are believed to mediate muscle growth due to autocrine and/or paracrine action. However, the extent to which these mechanisms are activated under metabolic stress is unknown. Additional randomized controlled trials are required to determine the degree and contribution of metabolic stress to the creation of mechanical stress in high threshold motor units.

Conflict of interest. The authors declare no clear or potential conflicts of interest associated with the publication.

Authors' contribution. Concept, design of the study, writing – F.A. Koloskov; data gathering – F.A. Koloskov, A.B. Miroshnikov; editing – A.V. Meshtel.

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INFLUENCE OF HYPEROXIC MIXTURE ON THE FUNCTIONAL STATE OF THE EXTERNAL RESPIRATION SYSTEM OF ATHLETES WHO HAD COVID-19 AND TRAIN IN MIDDLE ALTITUDE

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Annotation. The objective was to evaluate an effect of the inhalation course with the hyperoxic gas mixture on the functional state of the external respiration system of athletes who had COVID-19 and train in middle altitude. The study included 19 male athletes of following specialties: taekwondo, mountaineering, triathlon, badminton, underwater sports (qualifications: Candidate for Master of Sports, Master of Sports, Master of Sports of International Class, Honored Master of Sports). The athletes were divided into two groups: the experimental (who had COVID-19) and control (who did not have COVID-19). During the study (the inhalation course included not less than 7 procedures every day), the functional capabilities of the external respiration system in a form of increased gas exchange in the lungs, bronchial dilation and increased patency, were improving.

Keywords: hyperoxic mixture, athletes, COVID-19, external respiration, training camp, middle altitude.

Introduction. The pandemic associated with the SARS-coV-2 virus (COVID-19), which humanity has faced in the last three years, has significantly affected high performance sports, identifying new urgent problems for sports medicine experts. A need occurred in the development and application of methods that effectively restore the functional state of the respiratory and cardiovascular systems, increase working capacity of athletes, who had COVID-19 and resumed to training, as well as training in extreme conditions, e.g. middle altitude. Currently athlete training in hyperbaric hypoxia conditions has been firmly established in the practice of high performance sports. It is considered both as a way of successful preparation to competitions in the mountains and as a factor of mobilizing functional reserves of an athlete during their preparation to competitions on the plains [1-3]. However, athletes, who had COVID-19 and resumed to training in extreme conditions, need a specific approach, since high altitude hypoxia may be associated with high risks [4-5], despite the fact that hypoxia is a potentially effective preventive and therapeutic measure [6-8]. Taking into account different strategies of athlete preparation in middle altitude, application of mixtures with high oxygen content may become an additional way to support and recover their functional state. In sports practice, hyperoxic mixtures are already used for functional state correction and working capacity improvement [9-11]. There are data on influence of hyperoxic mixtures on functional capabilities of the respiratory system [12]. However, effect of these mixtures on the respiratory system of athletes, who had COVID and resumed to training, is understudied, but is an important and relevant aspect of sports practice, since the respiratory system is the main target of COVID-19.

The purpose of this work: to evaluate effect of an inhalation course with a hyperoxic gas mixture on the functional state of the external respiration system of athletes, who had COVID-19 and resumed to training in middle altitude.

Methods and organization. The study took place in the Center of Biomedical Technologies (FSBI "North-Caucasian Federal Research-Clinical Center of Federal Medical and Biological Agency"), in middle altitude

(Maloe Sedlo mountain, 1240 m, Kislovodsk), during training camps in the "Yug Sport" enterprise. The study included 19 male athletes of the following specialty: taekwondo (3 people), mountaineering (3), triathlon (4), badminton (4), underwater sports (5), age – 16 to 34 years (qualifications: Candidate for Master of Sports, Master of Sports, Master of Sports of International Class, Honored Master of Sports). All athletes are the members of the national teams of Russia. During the study, the athletes did not stop training (2-3 times a day). Among 19 athletes, 11 had COVID-19 and were included in the experimental group (EG), while the other 8 – in the control group (KG).

At the beginning of training camps, we have conducted a monitoring survey that included measurement of the external respiration function, blood saturation and heart rate (HR). Evaluation of the external respiration function was made with the MicroLoop portative spirometer (CareFusion, US). Following indices were analyzed: vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), Tiffeneau index – FEV1/FVC ratio, peak expiratory flow (PEF), maximum flow rate at the level of large, medium and small bronchi (MFR15, MFR50, MFR75), as well as due values calculated according to gender, age, height and ethnicity. Research of blood oxygen saturation (SpO_2) and heart rate (HR) was carried out with the ESTECK System Complex (LD Technology, US).

Then all test subjects passed the inhalation course with the hyperoxic gas mixture. To create the mixture, we used the JAY-10 oxygen concentrator (Longfian, China). The oxygen concentration amounted to 93±3%, productive capacity – 5 l/min, exposure time – 20 min. The mixture was taken into the respiratory tract through the mask. The inhalations took place every day, the course took not less than 7 procedures. At the end, we have conducted an additional survey.

The statistical data processing was made with the nonparametric Wilcoxon matched pair test and the Mann-Whitney U-test from the Statistica 6.0 software. The difference between the values was deemed significant if $p<0.05$. The data is presented in a form of mean (M) and square root deviation (sd).

Results and discussion. It is known that at the initial stage of staying in middle altitude, the blood oxygen saturation indices change. At the beginning of training camps, all athletes have decreased level of saturation (lower than 97%), which indicates hypoxia (table 1). The HR index remained within normal values in all athletes. The comparative analysis did not show statistically significant differences between the groups.

The external respiration indices in athletes of both groups are demonstrated in table 2.

We have found that values of VC related to the functional state of the external respiration system were within the standard limits in all athletes. FVC, FEV1 and Tiffeneau index (FEV1/FVC) that allow evaluating air passage through respiratory tracts were also within the normal values in all test subjects, which indicates an absence of obstructive disorders. The due values of mentioned indices in all athletes were slightly increased due to the respiratory system's adaptation to training activity aimed towards developing endurance. When assessing the MFR indices, we have discovered that higher values in both groups were identified in higher parts of the bronchi (MFR25), while the lowest ones – in lower parts (MFR75), which may be explained by air passage through bronchi of different calibers. According to all described indices, there were no statistically significant differences between the groups. The PEF analysis has shown that the index was higher in athletes of the experimental group ($p<0.01$).

After the inhalation course, there were no statistically significant changes for the saturation and HR indices in both groups. However, we have found a trend for a slight increase in saturation among all athletes: before the course in the experimental group – 93.9±1.75%, after – 94.1±1.69%; before in the control group – 93.1±1.07%, after – 93.9±2.41%. There was also a trend for a decrease in HR among all athletes, the index decreased to a greater extent in the experimental group: before the course – 75.6±9.05 beats/min, after – 71.9±8.76 beats/min. HR did not change substantially in the control group: before – 77.0±12.95 beats/min, after – 76.3±11.04 beats/min.

Table 1
Heart rate and blood oxygen saturation indices in athletes of both groups at the beginning of the training camps during while adapting to middle altitude hypoxia

№	Indices	EG	CG
1	HR, beats/min	75.6±9.05	77.0±12.95
2	SpO_2, %	93.9±1.75	93.1±1.07

Note: EG – experimental group; CG – control group; HR – heart rate; SpO_2 – blood oxygen saturation

Table 2
External respiration indices in athletes of both groups at the beginning of the training camps during while adapting to middle altitude hypoxia

№	Indices	EG	CG	P<
1	VC, l	6.2±1.11	6.0±0.76	-
2	% due	103.1±18.68	110.5±9.09	-
3	FVC, l	6.2±0.89	5.9±0.62	-
4	% due	107.4±15.27	113.3±7.76	-
5	FEV1, l	5.4±0.49	4.9±0.44	-
6	% due	112.0±11.9	112.3±6.65	-
7	FEV1/FVC %	86.6± 7.17	83.3±6.12	-
8	PEF, l/min	701.4±74.94	597.0±57.43	0.01
9	% due	111.8±13.03	101.5±8.96	0.04
10	MFR 25, l/s,	9.8±1.50	8.8±1.21	-
11	% due	111.2±17.79	106.5±13.16	
12	MFR 50, l/s	6.6±1.39	5.9±1.38	-
13	% due	114.5±24.0	107.5±22.68	
14	MFR 75, l/s,	3.2± 0.91	2.4±0.61	-
15	% due	114.7±29.98	91.2±21.83	

Note: EG – experimental group; CG – control group; VC – vital capacity; % due – percentage of due values; FVC – forced vital capacity; FEV 1 – forced expiratory volume in 1 second; FEV1/FVC – the Tiffeneau index; PEF – peak expiratory flow; MFR25, MFR50, MFR75 – maximal flow rate at the level of large, medium and small bronchi. Limits of standard values of the external respiration indices are presented according to L.L. Shik, N.N. Kanaev [13]

Dynamics of the external respiration indices of the experimental group athletes are presented in table 3. The study did not reveal statistically significant changes in these indices after the course. However, there was a trend for increasing FVC. PEF, MFR at the level of large, medium and small bronchi. FEV1 remained unchanged against the background of slight reduction of the Tiffeneau index.

Table 3

Comparative analysis of the external respiration indices in athletes of the experimental group before and after the inhalation course

№	Indicators	Experimental group	
		before	after
1	VC, l	6.2±1.11	6.2±1.01
2	% due	103.1±18.68	103.9±17.34
3	FVC, l	6.2±0.89	6.3±0.92
4	% due	107.4±15.27	109.7±16.39
5	FEV1, l	5.4±0.49	5.4±0.51
6	% due	112.0±11.9	111.7±12.45
7	FEV1/FVC, %	86.6±7.17	85.8±7.39
8	PEF, l/min	701.4±74.94	712.5±72.61
9	% due	111.8±13.03	112.8±12.85
10	MFR 25, l/s,	9.8±1.50	10.2±1.22
11	% due	111.2±17.79	112.6±13.67
12	MFR 50,l/s	6.6±1.39	7.0±1.69
13	% due	114.5±24.0	112.1±23.99
14	MFR 75, l/s	3.2±0.91	3.0±1.33
15	% due	114.7±29.98	102.9±23.02

Note: VC – vital capacity; % due – percentage of due values; FVC – forced vital capacity; FEV 1 – forced expiratory volume in 1 second; FEV1/FVC – ratio of forced expiratory volume in 1 second to forced vital capacity (the Tiffeneau index); PEF – peak expiratory flow; MFR 25, MFR 50, MFR 75 – maximal flow rate at the level of large, medium and small bronchi. Limits of standard values of the external respiration indices are presented according to L.L. Shik, N.N. Kanaev [13]

Increase of the LC index was found in athletes of the experimental group (before – 6.0±0.8, after – 6.1±0.8, $p<0.03$). There were no significant changes in other indices. However, a trend for increasing FVC and FEV1 was identified: before – 5.9±0.6 l, after – 6.0±0.8 l (FVC); before – 4.9±0.4 l, after – 5.0±0.8 l (FEV1).

Conclusion. Therefore, as a result of the inhalation course, we have identified a trend for increasing functional capabilities of the external respiration system of athletes, including those, who had COVID-19 and is training in middle altitude. This trend was manifested in increased gas exchange in the lungs, bronchial dilation and patency. Considering the fact that the course with inhaling a hyperoxic mixture during high-intensity training in middle altitude included not less than 7 procedures, the revealed trend for improving the external respiration system of athletes, who previously had COVID, reflects a necessity in conducting further research with greater sample number, taking into account the disease's severity and specificity of examined sports.

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PHYSICAL RECOVERY OF SOCCER PLAYERS AGED 15-18 AFTER THE ANTERIOR CRUCIATE LIGAMENT RUPTURE AT THE SPORTS REHABILITATION STAGE

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Annotation. The article presents a program of physical recovery of young soccer players after a rupture of the anterior cruciate ligament at the stage of sports rehabilitation. Statistics show that 30% of all injuries in soccer occur in the knee joints. Also, a large proportion is occupied by repeated, recurrent injuries. All this negatively affects the future professional activity of a young soccer player. The obtained positive results of the study allow us to recommend the developed physical rehabilitation program in the recovery and rehabilitation process of injured athletes.

Keywords: anterior cruciate ligament rupture, physical rehabilitation, exercise, young soccer players.

Introduction. An issue of recovering working capacity of athletes after traumatic injuries, their return to training was and still is relevant in modern sports.

Soccer is one of the most popular sports, but it is one of the most traumatic. Preparation of children in modern soccer is described with increasing physical and nervous loads and, consequently, the growth in a number of injuries. In adolescence, soccer is carried at a high impulsive level with a rather high energy expenditure, movement coordination defects, low attention span, emotional instability, as well as other factors typical for a youth stage that lead to high injury rate among players [1].

The knee joint injuries in young soccer players may affect their sports career. In case of the anterior cruciate ligament rupture, rehabilitation can take up to a year. However, the main point is that 8% of players usually finish their career with this injury, while 40% of athletes carry on playing. A percentage of recurrent injuries, according to data from researchers, is 18-25% [2-3]. Therefore, this injury severely affects the future career.

Recovery of the knee joint function and return to previous physical activity without recurrent injuries is a key for success in physical rehabilitation of an athlete [4].

Therefore, search for efficient rehabilitation measures and methods that speed up time for recovery of working capacity is of great relevance.

The purpose of the study is to evaluate efficiency of the physical recovery course for soccer players aged 15-18 after the anterior cruciate ligament rupture at the stage of sports rehabilitation.

Methods and organization. The study took place in the Spartak Academy named after F.F. Cherenkov and the A.I. Burnazyan Federal Medical Research Center.

The study included 8 soccer players aged 15-18 who suffered the anterior cruciate ligament rupture. At the previous stage of treatment, they got arthroscopic transplantation of the anterior cruciate ligament. They all went through the stage of post-surgical physical rehabilitation. The research was carried out at the sports rehabilitation stage.

To evaluate the rehabilitation's efficiency, we used following methods: knee joint goniometry, isokinetic testing of flexor and extensor muscles of the knee joint and motor testing that includes estimation of speed-strength capabilities of athletes, knee joint stability according to Noyes (jump tests) [5] and an ability to keep body balance in the static-dynamic mode (the Romberg test).

The data were processed with the Statistica 13 software. We have also calculated the arithmetic mean and standard deviation of the received indices. χ^2 was applied to check on the normality of distribution. The significance of differences between mean values of the examined indices in the compared group was assessed with the Student's t-test.

The physical rehabilitation course took 5 months and consisted of three periods that are different in content of general and specific exercises. It is important to note that duration of the whole sports rehabilitation stage, as well as its parts, depends on individual features of an athlete and should be corrected in the process.

Our program included: therapeutic gymnastics (TG), hydrokinesiotherapy, therapeutic massage, mechanotherapy, exercises with cardio and weight machines, physiotherapy, kinesiotaping, controlled walking and running.

Main tasks of physical rehabilitation were:

1) achieving symmetry of the lower limbs;

2) recovering general and specific working capacity;

3) preparing an athlete to training loads;

4) improving proprioception;

5) strengthening the stabilizing muscles.

The first (preparatory) period began from the week 3 after the surgery and carried on to the week 7.

Therapeutic gymnastic sessions were performed daily for 45 minutes and included following exercises: isometric tension exercises; myofascial release exercises; exercises with elastic bands; statodynamic exercises; proprioceptive exercises, relaxation exercises.

To reduce swelling, improve restoring processes and reduce pain sensations we used therapeutic massage 2 times a week in a course of 15 procedures.

The CPM-therapy (Continuous Passive Motion) was carried out with the Artromot-K1 device 3 times a week for 20-30 minutes. The amplitude and velocity aimed towards movement development and recovery of the knee joint function were selected individually for each patient.

The cold compression therapy was done with the Game Ready system. The procedure was made daily, exposure time at the beginning was 15 minutes and gradually increased up to 30 minutes. Temperature and compression degree were selected for each athlete individually depending on the degree of swelling.

The muscle electric stimulation was also done each day, after the therapeutic gymnastic session, for 10-15 minutes. The electrodes were put on motor points of the front and rear groups of hip and glute muscles.

During this period, in case if pain sensations and swelling were still present, it was advisable to conduct kinesiotaping to improve the lymphatic drainage function. An application of tapes is placed on the area of the injured joint, involving the lower third of the hip and the upper third of the crus.

The main period took 9 weeks (from week 8 to week 16 after surgery).

The therapeutic gymnastic sessions were performed daily, 60-70 minutes each. On these sessions, athletes performed exercises on unstable platforms (balancing disks, hard and elastic platforms). Near the end, we added locomotor exercises (in walking and running). Different variations of walking on an agility ladder were used as special preparatory exercises to develop specific coordination abilities of the athlete: quick short steps, steps sideways, steps with quick changes of direction and changes in speed – acceleration and braking.

The hydrokinesiotherapy was performed in a pool from week 8 after the orhtosis removal, once every 3 days for 30 minutes. Controlled swimming was a total of 1/3 of the session, the rest consisted of exercises at the pool side.

The main period included exercises with training devices (a bicycle ergometer and a cable-pull machine) for flexion and extension.

Walking was considered as an important part of the physical rehabilitation program. We started with controlled walking for 10 minutes, then we gradually added more time to 15 minutes, 3 times a week. Initially the patients walked on a treadmill with low speed – 2.5 km/h with obligatory support, then the speed was gradually increased to 3 km/h.

Duration of the final period – 8 weeks, from week 17 to week 24 after the surgery.

This period of final recovery of movement amplitude in the knee joint involves the return to sport-specific exercises. A number of training days decreases, however intensity and difficulty of the program increase (two days a week for special exercises for the knee joint, aerobic and strength training with training devices), including controlled running every day.

The therapeutic gymnastics sessions were performed 2 times a week, the duration increased to 90 minutes. The exercises on unstable platforms were supplemented with complex coordination and simulation exercises from the selected sport. To develop the functional stability of the knee joint in different planes, we have added dynamic sideways, forward, backward movements and plyometric exercises, such as: lateral trampoline jumps, jumps on the floor in different directions, bouncing on two legs with a minimal distance from the floor. The specific exercises with soccer elements were also introduced into the physical rehabilitation program: passing the ball in pairs, dribbling, exercises with a ball in partial amplitude and at low speed, shots from different positions, with different force and speed, different kinds of movements, etc.

In this period, patients were still training on cyclic and weight machines. Sessions on an elliptical trainer and a treadmill were added to training devices from the previous stage.

The kinesiotaping was done in order to stabilize the knee when performing plyometric exercises. Applications were changed once in 3-4 days, as well as in the preparatory period.

Results and discussion. To assess the developed program of physical rehabilitation of soccer players after the surgery, we conducted goniometry of the knee joint three times. A significant improvement of the extension indices, both active and passive, in the operated leg was found in the experimental group at the end of the pedagogical experiment (table 1).

The isokinetic testing was done at the end of the preparatory period (7 weeks after the surgery) and at the end of rehabilitation program. We evaluated difference in strength of extensor and flexor muscles of healthy and operated limbs. By the end of the 5th month after the surgery, imbalance of extensor muscles in the crus reduces to 10-18% (average index – 13.4%), flexor muscles – to 3-6% (average index – 4.6%) (table 2).

Table 1

The operated limb goniometry (flexion) results

Indicators	Observation periods			Difference in %	T_{calc} when T_{table}=2.37	P≤
	before the course	7 days after the surgery	after the course			
Active flexion, °	96.5±4.6	114.1±4.6	133.4±2.9	38.2	24.3*	0.05
Passive flexion, °	111.6±7.2	123.1±4.7	148.1±2.9	32.7	27*	0.05

Note: * – statistical significance of differences (before/after the course)

Table 2

Results of the isokinetic testing of flexor and extensor muscles in the knee joint

Indicators	Observation periods		Difference in %	T_{calc} when T_{table}=2.37	P≤
	7 days after the surgery	after the course			
Difference in strength of extensor muscles in the crus, %	62.9±18.1	13.4±3.3	78.7	25.8	0.05
Difference in strength of flexor muscles in the crus, %	28.3±3.2	4.6±1.5	83.75	26.8	0.05

There was a necessity to assess fitness of injured athletes to start the stage of initial training. For this purpose, at the end of the rehabilitation course (5 months after the surgery), we have conducted a jump test. Research of the limb symmetry index has shown that 5 months after the indices of the operated limb are close to those of a healthy limb: in the “Single leg jump” test the indices' values were 79%, in the “Triple leg jump” test – 84%, in the “Cross jump” test – 81%, in the “6m jump” test – 72% (table 3).

Results of different versions of the Romberg test that evaluates the sense of balance and total state of proprioceptive capabilities had significant improvement: values of indices in the “Tandem” test increased by 136.6%, in the “Stork” test with eyes closed – by 136.1% (table 4).

Table 3

Results of speed-strength abilities and the knee joint stability

Tests	5 months after the surgery		Difference		Limb symmetry index
	operated limb	healthy limb	abs.	%	
One leg jump, m	1.1±0.2	1.4±0.2	0.3	27.3	78
Triple jump test, m	3.8±0.4	4.5±0.1	0.7	18.4	84
Cross jump test, m	3.0±0.2	3.7±0.2	0.7	23.3	81
6 m jump test, m	6.1±0.8	4.4±0.7	1.7	27.9	72

Table 4

The Romberg test results

Indicators	Observation periods		Difference		T_{calc} when T_{table}=2.37	P≤
	7 weeks after the surgery	after the course	abs.	%		
“Tandem” test, s	36.1±5.1	85.4±7.2	49.3	136.6	26.9	0.05
“Stork” test, s	23.3±5.9	55.0±18.0	31.7	136.1	5.6	0.05

The indices of goniometry, isokinetic testing and motor tests obtained in the final testing, show fitness of athletes to begin the initial stage of training 5 months after the surgery.

Conclusion. Therefore, use of the developed physical rehabilitation program for soccer players after the anterior cruciate ligament surgery contributes to the improvement of athletes' recovery, maintains high indices of the joint's stability, functional recovery of lower limbs and better motor control of movements.

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EFFICIENCY OF THERAPEUTIC PHYSICAL CULTURE FOR CHILDREN AGED 5-7 WITH SPASTIC DIPLEGIA

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Annotation. The article presents the results of the therapeutic physical culture (TPC) used in children aged 5-7 years with spastic diplegia of cerebral palsy. The effectiveness of TPC is represented by an increase in the range of motion in all joints according to goniometry, a decrease in spasticity according to the Ashworth scale and an increase in muscle strength according to the Lovett scale in the affected lower limb. The data obtained can be used in the development of physical rehabilitation programs for spastic diplegia of cerebral palsy and in the work of specialists in adaptive physical culture with this contingent.
Keywords: spastic diplegia, cerebral palsy, therapeutic physical culture.

Introduction. Infantile cerebral palsy is a condition caused by brain damage sustained during the perinatal or the newborn period [1]. This disease is the most common cause of disability in childhood [2].

Cerebral palsy is one of the most severe diseases of the central nervous system, which manifests itself in combined motor, speech and mental disorders of varying severity. The structures of the brain that regulate voluntary movements, speech and other cortical functions are most affected [3].

The disease is characterized by a wide variety of clinical signs, associated symptoms, severity of motor impairment, degrees of compensation, and the causes of the disorder, which pose complex problems for the formation and development of life skills [2, 4, 5].

The purpose of this study: to assess efficiency of therapeutic physical culture for children aged 5-7 with spastic diplegia.

Methods and organization. The study included children aged 5-7 (n=7) with spastic diplegia of cerebral palsy. The research took place in the Regional Children Hospital (Yaroslavl), the Department of Speech Pathology and Neurological Rehabilitation.

Goniometry was used to assess the range of motion in the affected lower limbs and mobility in the hip, knee and ankle joints was studied. Flexion and extension amplitude in the studied joints were examined and the results were recorded in degrees.

The degree of muscle spasticity in the affected lower limb was evaluated with the Ashworth scale. Muscle strength of the affected limb was assessed with the Lovett scale. The results were statistically processed; arithmetic mean and standard deviation were calculated. Significance of changes in the investigated indices of parametric methods was assessed with the Student’s t-test if $p \leq 0.05$. The data were checked for normality of the distribution using the Shapiro-Wilk test.

To correct motor disorders, children aged 5-7 years with spastic diplegia underwent a course of rehabilitation measures with therapeutic physical culture (TPC), consisting of 3 periods: introductory, main, final, with total duration of at least 21 days.

The morning hygiene exercises were carried out daily and individually for 10-15 minutes under the supervision of a child's parents. The therapeutic gymnastics sessions included calisthenics for all muscle groups, breathing exercises of static and dynamic nature, as well as special exercises, which included stretching, relaxation, and coordination exercises. During the classes, the calisthenic exercises for large and small muscle groups were alternated by day. Additional equipment could also be used. As adaptation to physical activity was made, calisthenic and special exercises were used to increase muscle volume and strength as well as to teach the young patients household and self-care skills. Massage was aimed at relaxing the spastic muscles. Independent outdoor sessions were carried out at weekends with parents for 1-1.5 hours in game form. They were aimed at build and improvement of walking.

Results and discussion. After the course of recovery measures with TPC exercises for children aged 5-7 years with spastic diplegia, dynamics of goniometry indices in the affected lower limb's joints has changed (table):

- in the hip joint at flexion it was 4.26%, changing from 110.3±1.4° to 115±1.4°, at extension – from 11±0.7° to 14.2±0.5° with dynamics of 29.1%;
- in the knee joint at flexion it was 2.65%, changing from 147.2±0.72° to 151.1±0.66°, at extension – from 3.01±1.84° to 4.99±1.88° with dynamics of 65.4%;
- in the ankle joint at flexion it was 11.6%, changing from 22.4±0.85° to 25.0±1.22°, at extension – from 13.8±0.42° to 15.3±0.6° with dynamics of 10.87%.

We believe that the use of special exercises (correcting the main defect, stretching, relaxation exercises, positional therapy), therapeutic massage and therapeutic swimming contributed to the increase in the mobility of all joints of the affected limb.

The dynamics of muscle strength and spasticity after a course of rehabilitation measures for 5-7-year-old children with spastic diplegia, as assessed by specialized scales, are shown in the figure below.

Table

Results of goniometry of the affected lower limb joints during rehabilitation measures for 5-7-year-old children with spastic diplegia, °, X±σ

Lower limb joints	Function	Indices		P≤
		Before	After	
Hip joint	Flexion	110.3±1.4	115±1.4	0.05
	Extension	11.0±0.7	14.2±0.5	0.05
Knee joint	Flexion	147.2±0.72	151.1±0.66	0.05
	Extension	3.01±1.84	4.99±1.88	0.05
Ankle joint	Flexion	22.4±0.85	25.0±1.22	0.05
	Extension	13.8±0.42	15.3±0.6	0.05

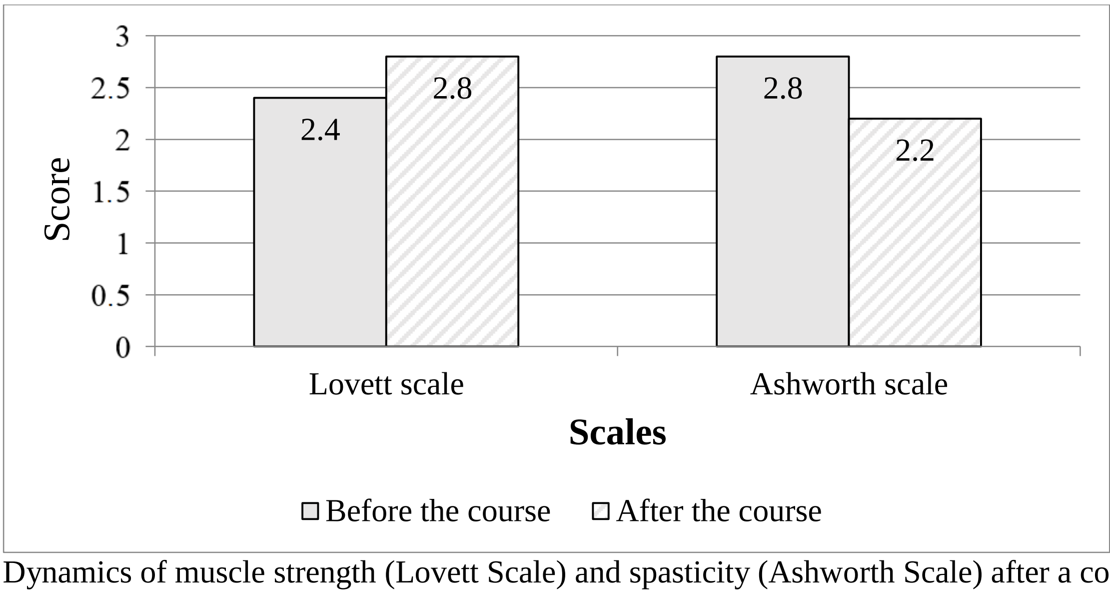

Fig. Dynamics of muscle strength (Lovett Scale) and spasticity (Ashworth Scale) after a course of rehabilitation measures for 5-7-year-old children with spastic diplegia

Muscle strength accessed with the Lovett scale in the examined group significantly increased after the course by 58.82% (at p≥0.05), from 2.43±0.98, corresponding to an intermediate level of strength development to 3.86±0.9, corresponding to satisfactory muscle strength.

Muscle spasticity examined with the Ashworth scale decreased by 53.85% (at p≥0.05) from 2.79±0.99 corresponding to an insignificant increase in muscle tone to 1.29±0.7 points, corresponding to a slight increase in muscle tone.

Conclusion. As a result of the course of rehabilitation measures with therapeutic physical culture, according to goniometry parameters the range of motion in all joints of the affected lower limb increased, muscle spasticity reduced and muscle strength increased, indicating the effectiveness of therapeutic physical culture for children aged 5-7 with spastic diplegia.

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METHODS OF CORRECTION OF ORTHOPEDIC FOOT DISORDERS IN PATIENTS WITH MULTIPLE SCLEROSIS

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Annotation. Patients with multiple sclerosis (MS) often have orthopedic disorders of the feet (changes in the tone of the muscles of the lower leg, valgus or sail deformity). Such disorders occur due to spasticity of the muscles of the posterior surface of the lower leg and weakness of the anterior. This article discusses the effectiveness of a set of physical exercises and orthopedic braces used after botulinum therapy. According to the results of the work, a positive effect of the proposed technique was revealed on leg supportability (improvement in the Romberg test on two legs by 92.3% $t=8$, $p\leq0.01$; improvement in the Romberg test on one leg by 144% $t=9.4$, $p\leq0.01$) and lower leg muscle strength (improvement in the test task “toe lifts in 30 seconds” by 133.3% $t=11.5$, $p\leq0.01$; improvement in the test task “dorsiflexion in the ankle joint while sitting in 30 seconds” by 400% $t=23.4$, $p\leq0.01$).
Keywords: orthopedic foot disorders, feet valgus, multiple sclerosis, neuro-orthopedics.

Introduction One of the current problems of patients with multiple sclerosis is spasticity of the lower leg muscles. This problem affects the patients' ability to walk [1]. In this case, patients can often perform such tasks as “toe lift” and plantar flexion in the ankle joint, but are dorsiflexion in the ankle joint is practically impossible. Such imbalance is associated with increased muscle tone of the posterior surface of the tibia and weakened extensor muscles of the foot and toes. In addition, patients also develop feet valgus or varus due to improper distribution of the load on the feet [2]. As methods of correction, a number of modern authors mention botulinum therapy, wearing orthopedic braces, braces with myostimulation (for example, walkaide), therapeutic gymnastics, orthopedic shoes, taping, hydrotherapy et al. At the same time, many authors note the importance of using physical exercises after botulinum therapy of the lower leg muscles [3]. It is due to the fact that botulinum injection lowers the muscles’ spasticity, which allows performing exercises that were earlier inaccessible.

We have assumed that application of a set of exercises with orthopedic correction with braces after botulinum therapy would have a positive effect on strength of the foot muscles and support ability of the legs.

The purpose of our study was to identify effectiveness of a developed set of exercises accompanied with application of orthopedic braces after botulinum therapy on support ability of the legs of strength of the lower leg muscles.

Methods and organization. The study included 10 patients aged 30-40 with remitting and secondary progressive MS who had orthopedic foot disorders and botulinum therapy within 2-7 days prior to the study. The inclusion criteria: spasticity of the lower leg muscles before botulinum therapy, valgus deformity of the feet, preserved walking function with 1 or 2 supports (more than 300 meters), ability to maintain balance without a support, agreement to perform a set of exercises daily for 6 months. The study took place in the Moscow Society of Multiple Sclerosis for 6 months, from September 2022 to February 2023.

As a method of correction, the patients were prescribed a set of exercises for daily performance. The complex included exercises for stretching and relaxing the muscles of the posterior surface of the lower leg; strengthening the muscles responsible for the extension of the foot and toes; exercises to strengthen the muscles of the thigh and buttocks; passive development exercises for the ankle joint and passive movements of the toes. The set took

15-20 minutes, each 3 weeks the exercises were revised and made more difficult. For the first 3 months, the initial positions were lying on a floor and sitting in a chair, then exercises while standing and walking were added. As an additional method, special orthopedic braces used for neurological patients to correct the foot position were worn daily during walking and standing exercises.

At the beginning and at the end of the study we applied methods for functional assessment of the lower leg strength and the feet support ability:

1) toe lifts in 30 seconds (maximum number of tries) – one could hold on to the extra support while doing the test;

2) dorsiflexion in the ankle joint while sitting in 30 seconds (number of tries) – the test was performed sitting on a chair with the leg bent 90 degrees at the knee and hip joints, and the patients were asked to perform dorsiflexion in the ankle joint with as much amplitude as possible;

3) keeping balance in the Romberg test on two legs with eyes open (maximum time in seconds) – patients took an initial position with legs together and arms outstretched forward, and the time to loss of balance was assessed;

4) keeping balance in the Romberg test on one leg with eyes open (maximum time in seconds) – patients took an initial position on one leg, with the other leg bent and pressed to the shin by the medial part of the foot, the knee joint of the bent leg pointing forward, arms outstretched forward, and the time to loss of balance was assessed.

To evaluate statistical significance of the study we used math-and-stats methods of (calculation of arithmetic mean, standard deviation, difference and Student's t-test if $p \leq 0.01$), normality of distribution was identified with the Kolmogorov-Smirnov test. Calculations were performed with the Stata software.

Results and dicsussion. At the final stage the obtained results were processed with the aforementioned methods and tabulated.

Table

Test results obtained as part of the study

Tests	n=10					
	Before	After	Difference		T_{emp} (if t_{cr}=3.1)	P≤
			absol	%		
Toe lifts in 30 s, number of tries	6±2.1	14±3.5	8	133.3	11.5	0.01
Dorsiflexion in the ankle joint while sitting in 30 s, number of tries	1.2±1.1	6±2.6	4.8	400	23.4	0.01
Keeping balance in the Romberg test on two legs, s	18.2±6.5	35±8	16.8	92.3	8	0.01
Keeping balance in the Romberg test on one leg, s	5±5.3	12.2±4.3	7.2	44	9.4	0.01

The results obtained show a trend for improvement of all studied indicators, which reflect effectiveness of the developed program and positive effect of selected exercises. Indices of the lower leg strength increased by 133.3%, t=11.5, $p \leq 0.01$ (“toe lifts in 30 s”) and by 400%, t=23.4, $p \leq 0.01$ (“dorsiflexion in the ankle joint while sitting in 30 s”). The Romberg test indices also demonstrated improvement: by 92.3%, t=8, $p \leq 0.01$ for keeping balance on two legs and by 144%, t=9.4%, $p \leq 0.01$ for keeping balance on one leg.

Conclusion. The method for correction of orthopedic foot disorders in patients with multiple sclerosis, based on the use of special complexes of exercises and wearing orthopedic braces after botulinum therapy of the lower leg muscles, has proven effective. This technique can be recommended for neurological patients with orthopedic foot disorders.

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YOGA AS AN ALTERNATIVE PRACTICE FOR THE REHABILITATION OF PEOPLE WITH HYPERTENSION

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Annotation. This article discusses the ways and methods used in yoga to protect the health of people prone to hypertension. We have examined the indications and contraindications to the use of physical exercises for hypertension, as well as recommendations for the inclusion of special breathing exercises and the exclusion of a number of such exercises from the exercise set. Brief characteristics of breathing exercises in terms of their effect on the autonomic nervous system are presented. Basic relaxation techniques for the rehabilitation of people with hypertension are also demonstrated.

Keywords: yoga, hypertension, blood pressure, heart rate, cardiovascular system, breathing exercises, meditation, relaxation techniques, rehabilitation.

Introduction. Hypertension (essential or primary hypertension) is one of the most common diseases in people over 40 years. According to the World Health Organization (WHO, 25 August 2021, joint press release, Geneva, Switzerland), "over the past 30 years, the number of hypertensive adults aged 30-79 has increased from 650 million to 1.28 million. Older people over 60 are particularly at risk". Hypertension is a significant risk factor for the development of various cardiovascular diseases, which has been confirmed by a number of epidemiological studies [1-3]. Hypertension is both associated with other risk factors for major diseases and triggers them as well. Arterial hypertension has been found to account for about 50% of cardiovascular mortality [4-5]. There are many factors that can cause it: dysfunction of the central nervous system or the neuroendocrine system, membrane receptor pathology that leads to vascular, cardiac and renal structural remodeling, as well as heredity. [6]. Some authors point out the following main factors of hypertension [1, 4, 5, 7]:

1) stress-inducing factors;
2) occupational factors also associated with stress;
3) genetic predisposition;
4) age;
5) bad habits (smoking, alcohol, unhealthy diet);
6) lack of physical activity;
7) excess weight.

In view of the above we can conclude that to prevent and treat hypertension one needs to break bad habits, exclude unhealthy food from their diet. In case of risk, one should get rid of the factors that cause stress and burnout, and start working out. In addition, as a non-drug treatment, there are many different lifestyle-changing strategies that need to be studied.

The aim of the work is to explore the means and methods of yoga for further effective use in the rehabilitation of people with hypertension.

Methods and organization. The literature data analysis included following scientific databases: PubMed, PsycInfo, the Cochrane Databases, elibrary.ru.

Results and discussion. *Effect of physical yoga exercises on the cardiovascular system*

E. Dietrich, A. Safronov, A. Frolov and other researchers in their scientific works have noted the positive effect of yoga exercises on the work of the cardiovascular system [8-14]. It is necessary to pay attention to the structure of yoga classes and take into account the different effects of asanas on the human body. First of all, one needs to understand which exercises should be excluded from the yoga course for hypertension treatment. The following exercises, which increase the tone of the sympathetic division of the autonomic nervous system (ANS) and may provoke a rise in blood pressure, should be in the exclusion list: asanas for strength with prolonged fixation, dynamic practices, active and deep bending, standing pelvic tilts with the head below the heart with prolonged fixation, balances on hands, inverted asanas. In other cases, these exercises should be performed with caution and only in an adapted version with an experienced yoga therapist.

As Artem Frolov noted in his practical guide to yoga therapy, “Controlled physical effort reduces activity of the sympathetic nervous system and the catecholamine level in the blood. In the whole, the classes are constructed in a mild, relaxing mode, calm dynamics in the rhythm of natural breathing (marjariasana cycle), articular warm-ups without breath-ups and sharp exhalations, ujjayi breathing in the 1:2 ratio are also possible. Arch exercises are used in mild variants and in moderate quantities as asanas that precede longer bends in available variants” [14]. Taking the aforementioned into account, we recommend including the asanas that stimulate the parasympathetic division of the ANS: tadasana (mountain pose), utthita trikonasana, pelvic tilts with a support (make sure your back is parallel to the floor), ardha uttanasana, ardha parshvatanasana (adapted versions), tilts while sitting with support, janu shirshasana, pashchimottanasana, virasana, balasana (baby pose), marjariasana (cat pose) and shavasana. We also recommend keeping an eye on heart rate and blood pressure during the whole class.

Effect of breathing exercises of yoga on the cardiovascular system

The ancient yogic texts describe the physiological effects of certain types of breathing, which affect the general state of the body and human consciousness [10, 12, 15, 16].

A number of scientific papers indicate the positive impact of breathing exercises on the cardiovascular system and the possibility of reducing the risk of such diseases as arterial hypertension, coronary heart disease, etc. [2, 3, 8, 11, 17]. For effective yoga practice in the fight against hypertension, it is necessary to know about the effects of breathing exercises on the sympathetic and parasympathetic divisions of the ANS [5, 8, 12, 18]. In yoga there are various breathing exercises that stimulate the sympathetic nervous system, and such exercises should be excluded from yoga practice for people who suffer from hypertension or have a predisposition to this disease. Such exercises include: intensive breathing exercises with sharp deep inhalations and exhalations, bhastrika, breathing techniques with sharp shortened exhalation – kapalabhati, usually used in the practice of articulate gymnastics (Sukshma vyayama), breath-holding (kumbhaka). It is advisable to include breathing exercises that stimulate the parasympathetic division and lower blood pressure (BP), such as full yogic breathing and extended exhalation ujjayi, nadi shodhana, bhramari pranayama and chandra-bhedana

Even a five-minute breathing exercise with a special technique can lower blood pressure and improve cardiovascular performance at least no worse than aerobic exercise or antihypertensive drugs. Here are the results of the work of American researchers from the University of Colorado, published in the Journal of the American Heart Association [19]. The study included 36 volunteers with elevated blood pressure (BP) over 130 mmHg, aged 50-79 years. Half of them performed Inspiratory Muscle Strength Training – IMST (30 inhalations a day at high resistance for 6 days a week), the other part participated as a control group with a significantly lower inhalable air resistance protocol. 6 weeks later the IMST group had lowered systolic BP by 9 mmHg. Such decrease can be achieved with aerobic exercises (30-minute walks 5 times per week) or antihypertensive drugs. The effect persisted even after stopping training (6 weeks after). In the main group there was also a 45% improvement of endothelial function (the ability to expand in response to the corresponding stimulation), a significant increase in nitric oxide level, which is central for vascular dilatation, as well as a decrease in inflammation and oxidative stress. The mechanisms explaining this phenomenon have not yet been sufficiently investigated, but the authors of the study suggest that breathing forces the vascular endothelium to produce more nitric oxide. The researchers from Colorado presented a simple and accessible non-drug method of blood pressure decrease [19].

Use of meditation for hypertension

One of the important factors that increased HR and BP is stress. To relieve stress and balance the nervous system meditation and relaxation techniques are actively used today. The role of various meditative techniques, such as cyclic meditation, yoga-nidra, visualization techniques, relaxation, etc., coming from the ancient tradition of yoga, are now actively studied by foreign scientists. It is scientifically confirmed that people practicing meditation cope better with stress, they are less anxious, and their nervous system is more stable [9-10]. The data are also presented on Internet resources in foreign databases: PubMed, PsycInfo, and the Cochrane Databases, etc. [9, 15].

The most safe and accessible are the relaxation exercises, the effectiveness of which in treating hypertension is scientifically approved in the studies of V.S. Volkov and A.E. Tsikulin (1989). Special relaxation therapy, in which a daily relaxation session of 15-20 minutes 2 times a day was used, demonstrated its effectiveness in hypertensive patients. The researchers revealed that in the early stages of hypertension autogenic training itself can be sufficient to normalize BP [20].

Conclusion. Indeed, today yoga is successfully applied as a method of recovery and correction of all systems of the human body, including the abovementioned exercises. Yoga techniques are effective ways to combat hypertension and other diseases of the cardiovascular system. The controlled use of physical activity and properly selected breathing and physical exercises regulates and balances the excitation and inhibition of the central nervous system, strengthens its integrating role in the work of the organs and the body as a whole. However, independent training in yoga for hypertension is not recommended, instead one should contact an experienced teacher of yoga or yoga therapist.

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