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MECHANISMS OF BLOOD CIRCULATION REGULATION UNDER THE INFLUENCE OF THE DYNAMICS OF ENVIRONMENTAL CONDITIONS AND PHYSICAL ACTIVITIES

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Abstract

The vital functions of a multicellular organism are carried out with the assistance of its constituent cells, tissues, and organs, integrated into systems through dynamic interactions with the environment during the exchange of substances, energy, and information. In this regard, in accordance with the traditions of Russian physiology, formulated in the mid-19th century by I.M. Sechenov: " the scientific definition of an organism must also include the environment that influences it." Moreover, in accordance with the concepts of the theories of V.I. Vernadsky and A.L.I. Chizhevsky, it is not simply the state of the external environment, but specifically its dynamics, that determines the anticipatory tendencies in the organism's activity. It is generally accepted that the anticipatory reflection of reality, as an attribute of living systems, arose due to the fact that the temporal structure of reality is represented by repeating series of events. From this perspective, the activity of an organism during a certain period of time reflects anticipatory preparation for upcoming activity. Fluctuations in the state of the organism and the functioning of its systems occur under the influence of the dynamics of environmental conditions and during the course of activity. Factors affecting the body, depending on the type of reaction, are classified as episodic (acute, sudden) and periodic (chronic). In response to sudden stimuli, the body responds with a nonspecific reaction, which, depending on the strength of the stimulus, represents a tension reaction (stress), activation, or training. The body reacts to repeated stimuli according to the principle of anticipatory reflection of reality. Natural and man-made environmental conditions are represented by abiotic and biotic factors. Perception of changes in abiotic factors is ensured through sensory systems, and biotic factors are perceived through the immune system. Moreover, abiotic factors directly influence the central links of neural and neuroendocrine regulation, and the effect of biotic factors on regulatory mechanisms is mediated by the state of the effector and secretory functions of immune system cells. It is known that various leukocyte populations, in response to antigens, secrete cytokines and mediators that influence the state of the central structures of autonomic and neural regulation.

Introduction

On the other hand, athletes' physical activity is associated with increased energy metabolism in active tissues. Increased energy production during muscular activity is achieved by increasing the rate of anaerobic and/or aerobic resynthesis of high-energy substrates. This is accompanied by activation of the respiratory, hemodynamic, and blood systems to maintain homeostatic constants. Physical activity can contribute to both increased and decreased immunoreactivity.

The effect of physical activity on the immune system is mediated by neuroendocrine mechanisms. Thus, adaptation to prolonged physical work is accompanied by increased NA secretion to enhance aerobic ATP resynthesis, while anaerobic exercise is accompanied by increased adrenaline and GC production. Consequently, with a rationally organized training process, the ability to dose physical activity allows not only to develop an individual's motor abilities but also to regulate the degree of stress on adaptive mechanisms. This makes it possible to specifically influence the state of the body's nonspecific resistance and immunoreactivity. Indicators of peripheral blood lymphocyte content and functional activity are widely available, tested, and reliable indicators of the body's adaptive capacity. Subpopulation level dynamics. The composition and state of lymphocytes in the blood and their functional state are primarily associated with abnormal antigen homeostasis in tissues, primarily in the mucous membranes and epithelium. Furthermore, changes in the composition and state of lymphocytes in the blood normally closely correlate with the dynamics of neuroendocrine regulation of energy supply for motor activity. Lymphocytes participate in the regulation of body functions through terminal enhancement of neuroendocrine stimulation of somatic cells and tissues and by modulating the functional state of the central nervous system (CNS) through the cytokines, peptide hormones, and neurotransmitters they secrete. The mechanisms of nonspecific resistance and immunoreactivity are subject to seasonal fluctuations due to the circadian rhythm of neuroendocrine system activity. Thus, in autumn and winter, increased levels of NA, GC, and thyroids are observed in the blood. In spring and summer, the secretion of mineralocorticoids and gonadotropic hormones increases, while in summer and autumn, androgens increase. Seasonal photoperiod dynamics are believed to influence serum melatonin levels, reproductive functions, and thermoregulation. In the latter case, this is related to the balance between the calorigenic and vasomotor effects of NA. Since Lc populations have receptors for specific hormones, it can be assumed that circannual fluctuations in the neuroendocrine system modulate the seasonal dynamics of immunoreactivity and nonspecific resistance.

At the same time, seasonal changes in dietary composition and environmental antigens directly impact the immune system through the mucous membranes and epithelium. Therefore, the body's mechanisms of nonspecific resistance and immunoreactivity are modified by seasonal changes in biotic environmental factors and modulated by circadian fluctuations in the neuroendocrine system.

Thus, in mid-latitude conditions, an important physiological principle underlying the use of motor activity to regulate nonspecific resistance and immunoreactivity is that physical activity

occurs during adaptation to seasonal changes in environmental conditions. The interaction of neurohumoral regulatory mechanisms during adaptation to anaerobic or aerobic physical activity and seasonal changes in environmental conditions determines the rhythm of fluctuations in nonspecific resistance and immunoreactivity, thereby determining the level of "adaptation costs." Therefore, the relevance of the problem lies in determining the physiological patterns of fluctuations in nonspecific resistance and immunoreactivity mechanisms in athletes exposed to seasonal changes in environmental conditions and anaerobic or aerobic physical activity.

The aim of the study was to identify patterns of interrelationships between the mechanisms regulating the activity of oxygen transport systems and immunity in athletes exposed to physical activity and seasonal environmental conditions.

To achieve this goal, the following tasks were set:

1) to study the patterns of changes in the indicators of the state of oxygen transport systems in athletes under the influence of seasonal dynamics of environmental conditions and anaerobic or aerobic physical activity;

2) to determine the patterns of dynamics of the immune status of athletes under the influence of anaerobic and aerobic physical activity depending on seasonal changes in environmental conditions.

Study Results

For the first time, relationships between changes in the oxygen transport and immune systems in athletes under the influence of seasonal changes in environmental conditions and various types of physical activity were identified. It was established that, regardless of the dynamics of anaerobic and aerobic physical activity during the annual training cycle, seasonal changes in environmental conditions caused in-phase fluctuations in the expiratory capacity of the external respiration system and the oxygen capacity of peripheral blood, as well as the state of the alactate and glycolytic mechanisms of muscle energy supply. It was revealed that the parameters of the fluctuation rhythm in the annual cycle of activity of the external respiration and circulatory systems, as well as the morphofunctional indicators of the peripheral erythron and maximum oxygen consumption, are associated with the modifying effects of anaerobic and aerobic physical activity on the state of the neurohumoral regulation of these systems.

Anaerobic and aerobic exercise were found to modify the circadian rhythm parameters of the immune system in athletes. Anaerobic exercise in the spring was associated with increased phagocyte activity and elevated proinflammatory cytokine levels (interleukin-1, γ-interferon), while aerobic exercise in the fall was associated with a decrease. It was found that the increase in neutrophil functional activity in wrestlers in the spring was associated with a decrease in the level of oligomeric fractions of medium-molecular -weight peptides under the influence of anaerobic exercise. In the fall, a less pronounced increase in neutrophil functional activity in skiers was associated with an increase in high-polymer " medium-molecular-weight " peptides under the influence of aerobic exercise. It has been shown that fluctuations in the state of oxygen transport systems in wrestlers under the influence of anaerobic physical exercise are

caused by changes in the activity of neutrophils and monocytes phagocytosis, combined with the dynamics of the content of heptane and isopropanol lipid peroxidation products. In skiers, the dynamics of oxygen transport systems over the annual cycle under the influence of aerobic physical exercise are caused by a decrease in the amplitude of circannual fluctuations in the activity of neutrophils and monocytes phagocytosis, combined with changes in the content of high-polymer and oligomeric fractions of " medium molecular weight " peptides. A new approach to determining the normal values of immune system and oxygen transport parameters in athletes is substantiated, changing depending on the synchronization of seasonal fluctuations in environmental conditions and the dynamics of anaerobic or aerobic physical exercise over the annual cycle.

The identified patterns in the dynamics of the relationship between the state of peripheral blood leukocytes and the content of humoral factors regulating the activity of oxygen transport systems in athletes throughout the year provide a methodological basis for managing the human immune status through anaerobic and aerobic physical activity during adaptation to seasonal changes in environmental conditions. The identified patterns provide a theoretical basis for managing the dynamics of the functional state of athletes through the influence of anaerobic and aerobic physical activity on the circadian rhythm of immune regulation of the oxygen transport systems.

Regardless of differences in muscle energy supply and the dynamics of anaerobic and aerobic physical activity throughout the year, wrestlers and skiers showed consistent seasonal changes in expiratory reserve volume parameters, peripheral erythron function, creatine phosphokinase activity, and oxygen replenishment rates. The functional state of the respiratory and circulatory systems, maximum oxygen consumption, and morphofunctional parameters of the peripheral erythron are determined by the predominant mechanism of ATP resynthesis in wrestlers and skiers, and the nature of their seasonal fluctuations is largely determined by the dynamics of physical activity throughout the annual cycle. Fluctuations in the immune system in athletes with anaerobic or aerobic energy supply for motor activity were characterized by an increase in the phagocytic activity of neutrophils and monocytes in the peripheral blood in winter and a decrease in the summer. Anaerobic exercise in wrestlers promotes increased neutrophil and monocyte phagocytosis activity, while aerobic exercise in skiers leads to a decrease in phagocytosis activity. The dynamics of physical activity throughout the year modifies the circannual biorhythm parameters of the athletes' immune system, providing increased phagocytic responses during anaerobic exercise in the spring and a decrease in them under the influence of aerobic exercise in the fall. Adrenaline levels in athletes were significantly lower in the fall and winter than in the spring and summer. They also showed increased levels of interleukin-1a in the summer season. In the spring, athletes had increased levels of oligomeric " medium molecular weight " peptides and decreased levels of heptane-soluble ketodienes and conjugated trienes. The content of high-polymer " medium molecular weight " peptides decreased in the fall. Athletes with predominantly anaerobic energy supply of muscle activity had lower levels of high-polymer and oligomeric " medium molecular weight " peptides, and higher levels of cortisol and thyroxine, as well as primary and secondary isopropanol products

Web of Scientists and Scholars: Journal of Multidisciplinary Research

of lipid peroxidation, than athletes with predominantly aerobic energy supply of motor activity. In the spring, wrestlers had a lower level of the oligomeric fraction of " medium molecular weight " peptides. In the fall, skiers had a higher level of the high-polymer fraction of " medium molecular weight " peptides. These changes determined the modifying effect of anaerobic and aerobic physical activity on the circannual rhythm of phagocytic activity of neutrophils and monocytes in the blood of athletes. The dynamics of oxygen transport system parameters in wrestlers over the course of the year are associated with the influence of anaerobic exercise on the circadian rhythm of blood phagocytes, coupled with changes in the blood levels of primary and secondary heptane and isopropanol lipid peroxidation products. The dynamics of oxygen transport systems in skiers over the course of the year are associated with the modifying influence of aerobic exercise on the circadian rhythm of blood phagocytes, coupled with the levels of high-polymer and oligomeric " medium-molecular " peptides.

Conclusions

Seasonal changes in environmental conditions and the physiological rhythm of physical activity throughout the year significantly influence fluctuations in basal metabolic rate, the state of muscle energy supply mechanisms, and gas exchange. Metabolic dynamics induce regulatory changes in the activity of the immune system and indirectly affect the state of the immune system. Conversely, the circannual biorhythm of neurohumoral regulation and the seasonal dynamics of biotic environmental factors directly influence fluctuations in the functional state and secretory activity of immune cells. The latter, in turn, largely determines the state of iso-, para-, and juxtacrine regulation of the immune system. Ultimately, the dynamics of the immune system and immunity throughout the year are determined by numerous direct and feedback intersystemic relationships that ensure the interaction of these systems under the influence of biotic and abiotic seasonal environmental factors and are modulated by the circannual rhythm of neurohumoral regulation.

In athletes, fluctuations in the immune system and immune response occur under the influence of various exogenous and endogenous factors: seasonal dynamics of environmental factors, changing weather conditions, and levels of physical, mental, and operational stress. Perception of changes in environmental parameters and their signals, as well as social influences, is mediated by sensory systems. Perception of biotic factors is mediated by immune system cells diffusely located in areas of contact between the internal environment and antigens: in the epithelium, peripheral blood, and the mucous membranes of the respiratory, gastrointestinal, and genitourinary tracts. Ultimately, fluctuations in the immune system in athletes throughout the year are due to the synchronization of the physiological rhythm of muscle activity, the seasonal rhythm of the immune system, and the circadian rhythm of neurohumoral regulation.

Web of Scientists and Scholars: Journal of Multidisciplinary Research

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