UDC 612.66
DOI: 10.56871/RBR.2023.19.40.006

FUNCTIONAL FEATURES OF THE CARDIORESPIRATORY SYSTEM OF THE ALIEN POPULATION LIVING IN THE REGIONS OF THE FAR NORTH AND AREAS EQUATED TO THEM (LITERATURE REVIEW)

© Olga G. Litovchenko, Narmin G. kizi Gadzhibekova

Surgut State University. Lenin ave., 1, Surgut, Russian Federation, 628412

Contact information: Narmin G. kizi Gadzhibekova — Doctor of functional diagnostics. E-mail: narmina567@mail.ru ORCID ID: 0000-0003-3772-569X

For citation: Litovchenko OG, Gadzhibekova N kizi G. Functional features of the cardiorespiratory system of the alien population living in the regions of the Far North and areas equated to them (literature review) // Russian biomedical research (St. Petersburg). 2023; 8(3): 36-49. DOI: https://doi.org/10.56871/RBR.2023.19.40.006v

Received: 02.06.2023 **Revised: 11.07.2023** **Accepted: 21.09.2023**

Abstract. The development of oil and gas resources of the Far North and equivalent areas of Russia is accompanied by the construction of strategically important facilities and territorial production complexes, which lead to the migration of a large number of people from various regions of Russia. Specific climatogeographic and ecological conditions of the North determine the unique course of all biological processes, affecting all functional systems of the body, including cardiorespiratory. The study of functional capabilities and adaptation mechanisms to environmental conditions remains an urgent task of human physiology in connection with the active development of natural resources at the expense of productive forces coming from other regions. The article presents a brief overview of research papers that reflect the functional features of the cardiorespiratory system of the alien population living in various regions of the Far North and equivalent areas of Russia. The presented literature data indicate the presence of specific adaptation processes of the cardiorespiratory system in representatives of the alien population in the harsh climatic and geographical conditions of the northern regions, manifested in hyperfunction of external respiration, hemodynamic reactions, special compensatory changes in the respiratory and circulatory systems. The development of the northern regions increases the relevance of the development and implementation of measures to assess the endurance of the respiratory and circulatory systems of representatives of the alien population, as well as the prediction of possible risks to their health.

Key words: cardiorespiratory system; adaption; alien population; northern region.

ФУНКЦИОНАЛЬНЫЕ ОСОБЕННОСТИ КАРДИОРЕСПИРАТОРНОЙ СИСТЕМЫ ПРИШЛОГО НАСЕЛЕНИЯ, ПРОЖИВАЮЩЕГО В РАЙОНАХ КРАЙНЕГО СЕВЕРА И ПРИРАВНЕННЫХ К НИМ МЕСТНОСТЯХ (ОБЗОР ЛИТЕРАТУРЫ)

© Ольга Геннадьевна Литовченко, Нармин Гаджибала кызы Гаджибекова

Сургутский государственный университет, 628412, г. Сургут, пр. Ленина, 1

Контактная информация: Нармин Гаджибала кызы Гаджибекова — врач функциональной диагностики. E-mail: narmina567@mail.ru ORCID ID: 0000-0003-3772-569X

Для цитирования: Литовченко О.Г., Гаджибекова Н.Г. Функциональные особенности кардиореспираторной системы пришлого населения, проживающего в районах Крайнего Севера и приравненных к ним местностях (обзор литературы) // Российские биомедицинские исследования. 2023. Т. 8. № 3. С. 36–49. DOI: https://doi.org/10.56871/RBR.2023.19.40.006

Поступила: 02.06.2023 **Одобрена: 11.07.2023** **Принята к печати: 21.09.2023**

Резюме. Освоение нефтяных и газовых ресурсов Крайнего Севера и приравненных к ним местностей России сопровождается строительством стратегически важных объектов и территориально-производственных комплексов, которые приводят к миграции большого количества людей из различных регионов России. Специфичные климатогеографические и экологические условия Севера определяют уникальное протекание всех биологических процессов, влияя на все функциональные системы организма, в том числе и кардиореспираторную. Исследование функциональных возможностей и адаптационных механизмов к условиям окружающей среды остается актуальной задачей физиологии человека в связи с активным освоением природных ресурсов за счет производительных сил, приезжающих из других регионов. В статье представлен краткий обзор исследовательских работ, в которых отражены функциональные особенности кардиореспираторной системы пришлого населения, проживающего в различных регионах Крайнего Севера и приравненных к ним местностях России. Представленные литературные данные свидетельствуют о наличии специфичных адаптационных процессов кардиореспираторной системы у представителей пришлого населения в суровых климатогеографических условиях северных регионов, проявляющихся в гиперфункции внешнего дыхания, реакциях гемодинамики, особых компенсаторных изменениях систем дыхания и кровообращения. Освоение северных регионов повышает актуальность разработки и внедрения мероприятий по оценке выносливости систем дыхания и кровообращения у представителей пришлого населения, а также прогнозированию возможных рисков для их здоровья.

Ключевые слова: кардиореспираторная система; адаптация; пришлое население; северный регион.

INTRODUCTION

The evolutionary formation of an organism as a biological species is directly connected with the external environment and is determined by the influence of various climatic, geophysical and geochemical conditions. In the process of evolution, corresponding natural rhythms were formed in the activity of the cardiovascular and respiratory systems of the body [27]. In the process of adaptation to environmental conditions, an organism forms characteristics and properties that prove to be the most beneficial and thanks to which the organism acquires the ability to exist normally in a specific habitat [5].

Adaptation of an organism to new natural and production conditions necessary for the sustainable existence of the organism in a specific ecological environment occurs at the cellular, organ, systemic and organismic levels [7, 61]. The cardiovascular and respiratory systems together are a marker of the organism's adaptation to new environmental conditions, which is reflected in the morphological and functional changes of these systems [64, 75]. The cardiorespiratory system (CRS) as the main link in the life activity of the human body is aimed at continuously supplying it with oxygen [12]. The CRS is interconnected with external environment, so the system also is influenced by a complex of negative environmental factors [13]. The cardiovascular and respiratory systems serve as the most important link in the complex of visceral systems that ensure metabolism and maintain the constant internal environment of the body [34, 55].

The life activities of the immigrant and indigenous population living in regions of the Far North and equivalent localities are sharply limited due to harsh natural conditions. A number of researchers have proven the negative impact of the climatic features of the northern region on health of residents [41, 52]. Thus, a third of the residents of the surveyed territories describe the northern climate as "very severe" and "rather severe" (no differences in assessments were found between groups formed on the basis of age and gender criteria and degree of sedentarism) [41]. Moreover, immigrant population more often talk about the influence of certain climatic characteristics (for example, the polar night) on their physical and mental state [41]. Indigenous people, unlike the migrant population, have a natural adaptation to external environmental factors, as a result of which they are less susceptible to stress and premature pathologies [31]. The immigrant population is influenced by various factors of the changed habitat, as it finds itself in new social and cultural, physical and geographical conditions [66]. A study of technogenic impact on biological systems in the conditions of the Far North demonstrated the disastrous ecological state of the landscape in the territory of oil producing enterprises [37]. Increased physical and mental stress against the background of existing natural pressure can provoke high tension in the body's adaptation systems and the development of a special condition of the complex od symptoms [39].

Adaptation of the body of an immigrant population allows it to endure significant changes in the external environment and actively restructure organism's physiological functions in accordance with these changes, sometimes even ahead of them [1]. The immigrant population turned out to be more vulnerable to associated effects of northern risk

factors, which contributed to the development of the "polar tension" syndrome with its inherent initiation of free-radical oxidation and a decrease in overall antioxidant activity [37].

The health status of the immigrant population is under the continuous influence of specific risk factors, which leads to the formation of typical northern pathology. Since northern conditions require increased energy consumption and increased oxygen consumption, the cardiovascular and respiratory systems require a constant increase in oxygen supply. The appropriate utilization of oxygen is ensured by the respiratory and hemodynamic systems, which in different combinations lead to a change in the type of functional relationship between the parameters of the heart and lungs at certain age periods of a person [23]. For example, the same level of oxygen consumption can be achieved by different strategies: either increased ventilation or increased oxygen utilization [55]. To effectively assess the functional state of the body of the immigrant population, informative criteria of the cardiorespiratory system are considered in a complex, since each individual physiological parameter of respiration and heart is not as reliable and objective as a complex approach consisting of recording numerous indicators. In this regard, it is necessary to carry out a systemic quantitative analysis of the organism, which are the part of the general functional system of adaptation of the organism [27]. In this regard, it is necessary to carry out a systemic-quantitative analysis of the organism, which are part of the general functional system of adaptation of the organism [27].

The adaptation of the immigrants' body in northern latitudes has specific features. Some migrants adapt quickly, their organism is rebuilt to the so-called polar metabolic type, while others have a long adaptation period [30]. The adaptation of the immigrants' body in northern latitudes has specific features. Some migrants adapt quickly, their organism is rebuilt to the so-called polar metabolic type, while others have a long adaptation period [30]. With the increase in number of generations of people living in conditions of the northern region, optimization of the cardiorespiratory system indicators is observed with a decrease in the degree of reactivity in a series from zero to the second generation in response to the activation of the orthostatic test. This occurs against the background of an increase in the degree of influence of the autonomic nervous system in a state of rest and with a greater expression of the decrease in response to orthostatic test [2]. With an increase in the time of residence in the North-East of Russia, there is a gradual decrease in the level of stress in the work of the cardiorespiratory system, a decrease in the incidence of basal metabolic parameters exceeding the normative values [1]. At the same time, an increase in the specific weight of deviations in microcirculation indicators is observed in a series from zero to the third generation (a decrease in the diameter of arterial and venous sections, an increase in the coefficient of deformation of capillaries).

The study of the patterns and physiological mechanisms of adaptation of the aborigines of the North is of great importance for the preservation and development of health not only of small ethnic groups, but also of immigrants, since the indigenous population represents the adaptive standard that is most adequate to its habitat [73]. In order to minimize the incidence of heart and lung pathologies in the immigrant population living in the northern region, it is necessary to pay special attention to the cardiorespiratory system. The relevance of the topic is related to the need to generalize and analyze existing approaches to the study of adaptive capabilities on the health status of the migrant population under the influence of harsh climatic conditions.

GENERAL PATTERNS OF ADAPTATION IN THE NORTH

The development of new deposits, which have great political and economic potential, is closely linked with the study of the adaptation of the organism [70]. In this regard, the basis of modern medicine should be adaptive physiology [5]. The indigenous population is adapted to environmental factors both at the phenotypic and genetic levels. The best effect of the adaptation process is achieved with greater similarity of morphological and physiological characteristics in the indigenous and immigrant populations, and acclimatization in harsh living conditions requires the greatest stress on the adaptation processes [1]. Expeditions conducted in various extreme conditions of the Far North have shown that the body always pays with stress and expenditure of vital resources for adaptation to new environmental conditions [4]. This is why the leading aspect of the formation of the current morphological and functional state of human organs and its reserve capabilities is the type of adaptation of important body systems to climatic, geographical and seasonal conditions [33].

The difference between the functional characteristics of immigrants and native population is that even after the completion of the process of successful acclimatization, the organism of immigrants will work with maximum use of resources [72]. In immigrants, many physiological processes shift in the direction of characteristics typical for the natives of a given region [64, 82]. A transitional process of adaptation is established and characterized by the totality of the existing capabilities of the organism. The influence of climatological and territorial conditions of the North on the body's state was identified by researchers in the seventies and eighties of the last century. Scientists have proven that the hereditary capabilities of adaptation processes in more than 70% of the migrant population in the North can-

not ensure long-term health maintenance in harsh climatic conditions [30].

The entire adaptation process can be divided into stages. The first stage is the stage of anxiety, when the body rapidly rebuilds itself and the mechanism of adaptation to new living conditions begins. The second stage (resistance) is the level of significant resistance of the body's systems to the effects of the northern region. By the end of this stage, the body's condition stabilizes, functional indicators are normalized, and a completely new state of balanced, stable equilibrium is realized [5]. Thus, the respiratory and cardiac organs manage to successfully adapt to the climatic conditions of the northern region thanks to the restructuring of the most important systems of the body [56].

Exposure to the harsh conditions of the Far North and similar areas, such as pronounced ultraviolet deficiency due to low solstice, long and cold winters, and low air temperatures inevitably lead to the process of "light starvation" at night and "light excess" during the day. The complex of these mechanisms represents a difficult multi-stage social and physiological process, which is combined with pronounced stress on the body's adaptive systems [48]. As a result of the research, it was clearly demonstrated that at the first stage of adaptation to harsh environmental conditions, an urgent set of compensatory, protective reactions is acquired that support the normal functioning of the body's systems by straining functional reserves [1, 38].

The immigrant population is characterized by a specific form of continuous stress on the cardiovascular and respiratory systems, which is caused by the weakening of the body's stable resistance to extreme conditions [13]. Common features of the adaptation process are an increase in the size of the adrenal cortex and an increase in their secretory activity, a decrease in the lymph nodes, thymus, spleen, and a reorganization of blood composition indicators, a change in the ratio of metabolic processes in the body, the prevalence of decay processes that lead to a decrease in blood pressure and weight loss [66]. It has been proven that in the harsh conditions of the North, sympathicotonia is reduced in winter and increased in summer [56]. So, at low air temperatures the tone of the vagus nerve predominates. On the part of the immune system, there is a weakening of immunity and a tendency towards a protracted, chronic course of diseases in northerners [44]. Ineffective functioning of the immune system of immigrants of the north often leads to the spread of acute infectious pathology, which creates a threat of failure of protective adaptive mechanisms and determines the tendency for acute inflammation to become chronic [68].

A survey of the cardiorespiratory system indicators of the Salekhard population revealed a stress in the functional characteristics of the lungs and heart of immigrants, which is characterized by increased functional activity of the external respiration parameters, an increase in systolic and diastolic blood pressure, minute blood volume, and total peripheral vascular resistance [67]. Such a characteristic adaptive change in the functioning of the cardiovascular and respiratory systems is necessary to ensure the normal functioning of the body of the immigrant population in the conditions of the North [31].

When the body adapts to changing factors in the North, profound shifts in the internal environment of the body occur (hypoxia, hypercapnia, hypocapnia, acidemia), which, according to the principle of feedback, activate the physiological processes of regulation and the function of gas exchange of the respiratory system. Some northerners experience an increase in pulmonary ventilation, while others experience an increase in heart rate, which becomes one of the leading factors in providing the body with oxygen. It is necessary to coordinate work to ensure the supply and consumption of oxygen, which affects the contractility of the myocardium and the frequency of respiratory movements, which depend on the body's reserves [53].

FEATURES OF RESPIRATORY SYSTEM ADAPTATION

A pronounced feature of the adaptation process to the extreme conditions of the Far North are morphogical, physiological and functional changes in the respiratory system, which are often characterized by dyspnea [61], which is called polar. As compensation for hyperventilation of immigrants' lungs, metabolic acidosis develops in the conditions of the Middle Ob region [81]. The increase in the minute volume of respiration, typical for the northern region in plain conditions, is explained not only by metabolic acidosis, but also by a decrease in the aeroionisation of air [4]. When studying the mechanism of dyspnea as a phenomenon that occurs in depressive and anxious states, 4 clinical variants of hyperventilation syndrome not accompanied by hypoxia were identified [30].

CRS is susceptible to somatic, biological and psychological influences. The functional state of CRS depends on environmental factors. At the beginning of the adaptation process to cold, the functional depot accumulates due to additional opening of the alveoli at the level of the medium and large bronchi [3]. However, the long-term presence of immigrants in northern conditions leads to an increase in the area of gas exchange, which occurs due to morphological changes: diameter, quantity and volume due to morphological changes, quantity and volume of capillaries that bulge into the lumen of the alveoli. Against the background of these processes, the blood pressure in the pulmonary circulation significantly exceeds the normal values [56]. Changes in the respiratory system of a person living in the

North for several years correspond to adaptation to hypoxia [3, 5, 27].

Almost the entire immigrant population experiences difficulty breathing and shortness of breath at low air temperatures in the uncomfortable conditions of the northern region [48]. A study conducted in Surgut notes the highest and progressive incidence of diseases of the respiratory system and pathologies that make up metabolic syndrome — diabetes mellitus and obesity [15]. Blood oxygenation is controlled by important functions of the cardiorespiratory system: inhalation, exhalation, depth of breathing and respiratory rate, as well as the condition and functional characteristics of red blood [35]. In residents of the European North, the levels of red blood cells circulating in the peripheral blood and hemoglobin are within the physiological norm for the immigrant population [3]. The peculiarities of morphological and physiological data of erythrocytes in the blood test of the population of the northern territories are associated with an increased intensification of erythropoiesis [74]. These processes are directly dependent on the severity of the climatic conditions of the regions of the European North and worsen as one moves north [74]. An increase in the volume of pulmonary ventilation in northerners at rest and a decrease in the vital capacity of the lungs (VC) in residents of the North were also revealed [22, 46, 65]. It has been established that in population of the Magadan region, living in uncomfortable conditions for more than 5 years, the value of VC is reduced by 3% compared to the control parameters of Moscow [42]. Features of lungs of the Middle Ob region immigrants were identified, which consisted of a more developed bronchial system, which ensured more efficient gas exchange [9].

In different seasons of light aperiodicity, depending on the polar night and polar day, changes in external respiration were revealed according to spirometric examinations of natives of the Far North, residents of Murmansk [20]. It has been proven that the indicators and structure of vital capacity in girls and boys, the respiratory volume and the nature of the relationships between the indicators that comprise them decrease. The magnitude of the respiratory volume is one of the most demonstrative criteria of the external respiratory system, characterizing its pattern. As a result of the conducted studies, it was established that during the polar day, the residents of the Far North have a lower respiratory volume than during the polar night [69].

The adverse effect of hypoxia on the body is that during the transition to the cold period of the year, the load on the respiratory system increases [51]. A decrease in the oxygen utilization function in immigrants living in the conditions of the northern region has been established [70].

Chronic hypoxia in the North is the main cause of increased activity of the respiratory system, manifested by tissue hypoxia, the action of a complex of geophysical factors of high latitudes, which in the future may lead to high incidence of respiratory diseases [25]. During the compensation phase, reactions that are characteristic of hypoxia are formed in the body of northerners: the utilization of oxygen from the inhaled air and the delivery of oxygen by blood increases, and then the coefficient of oxygen utilization by tissues increases [14]. The adaptation mechanism in immigrants of the Far North is accompanied by a complex of symptoms that includes chronic hypoxia with corresponding changes in the cardiovascular and respiratory systems, forced to “fight” for oxygen. In northerners, oxygen saturation in arterial blood does not differ from the corresponding indicators in mid-latitudes [27], while carbon dioxide tension in both arterial [36] and venous blood [3] is increased. The arteriovenous difference in oxygen significantly exceeds the norms of mid-latitudes [10], which reflects the metabolic restructuring of energy processes [8].

It has been found that high hemoglobin level in blood of immigrants contribute to better oxygen exchange [43]. The ability of the body of northerners to tolerate hypoxia depends on the individual genetic characteristics of their body, as well as on the time of year and environmental conditions. The observed low levels of red blood cells and hemoglobin negatively affect a person’s mental activity [54].

In conditions of the northern region, the greatest impact on the functional state of the body is exerted by cold and a specific heliogeomagnetic environment [72]. With continuous exposure to cold, there is a decrease in respiratory heat loss and protection of the respiratory tract from the effects of cold, leading to morphological and functional restructuring of the respiratory system and the oxygen transport system of the blood [56]. In the cold season, heat emission through the respiratory system is also saved by reducing ventilation, the minute respiratory volume and respiratory rate are reduced [47].

The extreme impact of the oscillatory dynamics of heliogeomagnetic activity on the human body occurs against the background of meteorological factors or through them [31]. The activation of cold receptors leads to the activation and excitation of thermoregulation centers, which in the future, as a rule, leads to increased intensification of energy exchange processes in the central nervous system [18].

A number of studies have demonstrated a decrease in the vital capacity of the immigrant population of the northern region [46, 65, 76]. It has been shown that with more than 10 years of experience in the north, the vital capacity value is significantly lower by 8.2%, which indicates a morphological restructuring of the lung parenchyma [1].

During spirometry examination of the external respiration parameters in immigrants of the North-East of Russia, it was revealed that in healthy men, the residual volume of the lungs (RVL) and the functional residual capacity of the

lungs (FRC) are most often significantly increased in winter. An increase in functional dead space has been proven in immigrants of the Magadan Region, which is 90–110 ml higher than its value in men living in Western Siberia [19]. A close study of the mechanisms of the FRC clearly showed that the parameters of the FRC depend on the influence of external environmental factors. There is an increase in FRC parameters due to the opening of reserve acini involved in gas exchange and ventilation of the lungs. The identified adaptive changes in the respiratory system contribute to the protection of bronchial tree from cold exposure and damage, as well as the economical expenditure of energy under cooling conditions [72]. In the conditions of the North, a change in the vital capacity may be a cause of the formation of signs of obstructive pulmonary disorders [50]. This is evidenced by a violation of bronchial patency, identified by the Tiffeneau index.

In the majority of both the immigrants and indigenous populations of the northern region, in combination with the effective adaptive restructuring of the respiratory system, destruction and atrophy of the mucociliary, elastic and muscular apparatuses of the respiratory tract may be observed, followed by the formation of a violation of the bronchial drainage function, an increase in bronchial resistance and dynamic compression of the small bronchi. These lead to a decrease in the efficiency of gas exchange and an increase in the unevenness of alveolar ventilation [46]. The nature of the morphological and functional changes in the respiratory system of immigrant population allows us to consider such changes as a manifestation of compensatory and protective reactions aimed at reducing heat loss and minimizing the impact of cold air on the respiratory tract [57].

Most studies show that the incidence of pulmonary pathology in the North is very high and reaches more than 55% of all diseases [64]. The peculiarities of the development of pathological processes of the respiratory system in the North include: hyperventilation of the lungs in combination with obstructive changes in respiratory volumes; shortness of breath with little physical exertion; hypertrophy of the right ventricle of the heart; decreased respiratory reserves; pulmonary hypertension; dilation of the pulmonary artery and increased pulmonary pattern [51]. When studying the functional state of the aerohematic barrier in humans in the conditions of the Far North, a reliable increase in surfactant was revealed in histologically normal lungs of individuals who had lived in the North for more than 5 years [3]. Chronic respiratory diseases in the migrant population living in the North are characterized by rapid progression and the manifestation of severe intoxication, unlike similar diseases in the middle latitudes. Despite adequate drug therapy, the diseases become protracted and are manifested by long periods of exacerbation and short remissions [51].

FEATURES OF CARDIOVASCULAR SYSTEM ADAPTATION IN NORTH CONDITIONS

For population of the North, the most important limiting factor in the formation of health is adaptation to climatic conditions. At the initial stage of adaptation in immigrant population in the North, hypertension often develop [51]. The right heart side is a subject to the greatest stress, which subsequently manifests itself as adaptive pulmonary hypertension. As the migrant population adapts and stays for a long time, living and working in the conditions of the North, there is a decrease and subsequent depletion of the adaptation reserves of the left heart side, which in some migrants leads to an increase in pressure in the vessels of the systemic circulation [1]. High pressure in the pulmonary circulation and pronounced changes in pulmonary ventilation are not only interconnected, but also interdependent [46]. A moderate increase of systolic pressure to 40 mm Hg in pulmonary artery is aimed at ensuring optimal blood flow to the lungs and optimizing oxygen transport delivery under conditions of increased energy exchange [60].

During the adaptation process of the migrant's body to cold, the sensitivity of tissues to norepinephrine also increases, which indicates the transition of the cardiorespiratory system to a more economical regulation path [13]. A study conducted in Arkhangelsk confirms that local exposure to low temperatures activates the sympathetic nervous system, causing a reflex increase in the concentration of norepinephrine, adenosine triphosphate, a decrease in the intensity of peripheral blood flow, and an increase in heart rate [74].

In people living in the Middle Ob region, there is a "rejuvenation" of arterial hypertension [3, 32], which, being a multifactorial disease, develops as a violation of the processes of human adaptation to environmental conditions in presence of genetically predetermined violations of regulatory mechanisms and against the background of emerging pathophysiological and involutional processes in the body [21]. Blood pressure in men and women in the European North is higher than in residents of comfortable climate zones, and its age-related increase over decades of life is more significant than in those living in warm climates [13]. The risk of developing hypertension increases threefold in the working population after 10 years of work in the North. Hypertension was detected in 13.2% of northerners aged 30–39 years [71]. In Chukotka, a higher incidence of hypertension is observed among the population aged 30 to 60 years. An unfavorable outcome of cardiovascular system's adaptation is vascular dystonia, which represents a phenomenon of maladaptation.

Reduced humidity in the air of the external environment in northern conditions leads to stress on the right side of

heart, accelerates energy and water metabolism, reduces diuresis by 19% [55], leading to hyperventilation syndrome [80]. The immigrant population has a larger heart compared to the indigenous inhabitants, since the cardiovascular system of migrants is forced to adapt to harsh environmental conditions, which required more intensive work in uncomfortable conditions. This made it possible to improve blood circulation and provide the body tissues with oxygen [26].

Heart rate (HR) is one of the main integral characteristics of the cardiovascular system state [29]. At rest, HR fluctuates in the range from 60 to 90 beats per minute [79]. Conducted studies prove that northerners have higher systolic and diastolic blood pressure and heart rate than average age norms [24].

The prevalence of high functional values of minute blood volume, pressure, and heart rate in the conditions of the Middle Ob region has been confirmed by studies on the cardiorespiratory system in residents of northern regions [28, 62]. It can be argued that an increase in heart rate in immigrant population living in the Northern conditions indicates intense cardiac activity even at rest [63]. These indicators increase progressively with increasing duration of residence in harsh conditions and ultimately lead to a decrease in the reserve capacity of the cardiovascular system and the chronotropic reserve of heart [12].

There is data that allows us to reliably say that heart rate depends on the type of blood circulation [49]. The lowest heart rate values are observed with the hypokinetic type of circulation in all subjects. The highest heart rate values are observed in eukinetic and hyperkinetic types of circulation. Along with an increase in heart rate, when adapting the cardiac system and cardiac activity to muscle loads, the main role is played by stroke volume (SV), an increase of which is an important condition for ensuring muscle activity [69].

Changes in blood pressure in immigrant population of the Middle Ob region are one of the controversial issues. A tendency towards a decrease in blood pressure is noted [11]. When studying the parameters of the cardiovascular system in immigrant population of Surgut, it was noted that systolic blood pressure (SBP) slightly exceeded the level of 130 mm Hg in men and was consistently higher than in women [17]. The functional health of the immigrant population is characterized by a more pronounced tension of the body's adaptive capabilities compared to the native population. A study conducted in the Yamalo-Nenets Autonomous Okrug clearly showed that the immigrant population is characterized by a significantly smaller number of people with vagotonia and a high percentage of people with sympathicotonia, which should be attributed to signs of tension of the adaptive mechanisms [73]. It should be noted that for the indigenous peoples of the North, the shift in vegetative regulation towards vagotonia is a genetically fixed adaptation mechanism, which is also confirmed by a number of studies [45].

Seasonal fluctuations in blood pressure have been identified in both healthy individuals and individuals suffering from arterial hypertension, with higher levels in winter compared to summer. This is associated with an increase in the level of catecholamines in blood and total peripheral vascular resistance [12]. Determining the chronotype of the human body leaves its mark on the daily fluctuations of the heart rate variability indices. Thus, individuals with the morning chronotype are characterized by a tendency to sympathicotonia in the morning, weakening at the end of the day. Individuals with the evening chronotype are characterized by the manifestation of signs of sympathetic cardiointervalogram in the evening [24].

Morphofunctional changes in cardiac activity, which manifest themselves in the form of neurocirculatory dystonia in young people and increased blood pressure in older age groups, were identified in 55% of the examined people living in the North [13]. Every third of the examined northerners suffers from hypertension at the age of 20–59 years, with 60% of all cases of arterial hypertension occurring before the age of 40 years [51].

The fact that hypertension is malignant in the North is confirmed by the greater severity and high frequency of hypertensive crises [70]. Residents of the North-West region of Russia have higher blood pressure and lipid metabolism disorders, which may be associated with unfavorable climatic conditions and lifestyle. Arterial hypertension was detected in 35.4% of cases among visiting residents of the Tyumen North [6]. Among working-age residents of Novy Urengoy, borderline arterial hypertension was detected in 16.2% of those examined, essential hypertension in 30.5%, and symptomatic hypertension in 4.1% [71]. The highest incidence of coronary heart disease (CHD) among residents of this region was observed in the winter months [12]. A study by Litovchenko et al. (2021) showed that at the age of 26 years and older, there is a risk of developing cardiovascular changes in male students working in the oil industry. Changes in indicators such as the endurance coefficient, the circulatory efficiency coefficient and the Ruffier test indicate a deviation from the age norm and a disruption of the cardiovascular system [40].

Heart rate variability (HRV) reflects the ability of the cardiovascular system (CVS) to adapt. HRV decreases with increasing age [77, 78]. Deviation from the norm of HRV indicators is an unfavorable prognostic factor [58]. Against the background of a general decrease in both time and frequency indices of HRV, the subjects show an increase in parasympathetic influences with lower indices of differentiated assessment of the condition in those living for no more than 6 months and a predominance of sympathetic tone

with a high level of personal anxiety in those living for more than six months. This is expressed in a hyperadaptive state of mobilization of energy and metabolic reserves [59]. In 62 healthy young people aged 20 to 30 years, using the Holter monitoring, episodes of sinus arrhythmia were detected in 90% of subjects, in contrast to healthy older people, and a night-time decrease in blood pressure in healthy subjects within 10–20% compared to the daytime level [16].

Analyzing the frequency of detection of variations in the electrical axis of the heart in the population living in Surgut, Nifontova O.L. and co-authors concluded that with age, regardless of gender, the frequency of deviations of the cardiac axis from its normal position increased and the appearance of a fairly large percentage of people of both sexes with a horizontal position of the heart and a deviation to the right or left was determined [49]. Thus, the central hemodynamics, heart rate, and electrocardiogram data served as the basis for the conclusions about the presence of a tendency for hypertrophic changes in the myocardium with age in northerners. Most often, hypertrophic changes were determined in the left atrium, less often in the right atrium [49].

CONCLUSION

The territories of the Far North and equivalent areas remain the main source of fuel and energy resources for Russia. The extensive development of northern regions attracts new human resources. The immigrant population of the North is forced to adapt to severe climatic and geographical conditions, and the cardiorespiratory system determines the adaptive capabilities of the entire organism. Literary data indicate a significant strain on the functional capabilities of the oxygen-transport system in northerners, which leads to a decrease in the efficiency of gas exchange and an increase in the unevenness of alveolar ventilation.

The immigrant population exhibits significant seasonal variability in the parameters of the cardiorespiratory system, hemodynamic characteristics and external respiration parameters undergo changes, and an increase in heart rate, blood pressure, pulmonary ventilation, minute respiratory volume, vital capacity of the lungs, and bronchial resistance are observed.

REFERENCES

1. Aver'yanova I.V., Vdovenko S.I. Otsenka stepeni napryazheniya funktsional'nogo sostoyaniya organizma cheloveka pri razlichnykh srokakh adaptatsii k usloviyam Severa. [Assessment of the degree of stress of the functional state of the human body at various times of adaptation to the conditions of the North]. Ekologiya cheloveka. 2021; 7: 12–7. (in Russian).
2. Aver'yanova I.V., Maksimov A.L. Osobennosti perestroek kardiogemodinamiki i variabel'nosti serdechnogo ritma u evropeoidov — migrantov i urozhentsev Severa pervogo i vtorogo pokoleniy pri aktivnoy ortostaticheskoy probe. [Features of alterations of cardiohemodynamics and heart rate variability in Caucasians — migrants and natives of the North of the first and second generations with an active orthostatic test]. Sibirskiy nauchnyy meditsinskiy zhurnal. 2021; 41(3): 45–52. (in Russian).
3. Avtsyn A.P., Maracheev A.G., Matveev L.N. Vestnik AMN SSSR. [Sciences of the USSR]. 1979; 6: 32–9. (in Russian).
4. Agadzhanyan N.A. Ekologicheskaya fiziologiya cheloveka. [Environmental physiology of man]. Kruk Publ.; 1998. (in Russian).
5. Agadzhanyan N.A., Baevskiy R.M., Berseneva A.P. Problemy adaptatsii i uchenie o zdorov'e: RUDN. [Adaptation problems and health doctrine: RUDN]. 2006. (in Russian).
6. Akimov A.M. Zdorov'e sberezhenie uchastnikov osvoeniya arkticheskogo neftegazovogo regiona: monografiya. [Health savings of participants in the development of the Arctic oil and gas region: monograph]. Tyumen'; 2019. (in Russian).
7. Andronova T.I. Otsenka meteotropnykh reaktsiy organizma cheloveka k faktoram vneshney sredy: metod.razrabotki. [Assessment of meteorotropic reactions of the human body to environmental factors: methods of developmen]. Institut klinicheskoy i eksperimental'noy meditsiny. Novosibirsk; 1979. (in Russian).
8. Boyko E.R. Fiziologo-biokhimicheskie osnovy zhiznedeyatel'nosti cheloveka na Severe. [Assessment of meteorotropic reactions of the human body to environmental factors: methods of developmen]. Ekaterinburg: UrO RAN; 2005. (in Russian).
9. Borisenko I.V., Kosykh E.V., Kharlamov A.N. Osobennosti funktsional'nogo sostoyaniya legkikh zhiteley Srednego Priob'ya. [Features of the functional state of the lungs of residents of the Middle Priobye]. Vestnik Tomskogo gosudarstvennogo universiteta. 2017; 2: 94–102. (in Russian).
10. Bichkaeva F.A. Rezervnye vozmozhnosti endokrinnoy regulyatsii metabolicheskikh protsessov u cheloveka na Severe. [Reserve capabilities of endocrine regulation of metabolic processes in humans in the North]. Institut fiziologii prirodnykh adaptatsiy Ural'skogo otdeleniya Rossiyskoy akademii nauk. 2006. (in Russian).
11. Bobrov N.I., Lomov O.P., Tikhomirov V.P. Fiziologo-gigienicheskie aspekty akklimatizatsii cheloveka na Severe. [Physical and hygienic aspects of human acclimatization in the North]. Gigiena i sanitariya. 1979; 3: 75–8. (in Russian).
12. Vanyushin Yu.S., Khayrullin R.R., Elistratov D.E., Fedorov N.A. Adaptatsiya kardiorespiratornoy sistemy k dvigatel'noy deyatel'nosti. [Adaptation of the cardiorespiratory system to motor activity]. Fiziologiya sporta. Kazan'. 2020; 2: 31–2. (in Russian).
13. Varlamova N.G., Boyko E.R. Ob»emnye kharakteristiki funktsii vneshnego dykhaniya v godovom tsikle. [Volumetric characteristics of the external respiration function in the annual cycle]. Vestnik Tomskogo gosudarstvennogo universiteta. 2021; 55: 77–96. (in Russian).
14. Vasil'eva A., Konkieva N.A. Adaptatsiya cheloveka k usloviyam Kraynego Severa. [Adaptation of man to the conditions of the Far North]. Materialy VII Mezhdunarodnoy studencheskoy elektronnoy

nauchnoy konferentsii «Studencheskiy nauchnyy forum»; 2015. (in Russian).
15. Verizhnikova L.N., Aryamkina O.L., Terent'eva N.N. Somaticheskaya patologiya u zhiteley Khanty-Mansiyskogo avtonomnogo okruga — Yugry. [Somatic pathology in residents of the Khanty-Mansiysk Autonomous Okrug — Ugra]. Byulleten' sibirskoy meditsiny. 2020; 2: 13–9. (in Russian).
16. Voronin I.M., Bazhenova E.A. Variabel'nost' arterial'nogo davleniya v norme i pri patologii. [Variability in blood pressure is normal and in pathology]. Vestnik Tambovskogo universiteta. Seriya: estestvennye i tekhnicheskie nauki. 2007; 1(12). (in Russian).
17. Grigoruk S.D. Faktor meteochuvstvitel'nosti v razvitii serdechnoy nedostatochnosti u bol'nykh serdechno-sosudistogo kontinuuma. [Variability in blood pressure is normal and in pathology]. Materialy VI ezhegodnoy konferentsii Obshcherossiyskoy obshchestvennoy organizatsii: tezisy dokl. nauch. konf. Moskva: Institut biokhimii i genetiki; 2005: 37–9. (in Russian).
18. Gribanov A.V., Anikina N.Yu., Kottsova O.N. Raspredelenie tserebral'nykh energeticheskikh protsessov u molodykh lyudey, postoyanno prozhivayushchikh v Arkticheskom regione. [Kottsova Distribution of cerebral energy processes in young people permanently residing in the Arctic region]. Zhurn. med.-biol. issledovaniy. 2019; 1 (7): 118–23. (in Russian).
19. Gudkov A.B., Degteva G.N., Shepeleva O.A. Ekologo-gigienicheskie problemy na Arkticheskikh territoriyakh intensivnoy promyshlennoy deyatel'nosti (obzor). [Ecological and hygienic problems in the Arctic territories of intensive industrial activity (review)]. Obshchestvennoe zdorov'e. 2021; 1(4): 49–55. (in Russian).
20. Gudkov A.B., Popova O.N., Shcherbina Yu.F. Izmenenie prokhodimosti dykhatel'nykh putey u zhiteley kraynego Severa v kontrastnye sezony goda. [Change in airway patency among residents of the Far North in the contrasting seasons of the year]. Arkhangel'sk. 2013; 33–40. (in Russian).
21. Dzhanashiya P.Kh., Poteshkina N.G., Selivanova G.B. Arterial'naya gipertenziya. [Arterial hypertension]. Miklosh Publ., 2007. (in Russian).
22. Evdokimov V.G. Vozmozhnye puti normalizatsii sostoyaniya organizma cheloveka v usloviyakh Severa. [Possible ways to normalize the state of the human body in the conditions of the North]. Tez. dokl. II simpoziuma s mezhdunar. Uchastiem. Syktyvkar. 2004. (in Russian).
23. Es'kov V.M., Gudkov A.B., Filatov M.A. Printsipy gomeostaticheskogo regulirovaniya funktsiy organizma v ekologii cheloveka. [Principles of homeostatic regulation of body functions in human ecology]. Ekologiya cheloveka. 2019; 10: 41–9. (in Russian).
24. Zenina O.Yu., Makarova I.I., Ignatova Yu.P., Aksenova A.V. Khronofiziologiya i khronopatologiya serdechno-sosudistoy sistemy (obzor literatury). [Chronophysiology and chronopathology of the cardiovascular system (literature review)]. Ekologiya cheloveka. 2017; 1: 25–33. (in Russian).
25. Zyryanov B.N., Sokolova T.F. Adaptatsionnye reaktsii i immunitet u prishlogo naseleniya kraynego severa. [Adaptation reactions and immunity in the alien population of the far north]. Nauchnyy vestnik Yamalo-Nenetskogo avtonomnogo okruga. 2021; 2(111): 48–58. (in Russian).
26. Irzhak L.I., Dudnikova E.A., Parshukova A.N. i dr. Vliyanie fizicheskoy nagruzki na bioelektricheskuyu aktivnost' serdtsa zhiteley Evropeyskogo Severa Rossii. [Effect of physical activity on the bioelectric activity of the heart of residents of the European North of Russia]. Ekologiya cheloveka. 2021; 7: 35–42. (in Russian).
27. Kaznacheev V.P. Sovremennye aspekty adaptatsii. [Modern aspects of adaptation]. Novosibirsk: Nauka Publ. 1980. (in Russian).
28. Kandror I.S. Ocherki po fiziologii i gigiene cheloveka na Kraynem Severe. [Essays on human physiology and hygiene in the Far North]. Moskva: Meditsina Publ. 1968. (in Russian).
29. Kapel'ko V.I. Fiziologiya serdtsa i sosudistoy sistemy [Physiology of the heart and vascular system]. Vestnik Rossiyskogo fonda fundamental'nykh issledovaniy. 2017; 1: 78–86. (in Russian).
30. Karpin V.A. Meditsinskaya ekologiya Severa: aktual'nost', dostizheniya i perspektivy (obzor literatury). [Medical Ecology of the North: Relevance, Achievements and Perspectives (literature review)]. Ekologiya cheloveka. 2021; 8: 4–11. (in Russian).
31. Karpin V.A., Gudkov A.B., Shuvalova O.I. Analiz vozdeystviya klimatotekhnogennogo pressinga na zhiteley severnoy urbanizirovannoy territorii. [Analysis of the impact of climatotechnogenic pressure on residents of the northern urbanized territory]. Ekologiya cheloveka. 2018; 10: 9–14. (in Russian).
32. Katyukhin V.N. Arterial'naya gipertenziya na Severe. [Arterial hypertension in the North]. Monografiya. Surgutskiy gosudarstvennyy univer. Surgut; 2000. (in Russian).
33. Kim L.B. Transport kisloroda pri adaptatsii cheloveka k usloviyam Arktiki i kardiorespiratornoy patologii. [Oxygen transport in human adaptation to Arctic conditions and cardiorespiratory pathology]. Novosibirsk. 2015. (in Russian).
34. Koynosov P.G., Chiryat'eva T.V., Orlov S.A. i dr. Anatomo-antropologicheskie osobennosti fizicheskogo razvitiya zhiteley Srednego Priob'ya. [Anatomical and anthropological features of the physical development of residents of the Middle Priobye]. Meditsinskaya nauka i obrazovanie Urala. 2016; 17. (in Russian).
35. Koval'kova N.A., Travnikova N.Yu., Ragino Yu.I., Voevoda M.I. Rasprostranennost' disfunktsii vneshnego dykhaniya u molodykh lyudey. [Prevalence of respiratory dysfunction in young people]. Terapevticheskiy arkhiv. 2017; 3: 38–42. (in Russian).
36. Kozyreva T.V. Vliyanie Sa (2+) na termoregulyatornye reaktsii, sostav oipoproteidov krovi i immunnyy otvet pri deystvii kholoda na organizm v norme i pri arterial'noy gipertenzii. [Influence of Sa (2+) on thermoregulatory reactions, composition of blood oipoproteins and immune response under cold action on the body in normal and arterial hypertension]. Byulleten' SO RAMN. Novosibirsk. 2000; 4(126): 138–44. (in Russian).
37. Korchin V.I., Korchina T.Ya., Ternikova E.M. i dr. Vliyanie klimatogeograficheskikh faktorov Yamalo-Nenetskogo avtonomnogo okruga na zdorov'e naseleniya. [Effect of climatogeographic factors of

the Yamalo-Nenets Autonomous Okrug on population health. Journal of Biomedical Research]. Zhurnal mediko-biologicheskikh issledovaniy. 2021; 1(1): 77–88. (in Russian).
38. Krivoshchekov S.G., Okhotnikov S.V. Proizvodstvennye migratsii i zdorov'e cheloveka na Severe. [Industrial migrations and human health in the North]. Moskva–Novosibirsk: Izd-vo SO RAMN; 2000. (in Russian).
39. Litovchenko O.G., Bagnetova E.A., Tostanovskiy A.V. Ekologo-fiziologicheskie aspekty zdorov'e sberezheniya molodogo naseleniya Yugry. [Ecological and physiological aspects of the health of the savings of the young population of Ugra]. Sovremennye voprosy biomeditsiny. 2022; 1(6). (in Russian).
40. Litovchenko O.G., Ivanova N.L., Nishetenko E.Yu. Pokazateli molodykh rabotnikov neftyanoy otrasli Khanty-Mansiyskogo avtonomnogo okruga — Yugry. [Indicators of young workers in the oil industry of the Khanty-Mansiysk Autonomous Okrug–Ugra]. Chelovek. Sport. Meditsina. 2021; 1(21): 80–5. (in Russian).
41. Lebedeva-Nesevrya N.A., Barg A.O., Chechkin V.M. Prirodno-klimaticheskie i antropogennye faktory riska dlya zdorov'ya v sub»ektivnykh otsenkakh zhiteley gorodov kraynego severa. [Natural-climatic and anthropogenic health risk factors in subjective assessments of residents of cities of the far north]. Zdorov'e naseleniya i sreda obitaniya. 2020; 7(328): 8–13. (in Russian).
42. Lugovaya E.A., Aver'yanova I.V. Otsenka koeffitsienta napryazheniya adaptatsionnykh perestroek organizma pri khronicheskom vozdeystvii Severa. [Assessment of the stress coefficient of adaptation rearrangements of the body under chronic exposure to the North]. Analiz riska zdorov'yu. 2020; 2: 84–2. (in Russian).
43. Mayorova E.L., Kalacheva A.G., Voronkova I.A. Funktsional'noe sostoyanie kardiorespiratornoy sistemy u naseleniya Srednego Priob'ya. [Functional state of the cardiorespiratory system in the population of the Middle Priobye]. Sibirskiy meditsinskiy zhurnal. 2015; 5(30): 5–9. (in Russian).
44. Marasanov A.V., Stekhin A.A., Yakovleva G.V. Podkhod k obespecheniyu zdorov'esberezheniya naseleniya Arkticheskoy zony Rossiyskoy Federatsii (obzor). [Approach to ensuring the health of the population of the Arctic zone of the Russian Federation (review)]. Zhurnal mediko-biologicheskikh issledovaniy. 2021; 2(9): 201–12. (in Russian).
45. Markin V.V., Silin A.N., Vershinin I.S. Zdorov'e lyudey v Arktike: sotsial'no-prostranstvennyy diskurs (na primere Yamalo-Nenetskogo avtonomnogo okruga). [Health of people in the Arctic: socio-spatial discourse (using the example of the Yamalo-Nenets Autonomous Okrug)]. Ekonomicheskie i sotsial'nye peremeny: fakty, tendentsii, prognoz. 2020; 5(13): 182–99. (in Russian).
46. Marachev A.G. Patologiya cheloveka na Severe. [Human pathology in the North]. Moskva: Meditsina Publ.; 1985. (in Russian).
47. Matyukhin V.A., Razumov A.N. Ekologicheskaya fiziologiya cheloveka i vosstanovitel'naya meditsina [Environmental physiology of man and restorative medicine]. Moskva: Meditsina; 2009. (in Russian).
48. Naymushina A.G., Bakieva E.M., Solov'eva S.V. i dr. Psikhofiziologicheskie markery adaptatsii u muzhchin aktivnogo trudosposobnogo vozrasta, prozhivayushchikh na yuge i severe Tyumenskoy oblasti. [Psychophysiological adaptation markers in men of active working age living in the south and north of the Tyumen region]. Meditsinskaya nauka i obrazovanie Urala. 2020; 4(104): 35–40. (in Russian).
49. Nifontova O.L. Vozrastnaya izmenchivost' elektricheskoy aktivnosti serdtsa zhiteley Yugry. [Age variability of the electrical activity of the heart of residents of Ugra]. Vestnik Surgutskogo gosudarstvennogo pedagogicheskogo universiteta. Surgut; 2014: 11–7. (in Russian).
50. Nifontova O.L., Kon'kova K.S. Osobennosti parametrov vneshnego dykhaniya korennykh zhiteley Khanty-Mansiyskogo avtonomnogo okruga — Yugry v vozraste 11–14 let. [Features of external breathing parameters of the indigenous inhabitants of the Khanty-Mansiysk Autonomous Okrug — Ugra at the age of 11–14 years]. Ekologiya cheloveka. 2019; 8: 18–24. (in Russian).
51. Ovechkina E.S., Ovechkin F.Yu. Patofiziologiya cheloveka v usloviyakh severa Rossii. [Human pathophysiology in the north of Russia]. Byulleten' nauki i praktiki. 2021; 8(7): 185–91. (in Russian).
52. Pak A.V., Trufanova K.G. Vliyanie polyarnogo dnya i polyarnoy nochi na organizm cheloveka [Effects of polar day and polar night on the human body]. Byulleten' Severnogo gosudarstvennogo meditsinskogo universiteta. 2018; 1(40): 300–1. (in Russian).
53. Parshukova O.I., Varlamova N.G., Boyko E.R. Funktsional'naya rol' metabolitov oksida azota u vysokokvalifitsirovannykh lyzhnikov-gonshchikov s gipertonicheskoy reaktsiey na fizicheskuyu nagruzku. [Functional role of nitric oxide metabolites in highly qualified skier riders with hypertensive response to physical activity]. Chelovek. Sport. Meditsina. 2022; 2(22): 55–60. (in Russian).
54. Petrova N.B., Goncharov N.I., Nakhimova M.A. Kolichestvennye parametry i funktsional'nye svoystva eritrotsitov cheloveka na Severe. [Quantitative parameters and functional properties of human red blood cells in the North]. Vestnik Syktyvkarskogo universiteta. 2022; 3: 80–8. (in Russian).
55. Pogonysheva I.A., Pogonyshev D.A. Osobennosti morfofunktsional'nykh parametrov organizma molodykh lyudey, prozhivayushchikh v raznykh klimatogeofizicheskikh usloviyakh okruzhayushchey sredy. [Features of morphofunctional parameters of the body of young people living in different climatogeophysical environmental conditions]. Vestnik Nizhnevartovskogo gosudarstvennogo universiteta. 2017; 1: 68–74. (in Russian).
56. Pogonysheva I.A., Pogonyshev D.A., Postnikova V.V. Dinamika osnovnykh pokazateley fizicheskogo razvitiya studentov severnogo vuza. [Dynamics of the main indicators of the physical development of students of the northern university]. Teoriya i praktika fizicheskoy kul'tury. 2019; 8: 33–5. (in Russian).
57. Pushkina V.N., Gernet I.N., Olyashev N.V., Lubyshev E.A. Sostoyanie sistemy vneshnego dykhaniya u yunoshey, prozhivayushchikh v raznykh regionakh Rossii. [The state of the respiratory system in young men living in different regions of Russia]. Teoriya i praktika fizicheskoy kul'tury. 2020; 4: 17–9. (in Russian).
58. Prekina V.I., Chernova I.Yu., Efremova O.N., Esina M.V. Variabel'nost' serdechnogo ritma u zdorovykh lyudey. [Variability of heart rate in healthy people]. RKZh. 2020; 2. (in Russian).

59. Pryanichnikov S.V. Psikhofiziologicheskoe sostoyanie organizma v zavisimosti ot dlitel'nosti prebyvaniya v vysokikh shirotakh Arktiki. [Psychophysiological state of the body depending on the duration of stay in the high latitudes of the Arctic]. Ekologiya cheloveka. 2020; 12: 4–10. (in Russian).
60. Rusak S.N., Filatova O.E., Bikmukhametova L.M. Meteochuvstvitel'nye zabolevaniya naseleniya Yugry v usloviyakh pogodnoy izmenchivosti. [Meteorological-sensitive diseases of the population of Ugra in conditions of weather variability]. Vestnik novykh meditsinskikh tekhnologiy. 2017; 1: 30–7. (in Russian).
61. Saltykova M.M., Bobrovnitskiy I.P., Yakovlev M.Yu. i dr. Novyy podkhod k analizu vliyaniya pogodnykh usloviy na organizm cheloveka. [A new approach to analyzing the impact of weather conditions on the human body]. Gigiena i sanitariya. 2018; 11(97); 1038–42. (in Russian).
62. Serdyukovskaya G.N., red. Vnutrennie bolezni i funktsional'nye rasstroystva v podrostkovom vozraste. Okhrana zdorov'ya podrostkov. [Internal diseases and functional disorders in adolescence. Adolescent Health Care]. Moskva: Promedek Publ.; 1993. (in Russian).
63. Sokolov S.F. Klinicheskoe znachenie otsenki variabel'nosti serdechnogo ritma. [Clinical significance of estimating heart rate variability]. Serdtse. 2002; 2: 72–5. (in Russian).
64. Solov'ev V.S., Litovchenko O.G., Solov'eva S.V. i dr. Opyt kompleksnykh issledovaniy v izuchenii adaptatsii na Severe. [Experience in comprehensive studies in the study of adaptation in the North]. Vestnik Surgutskogo gosudarstvennogo universitetata. 2016; 3(13): 54–6. (in Russian).
65. Solonin Yu.G. Issledovaniya po shirotnoy fiziologii (obzor). [Studies in latitudinal physiology (review)]. Zhurnal mediko-biologicheskikh issledovaniy. 2019; 2(7): 228–39. (in Russian).
66. Staroded A.S., Maydan V.A., Tsvetkov S.V. Vliyanie medikogeograficheskikh osobennostey kraynego severa na protsessy adaptatsii. [Influence of medicogeographic features of the far north on adaptation processes]. Izvestiya Rossiyskoy Voennomeditsinskoy akademii. 2020; 3–5(39): 160–3. (in Russian).
67. Ustyushin B.V., Dedenko I.I. Osobennosti obespecheniya gomeostaza organizma cheloveka na Kraynem Severe. [Features of ensuring homeostasis of the human body in the Far North]. Vestnik AMN. 1992; 1: 6–10. (in Russian).
68. Utenkova E.O., Kaluzhskikh T.I. Estestvennoe proepidemichivanie u lits, prozhivayushchikh v endemichnykh rayonakh. [Natural epidemic in people living in endemic areas]. Zhurnal infektologii. 2020; 4(12): 112–3. (in Russian).
69. Filatova O.E., Gudkov A.B., Es'kov V.V., Chempalova L.S. Ponyatie odnorodnosti gruppy v ekologii cheloveka. [The concept of group homogeneity in human ecology]. Ekologiya cheloveka. 2020; 2: 40–4. (in Russian).
70. Frolkov V.K., Nagornev S.N., Bobrovnitskiy I.P. Patofiziologicheskie mekhanizmy neblagopriyatnogo vliyaniya klimatogeograficheskikh faktorov Arktiki na zdorov'e cheloveka i tekhnologii vosstanovitel'noy meditsiny. [Pathophysiological mechanisms of the adverse effect of climatogeographic factors of the Arctic on human health and technologies of restorative medicine]. Fizioterapevt. 2020; 1: 57–63. (in Russian).
71. Hajcev N.V., Vasil'ev A.G., Trashkov A.P. i dr. Vliyanie vozrasta i pola na harakter otvetnyh reakcij belyh krys pri dejstvii hronicheskoj gipoksicheskoj gipoksii. [The Influence of age and sex on the character of responce reactions of white rats to chronical hypoxic hypoxia]. Pediatr. 2015; 6(2): 71–7. (in Russian).
72. Khasnulin V.I., Voevoda M.I., Khasnulin P.V., Artamonova O.G. Sovremennyy vzglyad na problemu arterial'noy gipertenzii v pripolyarnykh i arkticheskikh regionakh. Obzor literatury. [A modern look at the problem of arterial hypertension in the circumpolar and Arctic regions. Literature review]. Ekologiya cheloveka. 2016; 3: 43–51. (in Russian).
73. Chashchin V.P., Gudkov A.B., Chashchin M.V., Popova O.N. Prediktivnaya otsenka individual'noy vospriimchivosti organizma cheloveka k opasnomu vozdeystviyu kholoda. [Predictive assessment of the individual susceptibility of the human body to the dangerous effects of cold]. Ekologiya cheloveka. 2017; 5: 3–13. (in Russian).
74. Shaymardanov A.R. Otsenka funktsional'nogo sostoyaniya organizma korennogo i prishlogo naseleniya v usloviyakh kraynego severa. [Assessment of the functional state of the body of the indigenous and alien population in the conditions of the far north]. Sovremennye voprosy biomeditsiny. 2022; 2(2). (in Russian).
75. Shan'gina A.A., Popova O.N., Tikhonova E.V. i dr. Osobennosti reaktsii legochnogo gazoobmena na lokal'noe kholodovoe vozdeystvie u molodykh lits trudosposobnogo vozrasta. [Features of the reaction of pulmonary gas exchange to local cold exposure in young people of working age]. Ekologiya cheloveka. 2018; 5: 33–8. (in Russian).
76. Abdurakhmonov S. K. The Importance Of A Healthy Lifestyle In Achieving Physical Perfection. The American Journal of Applied sciences. 2021; 3(03): 42–7.
77. Bassett Jr., Howley E.T. Limiting factors for maximum oxygen and determinants of endurance performance. Medicine and Science in Sports and Exercise. 2000; 32(1): 70–84.
78. Brewer H., Jalongo M.R. Physical Activity and Health Promotion in the Early Years: Effective. Springer. 2018; 14.
79. Brown S.J., Barnes M.J., Mündel T. Effects of hypoxia and hypercapnia on human HRV and respiratory sinus arrhythmia. Acta Physiol. Hung. 2014; 101: 263–72.
80. Garcia-Retortillo S., Javierre C., Hristovski R. et al. Cardiorespiratory coordination reveals training-specific physiological adaptations. Eur. J. Appl. Physiol. 2019; 119: 1701–9.
81. Goldberg S., Ollila H.M., Lin L. et al. Analysis of hypoxic and hypercapnic ventilatory response in healthy volunteers. 2017.
82. Lindsey B.G., Nuding S.C., Segers L.S., Morris K.F. Carotid bodies and the integrated cardiorespiratory response to hypoxia. Physiology. 2018; 33: 281–97.

ЛИТЕРАТУРА

1. Аверьянова И.В., Вдовенко С.И. Оценка степени напряжения функционального состояния организма человека при различ-

ных сроках адаптации к условиям Севера. Экология человека. 2021; 7: 12–7.
2. Аверьянова И.В., Максимов А.Л. Особенности перестроек кардиогемодинамики и вариабельности сердечного ритма у европеоидов — мигрантов и уроженцев Севера первого и второго поколений при активной ортостатической пробе. Сибирский научный медицинский журнал. 2021; 41(3): 45–52.
3. Авцын А.П., Марачеев А.Г., Матвеев Л.Н. Вестник АМН СССР. 1979; 6: 32–9.
4. Агаджанян Н.А. Экологическая физиология человека. Крук» 1998.
5. Агаджанян Н.А., Баевский Р.М., Берсенева А.П. Проблемы адаптации и учение о здоровье: РУДН; 2006.
6. Акимов А.М. Здоровье сбережение участников освоения арктического нефтегазового региона: монография. Тюмень; 2019.
7. Андронова Т.И. Оценка метеотропных реакций организма человека к факторам внешней среды: метод. разработки. Институт клинической и экспериментальной медицины. Новосибирск; 1979.
8. Бойко Е.Р. Физиолого-биохимические основы жизнедеятельности человека на Севере. Екатеринбург: УрО РАН; 2005.
9. Борисенко И.В., Косых Е.В., Харламов А.Н. Особенности функционального состояния легких жителей Среднего Приобья. Вестник Томского государственного университета. 2017; 2: 94–102.
10. Бичкаева Ф.А. Резервные возможности эндокринной регуляции метаболических процессов у человека на Севере. Институт физиологии природных адаптаций Уральского отделения Российской академии наук. 2006.
11. Бобров Н.И., Ломов О.П., Тихомиров В.П. Физиолого-гигиенические аспекты акклиматизации человека на Севере. Гигиена и санитария. 1979; 3: 75–8.
12. Ванюшин Ю.С., Хайруллин Р.Р., Елистратов Д.Е., Федоров Н.А. Адаптация кардиореспираторной системы к двигательной деятельности. Физиология спорта. Казань. 2020; 2: 31–2.
13. Варламова Н.Г., Бойко Е.Р. Объемные характеристики функции внешнего дыхания в годовом цикле. Вестник Томского государственного университета. 2021; 55: 77–96.
14. Васильева А., Конкиева Н.А. Адаптация человека к условиям Крайнего Севера. Материалы VII Международной студенческой электронной научной конференции «Студенческий научный форум»; 2015.
15. Верижникова Л.Н., Арямкина О.Л., Терентьева Н.Н. Соматическая патология у жителей Ханты-Мансийского автономного округа — Югры. Бюллетень сибирской медицины. 2020; 2: 13–9.
16. Воронин И.М., Баженова Е.А. Вариабельность артериального давления в норме и при патологии. Вестник Тамбовского университета. Серия: естественные и технические науки. 2007; 1(12).
17. Григорук С.Д. Фактор метеочувствительности в развитии сердечной недостаточности у больных сердечно-сосудистого континуума. Материалы VI ежегодной конференции Общероссийской общественной организации: тезисы докл. науч. конф. М.: Институт биохимии и генетики; 2005: 37–9.
18. Грибанов А.В., Аникина Н.Ю., Котцова О.Н. Распределение церебральных энергетических процессов у молодых людей, постоянно проживающих в Арктическом регионе. Журн. мед.-биол. исследований. 2019; 1(7): 118–23.
19. Гудков А.Б., Дегтева Г.Н., Шепелева О.А. Эколого-гигиенические проблемы на Арктических территориях интенсивной промышленной деятельности (обзор). Общественное здоровье. 2021; 1(4): 49–55.
20. Гудков А.Б., Попова О.Н., Щербина Ю.Ф. Изменение проходимости дыхательных путей у жителей крайнего Севера в контрастные сезоны года. Архангельск. 2013; 33–40.
21. Джанашия П.Х., Потешкина Н.Г., Селиванова Г.Б. Артериальная гипертензия. Миклош; 2007.
22. Евдокимов В.Г. Возможные пути нормализации состояния организма человека в условиях Севера. Тез. докл. II симпозиума с междунар. участием. Сыктывкар; 2004: 38.
23. Еськов В.М., Гудков А.Б., Филатов М.А. Принципы гомеостатического регулирования функций организма в экологии человека. Экология человека. 2019; 10: 41–9.
24. Зенина О.Ю., Макарова И.И., Игнатова Ю.П., Аксенова А.В. Хронофизиология и хронопатология сердечно-сосудистой системы (обзор литературы). Экология человека. 2017; 1: 25–33.
25. Зырянов Б.Н., Соколова Т.Ф. Адаптационные реакции и иммунитет у пришлого населения крайнего севера. Научный вестник Ямало-Ненецкого автономного округа. 2021; 2(111): 48–58.
26. Иржак Л.И., Дудникова Е.А., Паршукова А.Н. и др. Влияние физической нагрузки на биоэлектрическую активность сердца жителей Европейского Севера России. Экология человека. 2021; 7: 35–42.
27. Казначеев В.П. Современные аспекты адаптации. Новосибирск: Наука; 1980: 191.
28. Кандрор И.С. Очерки по физиологии и гигиене человека на Крайнем Севере. М.: Медицина; 1968.
29. Капелько В.И. Физиология сердца и сосудистой системы. Вестник Российского фонда фундаментальных исследований. 2017; 1: 78–86.
30. Карпин В.А. Медицинская экология Севера: актуальность, достижения и перспективы (обзор литературы). Экология человека. 2021; 8: 4–11.
31. Карпин В.А., Гудков А.Б., Шувалова О.И. Анализ воздействия климатотехногенного прессинга на жителей северной урбанизированной территории. Экология человека. 2018; 10: 9–14.
32. Катюхин В.Н. Артериальная гипертензия на Севере. Монография. Сургутский государственный универ. Сургут; 2000.
33. Ким Л.Б. Транспорт кислорода при адаптации человека к условиям Арктики и кардиореспираторной патологии. Новосибирск; 2015.
34. Койносов П.Г., Чирятьева Т.В., Орлов С.А. и др. Анатомо-антропологические особенности физического развития жителей Среднего Приобья. Медицинская наука и образование Урала. 2016; 17.

35. Ковалькова Н.А., Травникова Н.Ю., Рагино Ю.И., Воевода М.И. Распространенность дисфункции внешнего дыхания у молодых людей. Терапевтический архив. 2017; 3: 38–42.
36. Козырева Т.В. Влияние Са (2+) на терморегуляторные реакции, состав оипопротеидов крови и иммунный ответ при действии холода на организм в норме и при артериальной гипертензии. Бюллетень СО РАМН. Новосибирск. 2000; 4(126): 138–44.
37. Корчин В.И., Корчина Т.Я., Терникова Е.М. и др. Влияние климатогеографических факторов Ямало-Ненецкого автономного округа на здоровье населения. Журнал медико-биологических исследований. 2021; 1(1): 77–88.
38. Кривощеков С.Г., Охотников С.В. Производственные миграции и здоровье человека на Севере. Москва–Новосибирск: Изд-во СО РАМН; 2000.
39. Литовченко О.Г., Багнетова Е.А., Тостановский А.В. Эколого-физиологические аспекты здоровье сбережения молодого населения Югры. Современные вопросы биомедицины. 2022; 1(6).
40. Литовченко О.Г., Иванова Н.Л., Нишетенко Е.Ю. Показатели молодых работников нефтяной отрасли Ханты-Мансийского автономного округа — Югры. Человек. Спорт. Медицина. 2021; 1(21): 80–5.
41. Лебедева-Несевря Н.А., Барг А.О., Чечкин В. М. Природно-климатические и антропогенные факторы риска для здоровья в субъективных оценках жителей городов крайнего севера. Здоровье населения и среда обитания. 2020; 7(328): 8–13.
42. Луговая Е.А., Аверьянова И.В. Оценка коэффициента напряжения адаптационных перестроек организма при хроническом воздействии Севера. Анализ риска здоровью. 2020; 2: 84–2.
43. Майорова Е.Л., Калачева А.Г., Воронкова И.А. Функциональное состояние кардиореспираторной системы у населения Среднего Приобья. Сибирский медицинский журнал. 2015; 5(30): 5–9.
44. Марасанов А.В., Стехин А.А., Яковлева Г.В. Подход к обеспечению здоровьесбережения населения Арктической зоны Российской Федерации (обзор). Журнал медико-биологических исследований. 2021; 2(9): 201–12.
45. Маркин В.В., Силин А.Н., Вершинин И.С. Здоровье людей в Арктике: социально-пространственный дискурс (на примере Ямало-Ненецкого автономного округа). Экономические и социальные перемены: факты, тенденции, прогноз. 2020; 5(13): 182–99.
46. Марачев А.Г. Патология человека на Севере. М.: Медицина; 1985.
47. Матюхин В.А., Разумов А.Н. Экологическая физиология человека и восстановительная медицина. М.: Медицина; 2009.
48. Наймушина А.Г., Бакиева Э.М., Соловьева С.В. и др. Психофизиологические маркеры адаптации у мужчин активного трудоспособного возраста, проживающих на юге и севере Тюменской области. Медицинская наука и образование Урала. 2020; 4(104): 35–40.
49. Нифонтова О.Л. Возрастная изменчивость электрической активности сердца жителей Югры. Вестник Сургутского государственного педагогического университета. Сургут; 2014: 11–7.
50. Нифонтова О.Л., Конькова К.С. Особенности параметров внешнего дыхания коренных жителей Ханты-Мансийского автономного округа — Югры в возрасте 11–14 лет. Экология человека. 2019; 8: 18–24.
51. Овечкина Е.С., Овечкин Ф.Ю. Патофизиология человека в условиях севера России. Бюллетень науки и практики. 2021; 8(7): 185–91.
52. Пак А.В., Труфанова К.Г. Влияние полярного дня и полярной ночи на организм человека. Бюллетень Северного государственного медицинского университета. 2018; 1(40): 300–1.
53. Паршукова О.И., Варламова Н.Г., Бойко Е.Р. Функциональная роль метаболитов оксида азота у высококвалифицированных лыжников-гонщиков с гипертонической реакцией на физическую нагрузку. Человек. Спорт. Медицина. 2022; 2(22): 55–60.
54. Петрова Н.Б., Гончаров Н.И., Нахимова М.А. Количественные параметры и функциональные свойства эритроцитов человека на Севере. Вестник Сыктывкарского университета. 2022; 3: 80–8.
55. Погонышева И.А., Погонышев Д.А. Особенности морфофункциональных параметров организма молодых людей, проживающих в разных климатогеофизических условиях окружающей среды. Вестник Нижневартовского государственного университета. 2017; 1: 68–74.
56. Погонышева И.А., Погонышев Д.А., Постникова В.В. Динамика основных показателей физического развития студентов северного вуза. Теория и практика физической культуры. 2019; 8: 33–5.
57. Пушкина В.Н., Гернет И.Н., Оляшев Н.В., Лубышев Е.А. Состояние системы внешнего дыхания у юношей, проживающих в разных регионах России. Теория и практика физической культуры. 2020; 4: 17–9.
58. Прекина В.И., Чернова И.Ю., Ефремова О.Н., Есина М.В. Вариабельность сердечного ритма у здоровых людей. РКЖ. 2020; 2.
59. Пряничников С.В. Психофизиологическое состояние организма в зависимости от длительности пребывания в высоких широтах Арктики. Экология человека. 2020; 12: 4–10.
60. Русак С.Н., Филатова О.Е., Бикмухаметова Л.М. Метеочувствительные заболевания населения Югры в условиях погодной изменчивости. Вестник новых медицинских технологий. 2017; 1: 30–7.
61. Салтыкова М.М., Бобровницкий И.П., Яковлев М.Ю. и др. Новый подход к анализу влияния погодных условий на организм человека. Гигиена и санитария. 2018; 11(97); 1038–42.
62. Сердюковская Г.Н., ред. Внутренние болезни и функциональные расстройства в подростковом возрасте. Охрана здоровья подростков. М.: Промедэк; 1993.
63. Соколов С.Ф. Клиническое значение оценки вариабельности сердечного ритма. Сердце. 2002; 2: 72–5.
64. Соловьев В.С., Литовченко О.Г., Соловьева С.В. и др. Опыт комплексных исследований в изучении адаптации на Севере. Вестник Сургутского государственного университета. 2016; 3(13): 54–6.
65. Солонин Ю.Г. Исследования по широтной физиологии (обзор). Журнал медико-биологических исследований. 2019; 2(7): 228–39.
66. Стародед А.С., Майдан В.А., Цветков С.В. Влияние медико-географических особенностей крайнего севера на процессы адап-

тации. Известия Российской Военно-медицинской академии. 2020; 3–5(39): 160–3.
67. Устюшин Б.В., Деденко И.И. Особенности обеспечения гомеостаза организма человека на Крайнем Севере. Вестник АМН. 1992; 1: 6–10.
68. Утенкова Е.О., Калужских Т.И. Естественное проэпидемичивание у лиц, проживающих в эндемичных районах. Журнал инфектологии. 2020; 4(12): 112–3.
69. Филатова О.Е., Гудков А.Б., Еськов В.В., Чемпалова Л.С. Понятие однородности группы в экологии человека. Экология человека. 2020; 2: 40–4.
70. Фролков В.К., Нагорнев С.Н., Бобровницкий И.П. Патофизиологические механизмы неблагоприятного влияния климатогеографических факторов Арктики на здоровье человека и технологии восстановительной медицины. Физиотерапевт. 2020; 1: 57–63.
71. Хайцев Н.В., Васильев А.Г., Трашков А.П. и др. Влияние возраста и пола на характер ответных реакций белых крыс при действии хронической гипоксической гипоксии. Педиатр. 2015; 6(2): 71–7.
72. Хаснулин В.И., Воевода М.И., Хаснулин П.В., Артамонова О.Г. Современный взгляд на проблему артериальной гипертензии в приполярных и арктических регионах. Обзор литературы. Экология человека. 2016; 3: 43–51.
73. Чащин В.П., Гудков А.Б., Чащин М.В., Попова О.Н. Предиктивная оценка индивидуальной восприимчивости организма человека к опасному воздействию холода. Экология человека. 2017; 5: 3–13.
74. Шаймарданов А.Р. Оценка функционального состояния организма коренного и пришлого населения в условиях крайнего севера. Современные вопросы биомедицины. 2022; 2(2).
75. Шаньгина А.А., Попова О.Н., Тихонова Е.В. и др. Особенности реакции легочного газообмена на локальное холодовое воздействие у молодых лиц трудоспособного возраста. Экология человека. 2018; 5: 33–8.
76. Abdurakhmonov S. K. The Importance Of A Healthy Lifestyle In Achieving Physical Perfection. The American Journal of Applied sciences. 2021; 3(03): 42–7.
77. Bassett Jr., Howley E.T. Limiting factors for maximum oxygen and determinants of endurance performance. Medicine and Science in Sports and Exercise. 2000; 32(1): 70–84.
78. Brewer H., Jalongo M.R. Physical Activity and Health Promotion in the Early Years: Effective. Springer. 2018; 14.
79. Brown S.J., Barnes M.J., Mündel T. Effects of hypoxia and hypercapnia on human HRV and respiratory sinus arrhythmia. Acta Physiol. Hung. 2014; 101: 263–72.
80. Garcia-Retortillo S., Javierre C., Hristovski R. et al. Cardiorespiratory coordination reveals training-specific physiological adaptations. Eur. J. Appl. Physiol. 2019; 119: 1701–9.
81. Goldberg S., Ollila H.M., Lin L. et al. Analysis of hypoxic and hypercapnic ventilatory response in healthy volunteers. 2017.
82. Lindsey B.G., Nuding S.C., Segers L.S., Morris K.F. Carotid bodies and the integrated cardiorespiratory response to hypoxia. Physiology. 2018; 33: 281–97.