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MODERN VIEW ON PHYSIOLOGICAL AND MORPHOLOGICAL SPECIAL FEATURES OF THE ADAPTATION OF ORGANISM OF ATHLETES TO WEIGHTLIFTING EXERCISES

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Key words: weightlifting, adaptation, sex dimorphism, physiology of power sports, cardiorespiratory system, morphological status, neuromuscular apparatus.

Annotation. The purpose of this research is to analyze Russia-based and foreign scientific works dedicated to physiological and morphological special features of the adaptation of organism of athletes to weightlifting exercises. The results have shown that currently extensive data on special features of operation of vegetative functions of athletes during urgent and long-lasting adaptation to weightlifting exercises was collected. There is general representation on the work of the musculoskeletal system and muscles in the process of performing weightlifting exercises. However, with regard to substantial requirements to neuromuscular coordination, versatility and global nature of muscular work performed by an athlete, there is a need for a detailed examination and structuring the work of neuromuscular apparatus of athletes during performance of exercises. A simultaneous analysis of biomechanical and physiological parameters has the most potential in this direction.

Introduction. Weightlifting is a dynamic power, speed- and power-based type of sports, in which two versatile barbell lifts involving the whole musculoskeletal apparatus – snatch, clean and jerk – are being performed during competitions [1-4]. According to literature data, when performing competitive exercises, weightlifters achieve the highest values of absolute and relative peak power [5], which causes a significant tension of all systems of organism of athletes and is of great interest for scientists and practitioners from the point of physiology of manifestation of maximum capabilities of an organism.

The purpose of the study is the analysis of Russia-based and foreign scientific works on relevant issues of physiology and morphofunctional adaptation to weightlifting training.

Methods and organization. The analysis of Russia-based and foreign scientific works on relevant issues of physiology and morphofunctional adaptation to weightlifting training was conducted. 35 most relevant scientific works were analyzed and presented.

Results and discussion. Results of the conducted analysis of Russia-based and foreign scientific works dedicated to relevant issues of physiology and morphofunctional adaptation to weightlifting training has shown that studies in given direction has been conducted since 1970s and are still relevant to this day. Scientists examine special features of urgent and long-lasting adaptation with regard to various systems and functions of an organism, which are affected by tension and/or actively involved during the performance of weightlifting exercise.

Adaptation of the cardiorespiratory system. Weightlifting training cause long-lasting structural and functional adaptation on the part of the cardiovascular system, but there is contradictory data according to manner of such changes. As a rule, due to the rational organizing of training exercises, the changes that occur tend to be attributed to physiological changes, not pathological ones. The effect of economizing heart activity during weightlifting training, in which static loads are always present, is not registered [6-10]. HR at rest in female weightlifters is 70,5±2,3 beats/min, in male weightlifters – 68,7±1,7 beats/min, in comparison with women, who do not do sports, HR is 69,2±1,8 beats/min, in men, who do not do sports – 61,9±1,0 beats/min [11].

In studies of different scientists, the blood pressure (BP) data of weightlifters differs significantly. In 70s studies of the 20th century, A.N. Vorob’ev showed that BP in weightlifters at rest corresponds to normal values and is 108/71 mm of Mercury [12]. The data of studies of A.F. Sinyakov and S.V. Stepanova (1994) is aligned, in accordance to which BP is 116/74 mm of Mercury [13]. In studies of O.N. Kudri (2007) it has shown, that BP at rest is in on the upper limit of normal value (SBP = 125±11 mm of Mercury; DBP = 75±7 mm of Mercury) [14]. N.A. Fomin et al. (2002) have registered an increased mean and SBP (1-2-degree arterial hypertension) in athletes, who develop speed-power qualities [15]. According to data given by foreign scientists [16-17], SBP in male weightlifters fluctuates between 115 and 153 mm of Mercury, DBP – between 71 and 93 mm of Mercury.

This BP data in classified as normal or 1-degree hypertension in accordance with recommendations of the ACSM [18].

High intensity exercises increase resistance of peripheral vessels, stimulating the concentric hypertrophy of left ventricle (LV) [19-20]. The increase in thickness of the heart wall is caused due to the parallel addition of new myofibrils and is a compensatory attempt to decrease a tension on the wall of LV and systolic blood pressure [20].

In some studies, the morphology and functions of heart ventricles in elite weightlifters were examined [16, 17, 21]. It was revealed that the absolute mass of cardiac ventricles (gr) in weightlifters could be 13-30% more than in healthy subjects of the same age [16]. However, the increased mass of LV, which was demonstrated by weightlifters, is proportional to their total body mass, total body area and/or lean body mass, which indicates a physiological adaptation rather than a pathological. It is important, because the LV hypertrophy belongs to the category of independent factors of exposure to cardiovascular diseases [20].

In other studies, there were no significant differences in absolute or relative indicators of the heart morphology between weightlifters and healthy subjects, who do not do sports [17-22]. Thus, it is possible to implicate, that weightlifting does not cause a genuine concentric distention of LV, as it is observed in pathological states.

Cardiorespiratory function of elite male weightlifters according to data of maximum oxygen consumption (MOC) fluctuates between 42,0 and 50,7 ml/kg/min. During the intentionally conducted experiment on short-term (8 weeks) implementation of weightlifting exercises, an increase of both absolute and relative MOC up to ~6-7% was registered in healthy adult men [23]. However, during long-term special weightlifting training, sessions and the annual MOC evaluation for 3 years, a significant decrease of both absolute and relative MOC to 4% and 11% was revealed [24].

The stress index (SI) of regulatory systems in female weightlifters is 140,3±28,4 c.u., in comparison with women, who do not do sports – 124,0±28,3 c.u. It is significantly higher than those of male weightlifters – 79,2±8,2 c.u. and men, who do not do sports – 73,7±28,9 c.u., but these values remain within limits of physiological standards [11].

The minute blood volume (MBV) and the end-systolic volume (ESV) at rest in male weightlifters is 6,84±0,62 l/min и 98,4±8,7 ml [12], in men, who do not do sport – 7,36±0,62 l/min и 70 ml [25]. During performance of weightlifting exercises by elite athletes, MBV is doubled to 13 l, mainly due to an increase in HR. The ESV is increased from 80 to 126 ml in 20-30 s, MBV is increased threefold (to 20 l) in comparison with these indicators at rest. This phenomenon is called the “cardiac variation of the Lindgard phenomenon”, which is explained by the F. Starling’s law.

Weightlifting exercises are performed when holding your breath and straining. The straining state is characterized by an increase of intrathoracic and abdominal pressure during holding breath, which decreases the blood inflow to the heart.

Electrocardiogram of weightlifters at rest does not differ from indicators of people, who do not do sports. During performance of exercises, a moderate decrease of ST interval related to the delay of breath and straining is registered. During lifting of maximum weight barbell, signs of short-term myocardial ischemia based on disturbance of coronary blood flow: ST segment is shifted below the contour line and the T-wave becomes electronegative. Changes in BP, HR and MBV during performance of exercises are connected with the amount and duration of loads [12, 26].

Immediately during the weightlifting barbell lift, due to the limitation of venous inflow and ejection of remaining blood from its cavities the heart dimensions are decreased to almost 50%. After the end of an exercise, blood overfills right ventricular, then left ventricular, myocardial hypertrophy appears [12] and the hyperkinetic type of blood circulation forms due to the adaptation to such loads [9, 17, 28].

Holding of breath and straining cause an adaptation of brain blood circulation [11]. At rest, weightlifters have an increased tone of extracranial vessels in occipital mastoid lead, a peripheral vascular resistance in frontal mastoid lead of the left-brain hemisphere and in occipital mastoid lead of both brain hemispheres are decreased, the process of venous outflow in frontal mastoid lead of the right brain hemisphere and in occipital mastoid lead of both brain hemispheres is hindered. Holding of breath in relation to the state of rest does not cause a change in blood outflow and brain venous vascular tone. However, the tone of magistral arteries is decreased, which allows to preserve the acceptable level of blood supply to brain [29].

The performance of weightlifting exercises contributes to the formation of specific special features of peripheral hemodynamics. Female weightlifters are characterized by some normal and some increased indicators of the peripheral blood flow. Such indicators as a peripheral resistance and vascular tone of feet on the precapillary level, a venous outflow of small-caliber blood vessels, are within normal value. Such indicators as venous vascular tone of calf on the postcapillary level, extensional blood filling of magistral arteries of calves and feet, speed of blood flow of medium and small arteries of calves and feet are increased. In men, such indicators as peripheral vessel resistance, feet tone and speed of blood flow through medium-and small-caliber arteries are increased, signs of venous hyperemia in left foot and difficulties of venous outflow in right foot are present. The left sided asymmetry of blood flow in lower extremities is revealed in men [30]. Such changes could later have a pathological nature. In overall population of young male weightlifters, a venous disease of lower extremities in 27% and signs of venous lesion in 9% was revealed [31]. As other experts assume, the state of peripheral hemodynamics in female weightlifters is more stable, characterized by lesser indicators of asymmetry [32].

Morphological state of weightlifters. The body composition of weightlifters is the same as the body composition of athletes with the dame body mass in other power, speed- and power-based type of sports [5, 11].

Lesser height and length of extremities of weightlifters contribute to mechanical benefits when lifting heavy weight due to a decrease of mechanical moment of force and vertical distance, on which the barbell should be moved. Moreover, lesser body dimensions coincide with a bigger cross-section area of skeletal muscles, which is a benefit for weightlifting [4].

Conducted studies on morphological special features of elite weightlifters showed sex dimorphism in indicators of weight, body mass composition, body surface area, girth dimensions, thickness of skin and fat folds, diameter and girth of rib cage.

Differences between female weightlifters and women, who do not do sports, were established taking such indicators as weight, lean body mass, body fat mass, shoulder width, cross-sectional diameter and girth of rib cage, thickness of skin and fat folds, girth dimensions and indexes of physical development into account [11].

It was shown in studies of A.N. Vorob'ev, that biggest change during weightlifting training happens in musculoskeletal apparatus of an athlete. An increase in a diameter of tubular bone diaphysis and thickening of the compact layer of bones and places where tendons can attach to them are also registered. Such changes contribute to an increase in bone strength, which is necessary when working with maximum and near-maximum weights. Hypertrophy of skeletal muscles appears as a result of power training. A specific imbalance in the development of different muscle groups is present: mainly, leg, torso and arms extensor muscles develop. In weightlifters, an asymmetry in the development of muscle groups is revealed, for example in "speed and power-based capabilities" of the right and left knee joints extensors [12, 33].

The scientists see special features of the technique of pushing the barbell off the chest when doing the split stance, where the "take-off leg" is the most loaded, as a reason for the asymmetry. Manifestations of the asymmetry in elite weightlifters are also revealed when performing the snatch [34].

Adaptation of neuromuscular apparatus. Data from the cross-section of muscles suggest that weightlifting training is inducing a transformation of IIX fibers into IIA fibers. Moreover, a hypertrophy of II type fibers is revealed in weightlifters, which counts as a benefit for weightlifting and contributes to the generation of maximum power.

Thus, the isometric peak power and speed of the development of contractile forces in men are ~15-20% and ~13-16% higher than those in athletes of other power, speed- and power-based sports [5]. During the process of weightlifting training, initially an increase in muscle strength is more influenced by “nervous functions”, a subsequent long-term increase in power, as a rule, is a result of muscular hypertrophy.

The study of electrical muscle activity using surface electromyography (EMG) in weightlifters immediately during performance of weightlifting snatch with 80% intensity has shown, that with an increase of amplitude and frequency-related special features of EMG, power and speed of muscle contraptions increase. These indicators are highly dependent on sex-based features. The EMG amplitude is higher in men due to the manifestation of maximum power and speed- and power-related capabilities. EMG in women is characterized by high indicators of frequency characteristics (mean, median and peak frequency), which indicates a high frequency of motor neurons impulsion, but do not cause the same power indicators as those in men due to lesser functional capabilities of muscles [35].

Conclusion. Thus, currently the substantive data on special features of vegetative functions of athletes during urgent and long-term adaptation to weightlifting training. There is general representation of special features of work of the musculoskeletal system and muscles. However, due to substantial requirements to neuromuscular coordination, versatility and global nature of muscular work performed by an athlete, there is a need for a detailed examination and structuring the work of neuromuscular apparatus of athletes during performance of exercises.

Since weightlifting becomes more and more popular worldwide, further studies, dedicated to research from the point of anatomy and physiology of human organism of optimal and effective mechanics of body movements and techniques of performance of competition exercises, which are snatch, clean and jerk, are required.

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