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SEASONAL FUNCTIONAL ORGANIZATION OF THE EXTERNAL RESPIRATION SYSTEM IN CHILDREN OF SENIOR SCHOOL AGE, RESIDENTS OF THE ARCTIC REGION

Abstract

The aim of the work is to reveal the peculiarities of the seasonal functional organization of the external respiration system in children of senior school age living in the Arctic region.

Methods.

35 boys (16.3 ± 0.13 years) and 35 girls (16.6 ± 0.2 years old), residents of Arkhangelsk were examined in different season (winter, spring, summer, autumn). The following parameters were evaluated by spirography: the lungs volumes and capacity, patency of airways, gas analysis of the expired air.

Results and discussion.

The parameters of external respiration system and character of its connection are changing during the year. In the group of boys moderate positive correlation were revealed between minute respiratory volume (V) and oxygen consumption (VO_2) in spring (r=0,531; p<0,01), in summer (r=0,592; p<0,05), and in autumn (r=0,664; p<0,01), but from spring to autumn it is getting stronger, and in winter it getting weaker and become statistically insignificant. In winter there is strong positive correlation between tidal volume (TV) and VO_2 (r=0.786; p<0.01), which in the other season were moderate or weak. The negative connection between V and oxygen utilization coefficient (UCO2) in winter and autumn were revealed. In the group of girls moderate positive correlation between V and VO_2 were revealed in spring (r=0.676; p<0F.01), and strong (r=0.765; p<0.01) in summer, but in winter and autumn it getting weaker and become statistically insignificant. At the same time in winter in the group of girls also were revealed moderate positive correlation between TV and VO_2 (r=0.663; p<0.01). In the other seasons this connection statistically insignificant. In spring strong positive correlation between VO_2 and UCO2 (r=0.797; p<0.01) was revealed.

Conclusions. During the summer and transitional seasons of the year (spring and autumn), the change in the oxygen demand of the organism is provided by a changes in the V, and in winter - by optimizing the gas exchange conditions and changes in the ratio of static lungs volumes (TV and ERV).

Keywords: Arctic region, children of senior school age, external breathing, seasonal changes, functional organization of respiration.

Introduction. Senior school age is the final stage of the body formation when the structural and functional maturity of many systems occurs, puberty occurs, and environmental factors have a significant impact on these processes. The Arctic territories are characterized by extreme climatic conditions that cause stress on all functional systems of the human body, especially in children [6, 8, 9]. Among the environmental factors of high latitudes emit a whole group of pulmonotropic, which have a direct effect on the respiratory system [4, 10]. Therefore, regular changes occur in the respiratory system during the year due to seasonal dynamics of climatic factors. At the same time, the direction and severity of functional changes depend on the severity of the climate in the place of residence of the person [3, 5]. It should be emphasized that within the framework of these changes, the external respiration system should perform its main function - to ensure the necessary level of oxygen consumption and carbon dioxide excretion for the organism [6, 11, 12].

Currently, there are information about the functional intersystem organization of external respiration in healthy men living in territories with a continental climate (Western Siberia) [3,10], as well as seasonal changes in the external respiration system in residents of a temperate continental climate (Komi Republic) [2]. Publications devoted to the analysis of the seasonal functional organization of the respiratory system in children are practically absent, which prompted the present study.

Objective of the study is to identify the features of the seasonal functional organization of the external respiration system in children of senior school age living in the Arctic region.

Research materials and methods. The study of the functional parameters of the respiratory system dynamics were carried out in practically healthy children of senior school age who were born and permanently reside in an area with a moderate maritime climate in the city of Arkhangelsk, which belongs to the Arctic zone of the Russian Federation (AZ RF) [7]. Examination of the same students was conducted four times in year - in winter (January), in spring (April), in summer (June) and autumn (September) with observance of ethical norms.

The method of spirography (microprocessor portable spirometer SMP-21/01 - "RD") examined 35 boys (16.3 ± 0.13 years) and 35 girls (16.6 ± 0.2 years). We did not include children with chronic respiratory diseases, acute illnesses and complaints on the day of the survey.

The study was conducted in the morning in 1.5 - 2 hours after breakfast, with maximum physical, mental rest and temperature comfort, in conditions close to the main exchange. All parameters were recorded in a sitting position.

The subjects assessed pulmonary volumes and capacities: tidal volume (TV), reserve inspiratory reserve volume (IRV), expiratory reserve volume (ERV), vital capacity (VC); indices of pulmonary ventilation: respiratory rate (RR) and minute respiratory volume (V); airway patency: forced expiratory volume in the first 1 second (FEV_1). The percentage content of oxygen (FeO_2) and carbon dioxide ($FeCO_2$) in exhaled air was determined by gas analyzer PGA-200. The value of oxygen consumption (VO_2) and oxygen utilization coefficient (UCO2) were calculated.

The obtained data were subjected to statistical processing using the SPSS 21.0 package. The normal distribution of the obtained variables was determined using the Shapiro – Wilk test (n≤50). The distribution of data differed from the normal one; therefore, Friedman analysis of variance was used; for pairwise comparisons, the Wilcoxon criterion for dependent samples using the Bonferroni correction. The results of non-parametric data processing methods were presented as a median (Me), first (Q1) and third (Q3) quartile. A correlation analysis was conducted with the determination of the non-parametric Spearman rank correlation coefficient. The critical level of significance (p) for all tested statistical hypotheses was taken as 0.05.

Results and discussion. A seasonal survey of children of senior school age, natives of AZ RF, made it possible to identify the peculiarities of compensatory-adaptive reactions of the respiratory system and evaluate their functional significance. It was established that during the year not only the values of the external respiration system activity indicators, but also the nature of the connections between them changes. Thus, in the group of boys moderate positive correlation were found between the parameters of V and VO_2 in spring, summer and autumn, while from spring to autumn the correlation is getting stronger, and in winter it is getting weaker and becomes statistically insignificant (Table 1).

At the same time, in the winter there is strong positive correlation between TV and VO_2, which in the other seasons of the year was moderate and weak or statistically insignificant. Instead of the missing links between TV and VO_2, there is a moderate positive correlation between VO_2 with UCO_2 in summer and autumn, which was weak and insignificant in winter and spring.

There is negative correlation between the volume of pulmonary ventilation and its efficiency (V - UCO_2) in the winter and during the transitional period of the year from warm to cold (autumn). Also in the fall, negative correlation which depends on the moderate force between the RR and TV in providing the V was revealed.

The value ERV has moderate positive correlation in all seasons of the year with the VC. The strength of the correlation of other lung volumes that make up the VC (TV - VC, ERV - TV) for boys does not statistically significantly change during the year. During the annual cycle in boys of senior school age, the strength of the correlation between bronchial patency (FEV_1) and RR and TV values do not change either. The correlation between VO_2 and RR is expressed in winter ($p < 0.05$) and spring ($p < 0.05$), in summer this correlation disappears.

In the group of girls moderate positive correlation was found in spring and strong in summer between V and VO_2, and in winter and autumn it correlation is getting weaker and becomes statistically insignificant (Table 2). At the same time, in winter, as well as in the group of boys, there is moderate positive correlation between the values of VO_2 and TV. In the rest of the seasons, the relationship between VO_2 and TV is statistically insignificant. In autumn, instead of the missing correlation between VO_2 and TV, there is a strong positive correlation between VO_2 and UCO_2. Negative correlation has been revealed between the volume of pulmonary ventilation (V) and its efficiency (UCO_2), which in winter has strong positive correlation.

In the summer and autumn a strong negative correlation was found between RR and TV in providing V. The strength of the correlations of other lung volumes that make up the VC (ERV - TV and TV - VC) does not practically change in the dynamics of the annual cycle in girls, except for TV - VC in summer, when moderate correlation ($p < 0.05$) is established. During the year, the strength of the correlation between the integral bronchial patency index (FEV_1) and TV does not change.

Thus, the study indicates change in the seasonal functional organization of the respiratory system in children of senior school age, residents of the Russian Federation's AZ. Attention is drawn to the fact that the correlation between V and VO_2 in both boys and girls groups in winter disappears. In addition, this correlation disappears in girls in autumn. A similar fact was discovered earlier in adult residents of Western Siberia [10]. It can be assumed that this situation of the functional organization of the external respiration system is caused by the

Table 1

The correlation coefficients (r) between the indices of external respiration in boys of senior school age, natives of the AZ RF, in different seasons of the year

Correlation	Winter	Spring	Summer	Autumn
V– VO_2	0.343	0.531**	0.592*	0.664**
TV – VO_2	0.786**	0.379	0.295	0.202
VO_2 – UCO_2	-0.211	0.204	0.607*	0.596*
TV – RR	0.162	-0.318	-0.639	-0.652**
VC – ERV	0.562*	0.646*	0.543*	0.413
VC – TV	-0.199	0.359	0.283	-0.169
TV – ERV	-0.268	0.098	0.315	0.136
RR – FEV_1	0.041	-0.074	0.125	0.009
TV – FEV_1	-0.229	0.500	0.261	-0.240
RR – VO_2	0.521*	0.527*	-0.038	0.335
V – RR	0.638**	0.174	0.487	0.755**
V – TV	0.011	0.499	0.097	-0.113
V – ERV	-0.354	-0.011	0.130	0.309
V – UCO_2	-0.225	0.315	0.018	-0.163
VO_2 – ERV	-0.418	-0.379	-0.154	0.359

Note. In the Tables 1 and 2 significance at * - $p < 0.05$; ** - $p < 0.01$..

Table 2

The correlation coefficients (r) between the indices of external respiration in girls of senior school age, natives of the AZ RF, in different seasons of the year

Correlation	Winter	Spring	Summer	Autumn
V– VO_2	0.542	0.676*	0.765**	0.379
TV – VO_2	0.663*	-0.133	0.369	0.256
VO_2 – UCO_2	0.129	0.443	0.341	0.797**
TV – RR	-0.067	-0.510	-0.719**	-0.865**
VC – ERV	0.693**	0.505	0.322	-0.055
VC – TV	-0.113	-0.337	0.660*	0.221
TV – ERV	-0.386	-0.061	0.273	-0.333
RR – FEV_1	-0.056	-0.625**	-0.177	-0.469
TV – FEV_1	0.325	0.407	0.198	0.339
RR – VO_2	0.136	0.589*	-0.041	-0.372
V – RR	0.518	0.725**	0.208	-0.314
V – TV	0.718**	0.080	0.311	0.636*
V – ERV	-0.289	0.742**	-0.047	-0.104
V – UCO_2	-0.703**	-0.910	-0.212	0.110
VO_2 – ERV	0.204	0.753**	0.173	0.720**

action of the cold factors. Probably, the cold limits the number of functioning acini due to the fact that part of the cooled acini overlaps. However, the stable maintenance of the required level of VO_2 in this case is possible only with an increase in the efficiency of gas exchange in the respiratory regions of the lungs, as indicated by the UCO_2 value.

The correlation between TV and VO_2, which appeared in winter in both boys and girls, indirectly indicates an increase in the airiness of the lungs, i.e. those acini which continue functioning. Increasing the airiness of the acini leads to stretching of the interalveolar septa, reducing the thickness of the alveolar-capillary membrane and increasing the area of the respiratory surface [13, 14]. All this increases the diffusion capacity of the lungs, accelerates the transfer of oxygen from alveolar gas into the blood of the pulmonary capillaries, increasing the efficiency of pulmonary ventilation in winter.

The change in V in winter in boys and in spring in girls is consistently based on the respiratory rate, since a positive correlation was found between these parameters: moderate in winter and strong in spring. It can be concluded that in these seasons the restructuring of the V is carried out by increasing the RR, which leads to more intense work of the respiratory muscles.

Being the second component of the VC and the first component of the functional residual capacity of the lungs, the magnitude of the ERV has moderate positive correlation in all seasons of the year with the VC in the boys and in winter in the girls. It should be noted that ERV has an important role in the mechanisms of regulation and accumulation of metabolic CO_2, since, in functional terms, the reserve expiratory volume is a buffer capacity of conducting airways that reduces the possibility of unhindered release of metabolic CO_2 through the lungs to the outside [1]. Therefore, the reserve expiratory volume acts as a kind of locking mechanism, allowing to gradually reduce the oxygen tension in the inhaled air to the level of the alveolar and, conversely, prevent a sharp decrease in the partial pressure of CO_2 in the lungs to the level of atmospheric pressure.

Conclusion. Thus, in senior school age children, residents of the Arctic region, during the summer and transitional seasons of the year (spring, autumn), the change in the oxygen demand of the body (VO_2) is provided by a change in pulmonary ventilation (V), and in winter, by optimizing the gas exchange conditions as a result of a change in static pulmonary volumes (TV and ERV), leading to the fact that backup acini is included in ventilation and gas exchange, increasing, respectively, the respiratory surface and improving the conditions of oxygen diffusion in the lungs.

References

1. Агаджанян Н.А., Гневушев В.В., Катков А.Ю. Адаптация к гипоксии и биоэкономика внешнего дыхания. М.: Изд-во УДН. 1987:186. [Agadzhanyan N.A., Gnevushev V.V., Katkov A.Yu. Adaptation to hypoxia and bioeconomics of external respiration. *Moscow.* 1987:186. (in Russ.).]

2. Варламова Н.Г., Бойко Е.Р. Особенности функции внешнего дыхания у северян в годовом цикле. Морская медицина. 2017. 3 (3):43-49. [Varlamova N.G., Boiko E.R. Features of external breathing function among the northerners in the annual cycle. *Marine medicine.* 2017. 3 (3):43-49. (in Russ.).] DOI: 10.22328/2413-5747-2017-3-3-43-49

3. Гришин О.В., Устюжанинова Н.В. Дыхание на севере. Функция. Структура. Резервы. Патология. *Новосибирск: Изд-во «Art - Avence».* 2006:253. [Grishin O.V., Ustyuzhaninova N.V. Breathing in the North. Function. Structure. Reserves. Pathology. *Novosibirsk.* 2006:253. (in Russ.).]

4. Гудков А.Б., Кубушка О.Н. Проходимость воздухоносных путей у детей старшего школьного возраста – жителей Европейского Севера. *Физиология человека.* 2006. 32(3):84-91.[Gudkov A.B., Kubushka O.N. Airway conductance in high school students living in the European North. *Human Physiology.* 2006. 32(3):84-91. (in Russ.).]

5. Гудков А.Б., Попова О.Н., Никанов А.Н. Адаптивные реакции внешнего дыхания у работающих в условиях Европейского Севера. *Медицина труда и промышленная экология.* 2010; 4:24-27.[Gudkov A.B., Popova O.N., Nikanov A.N. Adaptive reactions of external respiration in workers of European North. *Occupational health and industrial ecology.* 2010;4:24-27. (in Russ.).]

6. Ким Л.Б. Транспорт кислорода при адаптации человека к условиям Арктики и кардиореспираторной патологии. *Новосибирск: Наука;* 2015:216. [Kim L.B. The transport of oxygen in human adaptation to Arctic conditions, and cardiorespiratory diseases. *Novosibirsk;* 2015:216. (in Russ.).]

7. О сухопутных территориях Арктической зоны Российской Федерации: указ Президента РФ от 02 мая 2014 г. №296. [Decree of the President of the Russian Federation dated May 2, 2014 N 296. «On land

territories of the Arctic zone of the Russian Federation». (in Russ.).]

8. Поливанова Т.В. Вопросы адаптации и патологии у населения Крайнего Севера. *Якутский медицинский журнал.* 2011; 35(3):67-71. [Polivanova T.V. Questions of adaptation and pathology in the population of the Far North. *Yakut medical journal.* 2011; 35(3):67-71. (in Russ.).]

9. 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.[Chashchin V.P., Gudkov A.B., Chashchin M.V., Popova O.N. Predictive assessment of individual human susceptibility to damaging cold exposure. *Human Ecology.* 2017; 5:3-13.]

10. Шишкин Г.С., Устюжанинова Н.В. Функциональные состояния внешнего дыхания здорового человека. Новосибирск: Изд-во СО РАН. 2012:329. [Shishkin G.S., Ustjuzhaninova N.V. Functional status of the external breathing in healthy person. Novosibirsk. 2012: 329. (in Russ.).]

11. Fitzgerald R.S. Oxygen and carotid body chemotransduction: the cholinergetic hypothesis – a brief history and new evaluation. *Respirat.Physiol.* 2000; 5 (120): 89-104.

12. van Ooijen A.M., van Marken Lichtenbalt W.D., van Steenhoven A.A. [et al.] Seasonal changes in metabolic and temperature responses to cold air in humans. *Physiol.Behav.* 2004; 2-3 (82): 545-553.

13. Weibel E.R. Gas exchange: large surface and thin barrier determine pulmonary diffusing capacity. *Minerva Anestesiol.* 1999; 6 (65):377-382.

14. West J.B. Respiratory physiology - the Essentialis. Baltimore: Lippincott, Wilcins, 2008: 180.

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MICROELEMENTAL COMPOSITION OF BLOOD AMONG ABORIGINAL INHABITANTS OF THE ARCTIC

ABSTRACT

The level of microelement status indicators in the blood of aboriginal inhabitants of the Arctic is determined, on the basis of which it is possible to conduct future comparisons under conditions of industrial development of territories. The study included 107 indigenous inhabitants of the North, belonging to the ethnic group of Dolgan, living in Yuryung-Khaya of the Anabar district of Yakutia. The content of 20 microelements in the blood serum was studied.

The content of many elements, including manganese, cobalt, strontium, nickel and iron in blood is higher than reference values, which can influence the development of diseases of the cardiovascular system, nephropathy and oncological diseases.

Keywords: trace elements, indigenous peoples of the North, Arctic.

Introduction. The stability of the chemical composition of the body is one of the most important and necessary conditions for its normal functioning. Accordingly, deviations in the content of chemical elements caused by environmental, occupational, climatogeographic factors or diseases lead to a violation in the state of health [6]. The Northern territories are extremely different from the Central regions of Russia by climatic, biogeochemical, dietary and adaptive characteristics.

Alluvial diamond deposits are being developed in the valley of River Ebelyah, which is the left tributary of the Anabar River in Yakutia. During the development of the natural landscape structure and environmental conditions have undergone significant changes. A special danger in the development of the Deposit is the contamination of the surface layer of soil with chemical elements with toxic and radioactive properties contained in the ore. Filtration effluents of the downstream of the wellhead dam of the concentrator form a clear technogenic hydrochemical anomaly of manganese, chromium, Nickel, copper, lead and molybdenum [4, 9].

Toxic elements, migrating to streams and rivers in the form of mineral particles, accumulate in the bottom sediments and gradually decomposing, for a long time, fall into large watercourses, on the banks of which are located settlements. The local population drinks this water, uses it for economic purposes, eats fish that lives in this water and feeds on microorganisms that inhabit these watercourses, thereby accumulating toxic elements in their bodies. The danger of area pollution of the environment with toxic radioactive elements and heavy metals is associated with wind drift of mineral particles from the quarry and from the dumps of off-balance ores [4, 9]. Area dispersion of mineral particles with toxic elements accumulates in plants, primarily in the moss, where it enters the body of animals and birds. When consumed in food, a person also accumulates toxic elements in his body. Poisoning of the body as a result of these factors, the process is hidden and "stretched" in time, depends on the individual characteristics of the human body