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WARM-UP EXERCISES AS A CRUCIAL FACTOR OF PREPARATION FOR PHYSICAL ACTIVITY: PHYSIOLOGICAL REASONING

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Abstract. *Physical activity can be challenging for the body, especially when performed suddenly and without proper preparation. To avoid the risk of injury and optimize a performance, athletes and trainers use warm-up exercises to prepare the body for activity. Proper increase of physiological indicators and providing safety as one of the most crucial points are primarily vital tasks of sports physiology. In our research, we summarized the physiological mechanisms underlying the body's preparation for physical activity and highlighted the importance of warm-up exercise. Warm-up exercise has a wide range of physiological benefits related to effects on many body systems like musculoskeletal, cardiovascular, respiratory and the whole body at all. The effectiveness of warm-up exercises is expressed in a quantitative increase in physiological indicators, which are pointed out in the article and explored from the physiological point of view. The article describes in details some physiological mechanisms performed during the warm up, emphasizes their mutual consequences, contributing to safety and qualitative improvement of further physical activity. Understanding the physiological mechanisms of body preparation for physical activity emphasizes the importance of sports warm-up as a crucial component of any exercise program. By performing the warming up, professional and amateur athletes can prime their bodies for optimal performance, reduce the risk of injury, and improve their overall physical and mental well-being. These aspects are discussed in our article with regard to the points of their practical application and scientific researching perspectives.*

Key words: *warm-up exercise, muscles chronaxie, acceleration of biopotentials formation, contractility of muscle, cardiorespiratory response, temperature response.*

Introduction.

Sports Physiology as a branch of physiology is primarily aimed at explaining certain mechanisms of sports activity and characterizing their impact on various body systems and the condition of the body in general [1]. Relevant information is a scientific and theoretical basis for creating optimal complexes of sports exercises, developing strategies and tactics of physical training in general and in a particular sport, predicting ways of rehabilitation, etc. [2]. Argumentation of physiological mechanisms of different exercises, stages of training and analysis of their physiological significance is the key of understanding the positive and negative effect of certain exercises or their complexes on the state of the athlete and the degree of preparedness.

Materials and Methods

The analysis of scientific data has been conducted on the basis of PubMed, Scopus and Web of Science databases in order to collect the existed results of researches about impact of warm-up exercises on effectiveness of further workout.

Discussion.

One of the important parts of both amateur and professional training of athletes is warm-up exercise, which is generally the performance of a certain set of exercises to prepare the body for further workout. Therefore, warm-up is defined as a complex of aerobic exercise of low-intensity and stretching, resistance exercise of low-intensity and special exercise depending on the type of activity, in order to increase the blood flow of skeletal muscles due to activation of autonomic nervous system and to increase temperature in muscles before proper workout, thus producing a positive physiological change for effective muscular performance [3, 4].

According to the tasks for which the warm-up exercise is carried out, it can be classified into general and special [5, 6].

The general warm-up exercise is directed first of all on the increase of the sportsman's efficiency, infusion into the training process, increase of homeostatic indicators of an organism (acceleration of metabolic rate, respiratory rate and depth, heart rate (HR), blood pressure (BP), improvement of blood supply to organs, increase of body temperature) in order to adapt to the further physical activity [7]. In turn, a special warm-up exercise, which is mostly performed after the general one, is aimed at preparing for intensive work primarily of the organs involved in the motor acts of a particular sport (muscles, joints, etc.). For instance, it has been defined that special warm-up increases the force output during squat workout only with 6 repetitions and 80% of the load. Also, authors have shown that warm-up with 40-80% of the load is the most effective providing shorter time to achieve maximal muscle performance [8]. Other researchers proposed application of properly structured exercises in the warm-up and avoiding a long rest in the post-warm-up, such strategies also help to improve muscle performance. Authors recommended an active warm-up lasting 10-15 min with gradual increase in intensity of 50-90% of maximal HR, additionally, it is recommended to use heated garments after warm-up to maintain muscle temperature [7].

The exercises and their sequence in such a warm-up workout are determined primarily by the sport for which it is created. In order to optimize such a set of exercises, it includes, for example, cyclic movements of cyclic sports, as well as the most frequently repeated movements of acyclic and mixed sports. For example, during the warm-up exercise for swimmer athletes are most often offered to perform arm swings, rotation of limbs in joints, etc., for basketball players the most typical special warm-up workout is rebounding the ball, for martial arts fighters – pushing movements, lunges, leg swings, etc [9, 10].

The indicators of influence on a muscular system because of performance of a warm-up exercise include reduction of chronaxie of muscles, improvement of blood supply to muscles, acceleration of biopotentials formation, increase temperature which accordingly has the consequences for muscular performance [11].

Reducing muscle chronaxie is a decrease in the minimum time required for a

doubled threshold strength to cause muscle excitation [12]. That is, because of warm-up exercising, which is the repeated performance of certain exercises that together form a cycle, a kind of development of appropriate algorithms occurs: the corresponding muscle receptors are pre-activated, calcium channels are activated by activating the T-system and accelerating the transport of the corresponding ions. Also, there is a preliminary release of neurotransmitter (acetylcholine) into the synaptic cleft, the activity of acetylcholinesterase increases and thus the functional activity of muscle fibers increases [13]. In exercising this effect is expressed in the fact that the athlete spends less time to perform a certain physical exercise, performs cyclic physical exercises quicker and agiler, which accordingly contributes to the improvement of time performance or distance coverage [14].

The acceleration of biopotentials formation, which occurs, among other things, due to the reduction of chronaxie, is expressed in a faster process of initiating exercise, a faster transition from one form of physical activity to another. Actually, it is expressed in the increase of muscles lability, that is improvement of functional mobility, increase of velocity of physiological processes of contraction and relaxation of muscles in the form of improvement of quantitative indicators of muscular tissue: excitability, conductivity, decrease of refractoriness. That is, as a result of repeated movements and tension of the same exercises in the process of performing a certain exercise, the velocity of excitation in muscle tissue and excitation in the neuromuscular synapse increases, the action potential is formed in the relevant structures at a higher velocity and moves along the relevant conductive pathways faster [15].

In addition, due to the development of mechanisms for performing certain exercises during the warm-up workout, the contractility of muscle filaments is improved qualitatively due to the functional improvement of the work of the corresponding proteins that provide muscle contractions, primarily actin, myosin, troponin, tropomyosin and titin. Actin and myosin, which respectively form thin and thick muscle filaments, increase their ability to contract under the influence of regular loads due to regular warm-up exercises, and further, due to an increase in their amount, muscle volume increases, which contributes to improved fitness and athleticism. Troponin, in its turn, binds actin, tropomyosin and calcium receptors, which contributes to faster contraction in the muscle. Tropomyosin, which also increases its functional activity during warm-up exercises, is located at the junctions between myosin and actin in a relaxed muscle. That is, as a result of its functional improvement, the mechanisms of calcium transfer as one of the key elements of muscle contraction are better realized, and the stability of the muscle structure is ensured. Improving titin activity, in its turn, also ensures the stability of the muscle structure, reducing the likelihood of structural and functional disorders that affect the quality of exercise performance. Titin also promotes muscle elasticity, which plays an important role in ensuring flexibility and reducing the likelihood of sports injuries [14, 16, 17].

As a result of gradual complication of loads during the warm-up exercise, the functionality of contractile proteins is also stabilized and improved, the main task of which is primarily regulation of the relative location of functional structures of a muscle (sarcomeres, contractile proteins), which promotes more accurate and faster excitation in muscles, that is again qualitatively and numerically improves sports

results [9].

There is evidence that the improvement in muscle performance after resistance warm-up is connected to post-activation potentiation, which leads to increase in muscle strength due to contraction during warm-up, that is effective for agility and ground reaction during workout because it increases the mobilization of motor units, activity of potential, and post-synaptic potentiation. Additionally, researchers have reported that isotonic contraction warm-up makes muscles activity and total work higher than isometric contraction warm-up [18].

In its turn, the improvement of blood supply to muscles occurs due to the reaction of the whole organism to the transition to a more excited state, increase in the rate and force of heart contractions, increase in pulmonary ventilation, decrease in blood viscosity due to an increase in temperature, change in body position in space, etc. The changes of cardiovascular and respiratory systems are achieved by the ergoreflex which is a cardiorespiratory feedback system [19]. It includes metaboreflex (result of accumulation of metabolites in the skeletal muscle) and the mechanoreflex (caused by activation of stretch receptors of muscle and tendons). Impulses from both stimuli are sent to nerve center in nucleus of the solitary tract, rostral ventrolateral medulla, caudal ventrolateral medulla, where integration with other peripherical and central components happens (chemoreflex, baroreflex, cortical areas). Metaboreflex activation results in an increase of blood pressure caused by increasing sympathetic outflow and leading to increased peripheral resistances and cardiac output. Metaboreflex activation also initiates a rise in pulmonary ventilation to compensate the requirements for increased oxygenation to the active muscles. On the other hand, mechanoreflex stimulation also increases peripheral vascular resistances, heart rate resulting in an elevation of blood pressure [20].

During the warm-up exercise the body gradually activates most of systems, because the increase of physical activity activates sympathetic innervation and as a result causes an increase in blood pressure, heart rate, blood vessels of skeletal muscles dilate, and the stroke volume of the heart increases. The gradual increase in the load, which is provided by the warm-up exercise, contributes to the fact that the filling of the vessels occurs gradually, and thus more fully. Due to this, the positive effect of the warm-up exercise becomes more generalized, nutrients are delivered to the muscles fully and quickly, due to which the body's reserves are spent in a balanced way and the performance of sports activity is improved [21].

In addition, stretching is useful for the effectivness of futher workout, it increases the range of motions of joints, muscle performance and flexibility. However, stretching as a warm-up activity may temporarily decrease muscle strength, muscle power, and exercise performance, however, aerobic-stretch-warm-up increases the psychological readiness for physical activity [22].

At the same time, the temperature increase is caused by the intensified course of biochemical reactions for energy supply in the mitochondria, i.e., an increase in energy production, part of which is used to perform work, and part is dissipated as heat in the body. By performing warm-up exercises, the athlete gradually "warms up" the muscles, provoking the need to provide them with nutrients to implement the relevant mechanisms. Due to this, the rate of catabolic processes also increases, which requires

an increase in oxygen supply for aerobic reactions and the synthesis of more ATP, which is accompanied by the release of thermal energy. Due to the increase in temperature, the viscosity of muscles naturally decreases and, accordingly, the speed of their contraction and relaxation increases, which can be perceived as a positive physiological effect for the training process. In addition, there is an acceleration of biochemical reactions in muscles, due to which the release of lactic acid into the blood decreases, and the oxygen debt increases to a lesser extent and, accordingly, the time before the onset of fatigue and exhaustion increases, that is, the endurance and performance of the athlete increases [23, 24]. Some researchers have defined that the muscle dependence on higher temperature during activation allows fast skeletal muscle fibers to contract once the temperature in cytosol increases during or after warm-up, at same time saving energy at rest condition [17].

In turn, the release of excess heat and the supply of necessary oxygen is ensured in the body by increasing the rate and depth of breathing during physical activity, increased sweating, and other mechanisms of thermoregulation. The role of increasing the rate and depth of breathing is primarily to gradually increase their respiratory volume due to a uniform increase in the use of inspiratory and expiratory reserves and thus increase the vital capacity of the lungs. Thus, the vital capacity of the lungs due to warm-up exercises increases to 6000-7000 ml, which contributes to a quantitative improvement of gas exchange due to an increase in the supply of oxygen to the tissues of the inhaled air [25].

In fact, the physiological significance of respiratory changes relates primarily to the adjustment of biochemical parameters of the blood, primarily the shift of its acid-base balance towards lower pH, that is, the occurrence of respiratory acidosis due to excessive accumulation of CO_2 in the blood during exercise, which may be accompanied by a decrease in the level of O_2 in the blood. These pathological phenomena are compensated by increased CO_2 release from the exhaled air and increased O_2 supply from the inhaled air, precisely by increasing the rate and depth of breathing and increasing the vital capacity of the lungs. In addition, respiratory acidosis is corrected by binding excess H^+ ions with the blood bicarbonate buffer system [26].

Endogenous opiates such as endorphins and enkephalins have numerous effects to the body systems including relief of pain, maintenance of heart function, growth of cells, modulation of immunity, and regulation of blood glucose concentration. Thus, the initial elevation of endorphins during warm up exercise helping to modify the immune response, to provide adaptation of cardiovascular system, analgesia effect, and aids with regulation blood glucose level [27].

To normalize mentioned above processes, and to avoid the phenomena of hyperthermia, shortness of breath, exhaustion, among others, it is necessary to perform warm-up and further workout in a room that meets sanitary indicators, is ventilated, and has normal humidity and air temperature [28].

Conclusion.

In general, the warm-up exercise is primarily aimed at improving the effectiveness of the training itself, a positive impact on further activities (improving indicators of agility, strength, speed, etc.) due to the activation of almost all body systems. Also, one of the vectors of warm-up exercise's positive impact is psychological, since when

performing simpler warm-up exercises through moderate physical activity and its impact on the condition of the systems, the athlete is psychologically prepared for further workout, improves mood and feels satisfied with own results compared to the results without warm-up exercise. The warm-up exercise promotes the increase of adaptation of an organism to the conditions of the increased physical activity, quantitative and qualitative improvement of initial efforts, and also gradual increase of plasticity, endurance, strength of muscles in comparison with the state before the warm-up exercise. These effects contribute not only to improving the effectiveness of training, but also to the prevention of injuries, exhaustion, and fatigue among athletes, which is significant in the context of sports medicine.

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