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Peculiarities of morphological and functional characteristics of residents of the North-East of Russia, depending on background meteorological and heliomagnetic indices

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Abstract

In order to reveal the functional interrelationships of the main physiological characteristics of the organism with the external environment exogenous abiotic factors, as well as the evaluation of the magnetic field factor effect on the morphofunctional status main characteristics, 18 healthy men aged 25–49 years old, residents of the North-East of Russia (Magadan) were examined. Parameters of the cardiovascular system, external respiration and gas exchange, as well as heart rate variability were studied. Environmental factors, such as air temperature, wind speed, air humidity, atmospheric pressure and K-index were separately analyzed. Identified were different types of responses by human organisms to the influence of environmental abiotic factors, depending on the initial vegetative tone of the examinees. Thus, the individual profile of the subject with a sympathotonic type of autonomic regulation was characterized by a pronounced dynamics of the studied indicators in response to the influence of environmental factors. At the same time, for the subjects with normotonic and vagotonic initial tone, positive air temperatures were found to be the most stressful factors. The obtained data indicate that the most pronounced stress of the functional state is observed with the synergistic action of the temperature factor and the perturbed magnetic field (according to the K-index data). The conducted correlation pleiades analysis have made it possible to establish an increase in the surveyed men's level of systolic and diastolic arterial pressure in response to the voltage of the Earth's magnetic field. It has been also revealed that the effect of the Earth's abiotic factors on the heart rate variability parameters is manifested in the activation of the parasympathetic part of the autonomic nervous system, which is most beneficial for the organism while forming response compensatory-adaptive reactions.

Keywords

North-East of Russia, Functional characteristics, Environmental factors, Autonomic regulation, Seasons of the year, Correlation pleiades

Imprint

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Introduction

The influence of meteorological, geomagnetic and especially weather factors on the human body remains an actual problem in modern physiology and medicine. It is believed that one of the first places in terms of the exposure of the human body is occupied by differences in atmospheric pressure. Running second is the effect of low and high temperatures, especially in the initial period of adaptation [1]. It should be said that there are a small number of works, in which the complex influence of both geomagnetic and meteorological characteristics on the functional state of the human subjects is analyzed, while the greatest percentage is devoted to the study of mortality and the level of special medical services provided on the days of helium-magnetic disturbances. In general, the weather effect on the human body occurs through the formation of adaptive reactions at the level of the central nervous system (CNS) and the autonomic nervous system (ANS), by fixing the conditioned reflex influence [2]. So, there is a correlation relationship between changes in temperature, relative air humidity, atmospheric pressure, the Earth's magnetic field and an increase in the maximal and pulse pressure, as well as the heart rate [3]. The previously studied influence of climatic characteristics (air temperature, humidity, atmosphere pressure, wind speed) on the morphofunctional indices of young people living in different climatic and geographical areas of the Magadan Region showed that the young individuals living in the continental natural climatic zone have a functional status, that is more influenced by the temperature factor (taking into account the fact that during the survey the air temperature dropped to -50 °C) [4]. At the same time, the physiological characteristics of young inhabitants of the region's coastal part are subject to a complex influence of wind speed, temperature and atmosphere pressure. Along therewith, the question of the simultaneous influence of both meteorological and helium-magnetic factors remains still open. In this connection, the aim of our research work was to identify the functional interrelationships between the main physiological characteristics and the exogenous abiotic factors of the external environment. In addition thereto, one of the tasks of the study was to evaluate an effect of both temperature and magnetic field factors on the main studied characteristics of the morphofunctional status in the dynamics of the 1.5-year experiment, i.e. in the seasonal aspect.

Materials and methods

18 men at the age from 25 to 49 years, permanent residents of the Magadan Region, took part in our research. Every month in a defined 18-month period they underwent surveys at the "Arktika" Scientific Research Center, FEB RAS. For an analysis of the functional state of the cardiovascular system at rest with the help of automatic tonometer Nessei DS–1862 (Japan) the measurements of systolic BPS (mmHg) and diastolic blood pressure BPD (mmHg), as well as the heart rate HR were recorded.

Pulse pressure PP (mmHg), the total peripheral vascular resistance TPVR (dyn^2 s cm^{-5}), stroke volume SV (mL) and cardiac output CO (L/min) were calculated [5].

To assess the series of parameters of the external respiration system and gas exchange in young men at rest with the help of metabolograph MedGraphics VO2000 (USA) the content of oxygen O_2 and carbon dioxide CO_2 in the exhaled air, oxygen consumption OC (mL/min), breathing volume BV (L/min), respiratory rate RR (circle/min), respiratory volume RV (mL), respiratory quotient RQ (arb. units) and energy consumption at rest (kcal/min) were determined. Pulmonary volumes and ventilation values were automatically assigned to the BTPS system, and the amount of oxygen consumption was referred to the STPD system. The examinations of young men were conducted in a room at a temperature of 18–20 °C, in the morning hours.

Parameters of external respiration were analyzed in an open system using spiro-analyzer KM-AP-01 Diamant-C (Russia). The recording was made in sitting position in two stages: the first one included a maximum inhalation from and a calm maximum exhalation into the tube of the gas analysis module; in the second stage, after the maximum inhalation, a rapid forced exhalation was also made to the limit. The highest values obtained over several measurements were taken into account. All the main characteristics were automatically compared with the proper values originally embedded in the software of the device, which represented the data obtained for the population of the inhabitants of the Central European part in Russia [6].

An assessment of the state of the external respiration system of the subjects was carried out on the basis of measurements and subsequent analysis of the following indices: T_{VLC} – time of calm exhalation (s), T_{FVLC} – time of forced expiration (s); VLC – the vital lung capacity (L); FVC – forced vital lung capacity (L); FEV_1 – the volume of forced expiration in the first second (L); PVR – peak volumetric expiratory flow rate, (L/s); $FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$ – instantaneous space velocities at 25%, 50% and 75% of FVC, respectively (L/s); $SV_{AV25-75\%}$ is average space velocity in the range of 25–75%, (L/s); Index Tiffno, (IT) – ratio FEV_1/VLC, (%); Index Gensler, (IG) – the ratio of FEV_1/FVC (%).

An analysis of the heart rate variability (HRV) was carried out according to the generally accepted methodology in accordance with the methodological recommendations issued by the group of recognized Russian experts [7]. The following data in the above subjects were recorded: heart rate (HR, beats per min); Mean (ms) is the mean; MxDMn (ms) is the difference between the maximum and minimum values of the cardio intervals, or the variation range; SDNN (ms) – standard deviation of the full array of cardiointervals; CV (%) – the coefficient of variation of the full array of cardiointervals; RMSSD is the square root of the sum of differences in a series of cardiointervals; MO (ms) – mode; AMO (ms) – the amplitude of the mode; SI (arb. units) – stress index (stress index of regulatory systems); TP, (ms^2) is the total power of the heart rate spectrum; HF – absolute (ms^2) and relative (in percentage) power spectrum of the high-frequency component of the high-frequency HRV (High Frequency) in the range 0.4–0.15 Hz (respiratory waves); LF – absolute (ms^2) and relative (in percentage) power spectrum of low frequency component of HRV (Low Frequency) in the range 0,15–0,04 Hz (vascular waves); VLF is the absolute (ms^2) and relative (in percentage) power of the very low-frequency component of the Very Low Frequency spectrum in the range 0.04–0.015 Hz; LF / HF – the ratio of low-frequency and high-frequency components of HRV, IARS, (arb. units) – an indicator of the activity of regulatory systems. A standard single-lead ECG was recorded in sitting position of every examinee.

For our analysis of climatic characteristics of various natural zones of the Magadan Region, data provided by the State Institution "Kolyma Division for Hydrometeorology and Environmental Monitoring" were utilized. The following characteristics were considered in our work: air temperature (T_{AIR}, °C), wind velocity (WV, m/sec), air humidity (H_{AIR}, %) and atmospheric pressure (AP, mm Hg). For the analysis, a database of 8 daily measurements with a total of 56 was generated. Data on the K-index level were provided by I. Poddelsky, Head of the Magadan Geophysical Observatory, FEB RAS. The obtained results were subjected to statistical processing using our application software system Statistica 7.0. The pair correlation of each parameter was computed with the calculation of the Pearson correlation coefficient with the construction of correlation pleiades to reflect inter-system relationships between meteorological and helium-magnetic characteristics and physiological parameters of the organism. Considered were statistically significant correlation coefficients with a tight connection from $r \geq 0.3$, $p < 0.05$ [8]. In addition, we analyzed the dynamics of a number of physiological characteristics (BPS, stress index and IARS) in the dynamics of a 18-month period in their dependence on the meteorological (air temperature) and geomagnetic (K-index) characteristics of the environment.

Results

To analyze the individual dependence on the meteorological and geomagnetic characteristics, we conducted an assessment of the subjects' individual profiles. Guided by the fact that ANS is one of the regulatory systems of the body that affects the activity of the cardiorespiratory system, and also taking into account the fact that now in many works, including ours, it is necessary to consider the initial autonomic tonus in the functional state analysis, in the given study we analyzed the dynamics of the physiological parameters in subjects that differed in the type of autonomic regulation of the heart rhythm (vagotonics, normotonics and sympathotonics), depending on the stage (in the seasonal aspect) of experiment, meteorological and helium-magnetic environment.

The individual analysis of the systolic blood pressure level dynamics during the 1.5-year dynamics (Figure 1), with the detailed data of every day study according to the level of the magnetic field and air temperature, revealed the following: in a young man - a vagotonic type under an increase in the K-index to a slightly disturbed (K-index = 3) and perturbed (K-index = 4), the highest values of the systolic blood pressure level were recorded (the changes were observed at the 3rd, 5th, 9th and 13th stages of the survey). The maximal BPS indices (Figure 2) in the representative of the group under study were revealed in the first month of autumn. An important point was that a relatively high air temperature in the summer periods of the study was not accompanied by an increase in the level of systolic blood pressure, and that at the time of the temperature curve transition through zero point in the autumn-summer and spring-winter periods of the year, there was a certain stability of this physiological characteristic recorded.

The next stage of our study was to reveal correlations between the basic physiological characteristics of the functional status and the meteorological helium-magnetic parameters. The analysis obtained is presented in the pleiade (Fig. 19–22). It is known that the cardiovascular system, as the most reactive one, is among the first involved in the process of adaptation to environmental conditions. According to the data of a number of authors [2, 9], the greatest influence of helium-geomagnetic and climatic factors is exerted just on the man's cardiovascular system. As a result of the analysis of the correlation of the climatic and helium-magnetic characteristics and the cardiovascular system parameters, the following relationships have been established (Fig. 19): increases in systolic and diastolic arterial pressure in response to the disturbed magnetic field, as well as a reduction in physiological characteristics with an increase in the temperature factor occur. The increase in the overall peripheral resistance of blood vessels and in the BPD index, which characterizes the small vessels tone state, in response to an increase in wind velocity should be mentioned. On the contrary, a severe wind situation leads to a decrease in important hemodynamic parameters, reflecting the body's supply of oxygen and nutrients: stroke and minute volume of blood circulation. The obtained data have confirmed the idea that the cardiovascular system is sensitive to the effects of space weather factors and climatic characteristics. In addition, the male individuals we surveyed had a definite meteosensitivity to the functional state of the vegetative tone. Thus, the state of the cardiovascular system, as exemplified by HRV characteristics (Fig. 20), is influenced by a number of meteorological characteristics, as well as the level of perturbation of the Earth's magnetic field.

Discussion and conclusions

Analyzing the dynamics of the stress index in the period under study (Fig. 3), it should be taken into account that in subject V. the highest values of the above index were fixed under a quiet magnetic field (stages 1, 6 and 10 of the experiment). On the contrary, a decrease in the index was observed on days with a weakly perturbed and perturbed magnetic field. Our analysis of the characteristic as a function of the temperature regime (Fig. 4) within the period under study revealed a certain pattern of the SI increase in the studied periods of the year, both spring-summer and autumn-winter stages of our research conducted in 2010 and in 2011. It is necessary to emphasize that the identified highest SI indices in the summer period of the 2010 survey, which is characterized by high ambient temperatures. Analyzing the changes in the IARS index (Fig. 6) depending on the air temperature, it can be noticed that the highest activity levels of regulatory systems were established for the summer periods of the study in 2010 and in 2011, as well as at the time of transition of the temperature curve through zero as in the autumn-winter period of 2010 and in the spring-summer phase of 2011. Moreover, it should be pointed out that during the summer period of research against the background of high air temperatures and the highest indices of the K-index (Fig. 5), indicative of a perturbed magnetic field, the highest IARS indices in the said subject were not typical for him. Thus, we can notice (Table 1) that in the subject characterized by a predominance of the initial vagotonic autonomic status, the level of systolic blood pressure was not affected by the dynamics in response to changes in the ambient temperature during the time period under study.

Based on the foregoing, it can be concluded that for a young vagotonic man, a decrease in ambient temperature below –25 °C and an increase above +18 °C, as well as transitions of the temperature curve through zero during critical periods of the year, is not a sufficient stress factor causing a definite reaction of the basic parameters of the cardiovascular system: the systolic blood pressure due to the presence of some compensatory-adaptive mechanisms aimed at reducing the stress of the body function status. At the same time, an increase in the K-index to a level of a weakly perturbed and to a perturbed level of the magnetic field causes an increase in the BPS. For characteristics such as IARS and stress index, typical was reaching of the highest values during the periods of the highest positive ambient temperatures (summer period), as well as in the transitional spring-summer and autumn-winter periods of the year. It was noteworthy that the highest parameters of IARS in the vagotonic subject (IARS = 7) were detected upon the combined effect of high positive temperatures and a perturbed magnetic field.

The results we have obtained indicate the presence of a similar dynamics of the BPS level as a function of the temperature indices in the male-sympathotonic type and normotonic type (Fig. 8, Fig. 14). Thus, the highest values of the indicator were recorded in the winter stage of the study (February), characterized by maximum negative air temperatures (up to -30 °C) and in the transitional autumn-winter period of the year. The increase in BPS, observed in December in the sympathetics vs the normotonics, was caused by the simultaneous action of a magnetic field raised at a given stage of the experiment to the level of a slightly disturbed one (Fig. 13). In the subject of the above group, it was possible to distinguish the periods of increase in arterial pressure in September of 2010 and 2011 also due to the increase in the K-index at that stage of the experiment. It should also be highlighted that we observed the lack of influence of the magnetic field on the level of systolic blood pressure in men-normotonics (Fig. 7).

Analyzing the values of the stress index in the subject-normotonics (Fig. 10), we can say that its highest values were recorded in the summer and at the time of temperature transition through zero in the spring-summer phase of the study. It was noteworthy that the high values of the stress index in the summer period of the year were apparently caused by the synergistic influence of high air temperatures and a perturbed magnetic field (the K-index during the survey period was at the level of 5, Fig. 9). Similarly to the dynamics of the stress index, we recorded the highest values of IARS (Fig. 12) in the summer period of the year and in the transitional spring-summer phase of the experiment. In addition, there were increases in IARS in response to the transition of the temperature curve through zero in the autumn-winter period of the year. Similar to the case with the values of the stress index, the highest values of IARS were identified with simultaneous influence of positive air temperatures and high K-index values (Fig. 11).

Thus, the functional state of the subject with the initial normotonic status (Table 1) in the dynamics of the studied time interval was characterized by the presence of an increase in the values of the analyzed physiological characteristics, mainly during the summer period of the study. We also identified the growth of BPS in the winter and autumn-winter period of the year. Mentioned should be the stability of the hemodynamic characteristic during the studied period in response to the dynamics of the Earth's magnetic field voltage. This circumstance indicates optimal homeostatic mechanisms in a young person belonging to a group with a normotonic orientation of the heart rhythm autonomic regulation. It should be emphasized that the unprecedented increase in IARS and stress index in the summer period in the subject of this group seems to reflect the combined effect of positive ambient temperatures and perturbed magnetic fields on an organism with sufficient functional reserves.

When analyzing the effect of the temperature factor on the stress index in a subject with a predominance of sympathicotonic initial autonomic tone, a certain coincidence of the SI trend lines and the temperature curve was detected (Fig. 16). Thus, with a decrease in the ambient temperature, a decrease in the stress index was identified, and, accordingly, with an increase in temperature, the highest indices of the stress index were revealed. A clear dynamics of the stress index due to changes in the degree of perturbation of the magnetic field in the subject-sympathotonic was not found in our studies (Fig. 15). The maximum value of IARS in the examined group was recorded in September of 2011. The observed dynamics can be explained by the beginning of the autumn-winter transition of the temperature trend through zero and the simultaneous increase in the K-index to 3 arb. units (Fig. 17, Fig. 18). Thus, it can be stated (Table 1) that in the subject with sympathicotonic autonomic reactivity one of the most important hemodynamic factors, which is an indicator of changes in the parameters of the environment (in particular, temperature), is the level of the stress index, which indicates a certain lability of physiological systems in a representative of this group. Thus, it can be seen that the SI level is characterized by maximum values in the period of positive air temperatures with a tendency to decrease during the transition of the temperature curve to the zone of negative values. We have revealed a lack of influence of the magnetic field on this characteristic in the subject-sympathicotonics. In this subject, a low ambient temperature has induced an increase in systolic blood pressure both during the winter period of the year and in the transitional autumn-winter stage of the experiment. Thus, we can state a certain sensitivity of this indicator (BPS), where the negative temperature of the air acts as an external stimulus that produces a certain reaction by the organism in the form of an increase in blood pressure that goes beyond the limits of the physiological norm [10]. Values of the activity index of regulatory systems have increased in the autumn period against the backdrop of low air temperatures with the simultaneous effect of a weakly perturbed magnetic field.

The indices of the magnetic field perturbation in the exemplary case of the K-index can be defined as the greatest biotropic factor, which exerts the maximum influence on the investigated characteristics of the cardiovascular system and HRV. This confirms some authors' statements that the geomagnetic storm is one of the unfavorable physical factors affecting the human body and that besides the nervous and endocrine systems the cardiovascular system is the most sensitive one to the change in the Earth's magnetic field [11, 12]. Thus, we have identified 13 interrelations between the K-index and the physiological characteristics of the hemodynamic system, such as: BPS, BPD, MxDMn, RMSSD, pNN50, SDNN, CV, TP, HF, LF, VLF, AMo, SI. The correlation analysis shows the presence of very strong links between changes in the Earth's magnetic field in the K-index and the ANS division, both sympathetic and parasympathetic: during periods of high magnetic activity, the activity of the central control circuit decreases (in the values of AMo and SI). At the same time, the increase in MxDMn, RMSSD, pNN50, CV in response to the influence of the disturbed magnetic environment of the Earth indicates an increase in the influence of the parasympathetic division of the ANS and a rise in the activity of self-regulation mechanisms. An increase in the Earth's magnetic field intensity leads to an elevation of the indices, and SDNN shows the lower control levels' activation. Moreover, we have detected activation of the respiratory center (in HF values), sympathetic

Table 1. Summary table, reflecting the influence of abiotic factors on the physiological characteristics of the subjects

Physiological characteristics	Abiotic factor	Type of autonomic regulation		
		Vagotonic	Normotonic	Sympathotonic
BPS, mmHg	t, ºC	no influence	↑ winter, ↑aut-wint	↑ winter (Feb, Dec), ↑aut-wint
	K-index, arb. units.	↑ at ↑ K-index	no influence	↑∑ t, K (Dec)
SI, arb. units	t, ºC	↑ summer, spr-sum, aut-win	↑↑ summer, ↑spr-sum	↑ at ↑ t, ºC ↓ at ↓ t, ºC
	K-index, arb. units.	↑ at ↓ K-index, ↓ at ↑ K-index	↑↑ summer at ∑ t, K	↑↑ autumn at ↓ K-index
IARS, point	t, ºC	↑ summer, spr-sum, spr-sum	↑↑ summer, ↑spr-sum, aut-wint	↑ autumn
		↑↑ summer at ∑ t, K	↑↑ summer at ∑ t, K	↑↑ autumn at ∑ t, K

Note: aut-wint is a transitional autumn-winter period at the time that the temperature curve crosses through zero; spr-sum is a transitional spring-summer period at the moment, which the temperature curve passes through zero; ∑ t, K-index is the combined effect of the temperature factor and the perturbed magnetic field; ↑↑ is significant increase in physiological index.

vascular center (in LF value) and a rise in the relative activity level of the energy-metabolic regulation link (VLF values) against the background of changes in the Earth's magnetic field. A second biotropic factor, which has a significant effect on the cardiovascular system and the autonomic tone of the organism, is the ambient temperature, which demonstrates 11 correlation links with HRV parameters.

Besides the above-described relationships between air temperature and blood pressure level (BPS and BPD), it has been found that the MxDMn, SDNN, CV, TP, HF, LF, VLF, AMo, SI characteristics are the most sensitive ones to the temperature factor. And it is necessary to mention the direct effect of temperature on all these indicators except AMo, SI. Thus, in our studies, we have detected a clear effect of the temperature factor on the indices reflecting the activity of the ANS sympathetic division. In particular, the transition of air temperature from negative to positive region, similar to that in the magnetic field intensity, leads to a decrease in the activity of the central control circuit, a decrease in the predominance of the sympathetic division (decrease in AMo and SI) and, accordingly, activation of the parasympathetic division of the ANS. Similarly to the exogenous factor described above, the temperature index causes the activation of the vasomotor and respiratory centers and also increases the energy-metabolic needs of the male body in response to an increase in the ambient temperature.

The next climatic indicator we have analyzed, the air humidity, is characterized by the presence of five correlation relationships towards the HRV parameters. Thus, an increase in air humidity leads to an increase in the parasympathetic orientation in the subjects' heart rhythm regulation (MxDMn, SDNN, CV), an increase in vascular center activity (LF), and a decrease in the stress index. The atmospheric pressure index has the lowest biotropic value against the cardiovascular system's one. In our studies, we have identified only two links between this test characteristic and HRV parameters: an increase in atmospheric pressure leads to a decrease in HR and MxDMn.

The adaptability of the external respiration apparatus is largely manifested when the conditions of the external environment change. Thus, as the atmospheric pressure increases, the time of forced exhalation decreases (TFVC). This fact seems to be quite natural, taking into account the higher resistance of air with increasing its density. At the same time, there is an increase in the indices of Tiffno and Genslar, which are integral and which show the developing possibility level of bronchoobstructive phenomena. In this case, the indices' growth indicates that the compensatory processes occurring in the lungs are directed towards the preservation of the bronchial tree optimal airway and smoothing the external factors vibrational effect. According to the pleiade, one can see that the increase in geomagnetic activity (K-index), as well as the increase in air humidity, leads to a decline in the permeability of the lungs within the physiological range, and this is typical both for large bronchioles (FEF_{25}) and for distal sections of the bronchial tree (FEF_{75}).

Considering the correlation pleiades with respect to the gas exchange system, a number of key points can be highlighted. Thus, the influence of the atmospheric air temperature is manifested in a very definite manner, for which a number of direct relationships can be identified. With an increase of this indicator, an

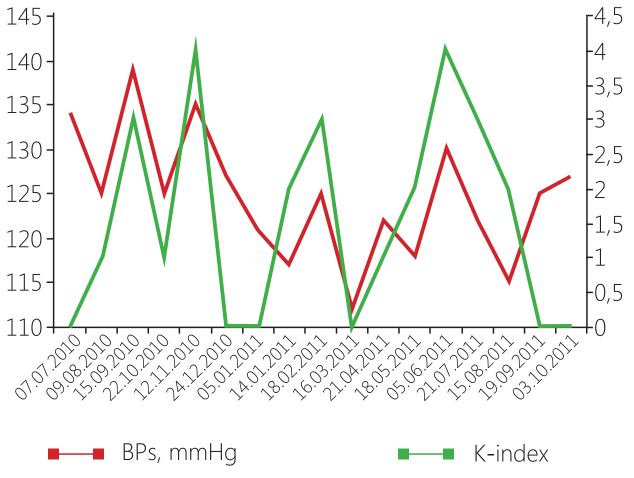
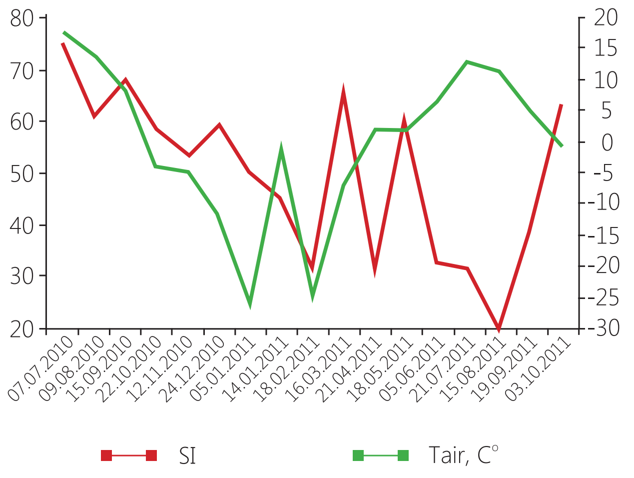


Figure 1



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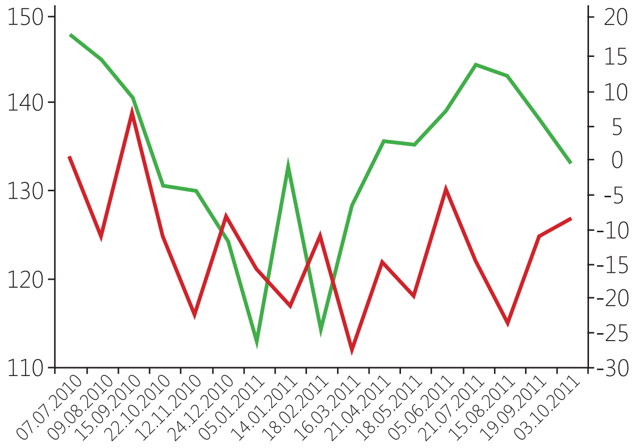

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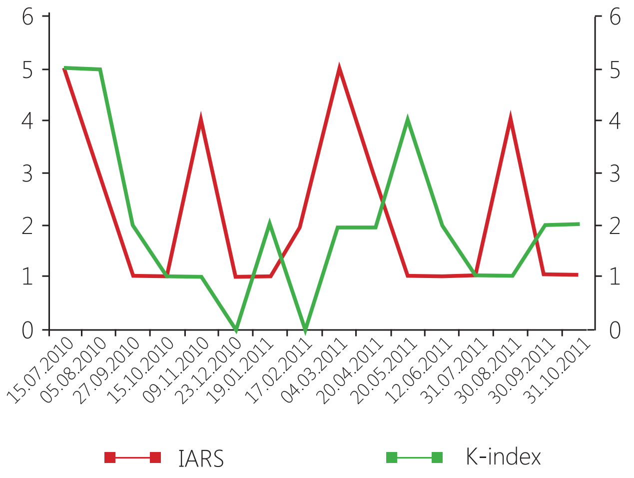

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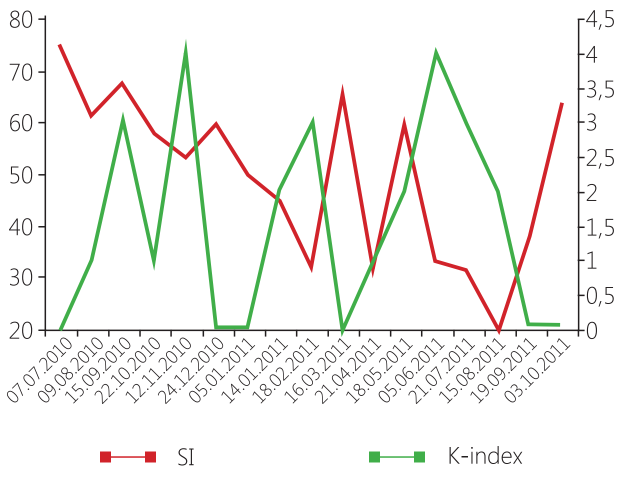

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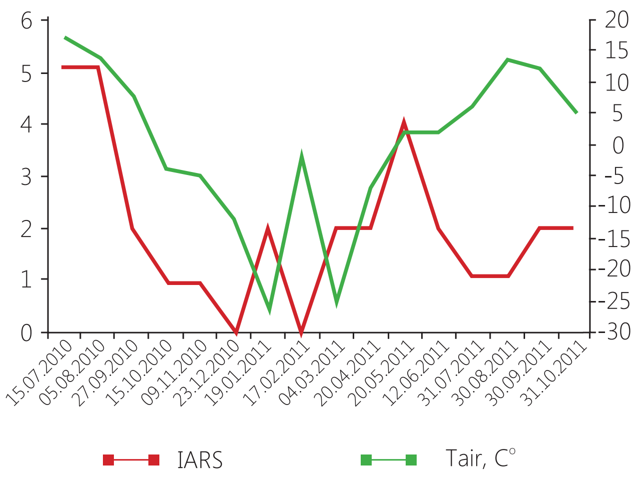

Figure 6

Figures 1–6. Indicators of the dynamics of some physiological characteristics, depending on the air temperature and the K-index at the time of the study in the vagotonic male (subject B-o)

increase in the breathing volume BV (L/min) is observed, which leads to a natural increase in minute respiratory volume RV (mL). It is important that in this case, an inverse relationship between the breathing volume and respiratory rate RR, is traced. Thus, the RV parameter increases precisely due to an increase in the RR indicator, which is the most economical option to enhance ventilation processes in the lungs [13]. Along therewith, a direct link is established between the air temperature and the organism's energy expen-

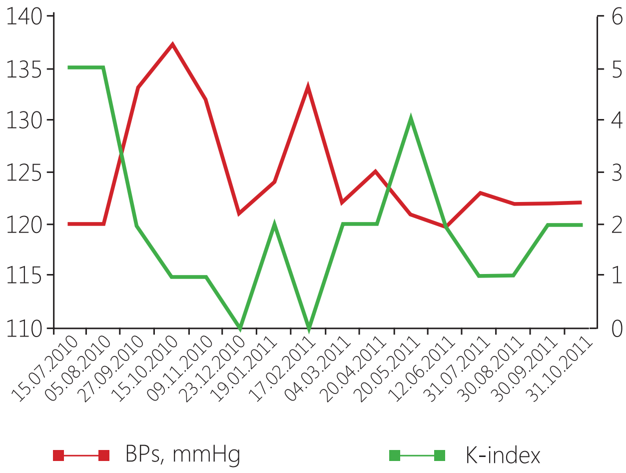

Figure 7

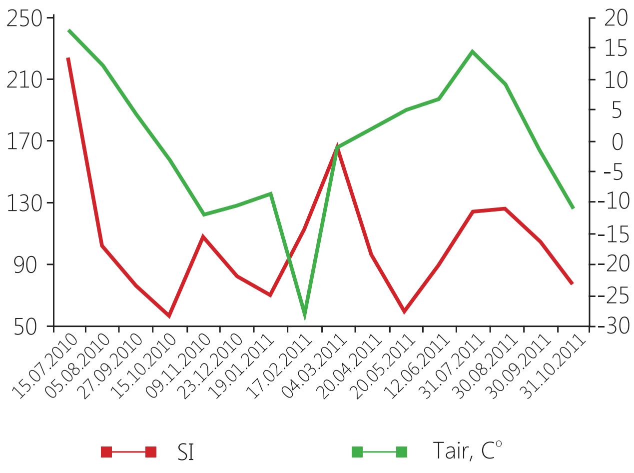

Figure 10

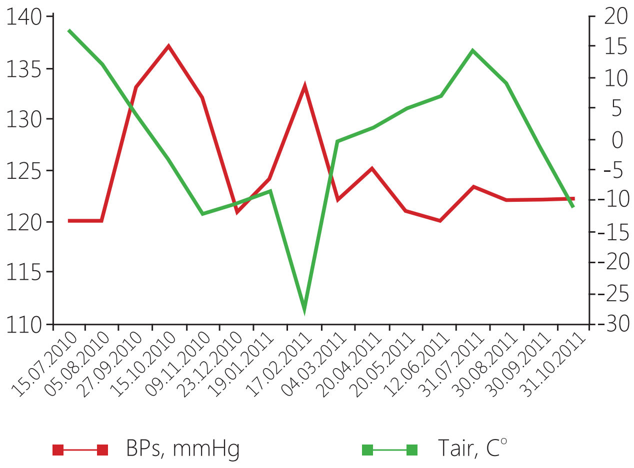

Figure 8

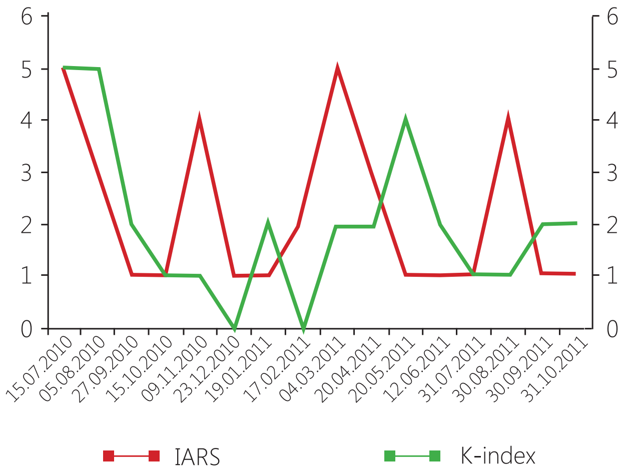

Figure 11

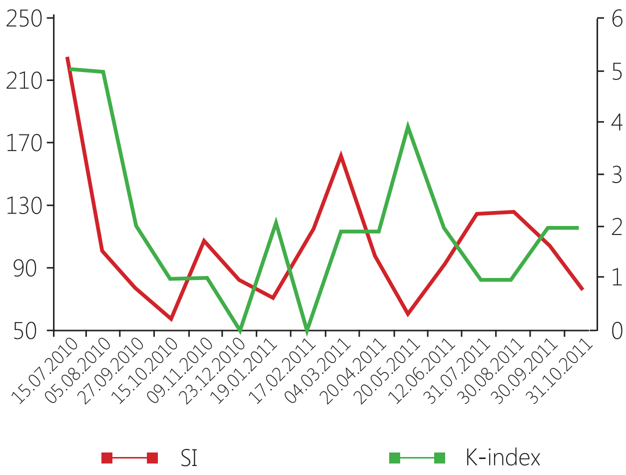

Figure 9

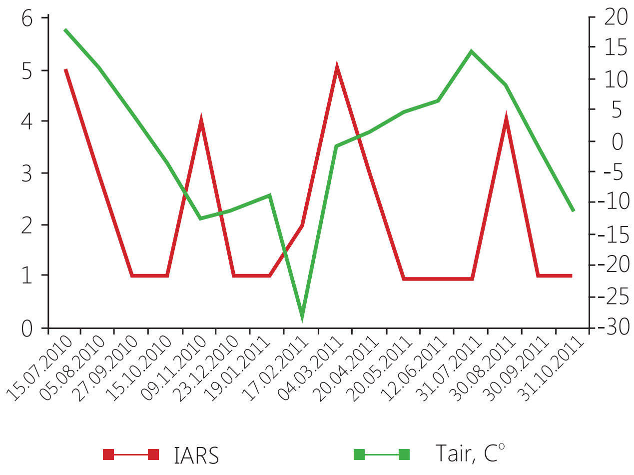

Figure 12

Figures 7–12. Indicators of the dynamics of some physiological characteristics as a function of air temperature and K-index at the time of the study in the normotonic male (subject M-v)

diture, rising of which creates the need to increase oxygen consumption OC, which is provided by the respiratory volume growth.

It is interesting that an increase in geomagnetic disturbance causes an increase in the respiratory quotient RQ, and the latter occurs due to an increase in the release of carbon dioxide from the body, which may indicate the process of the carbohydrates oxidation activation in the body. Regarding the air humidity, we have established the same pattern.

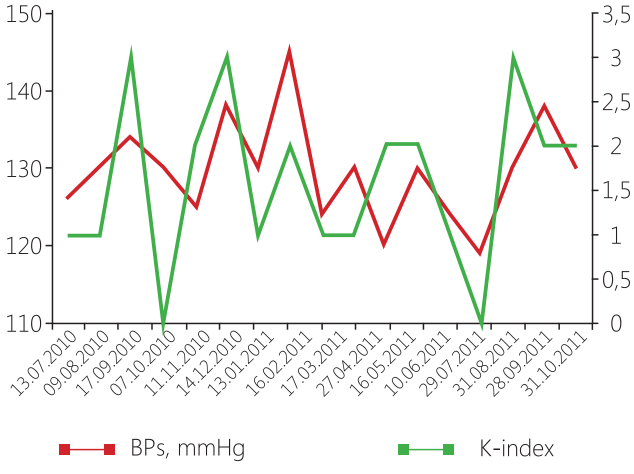

Figure 13

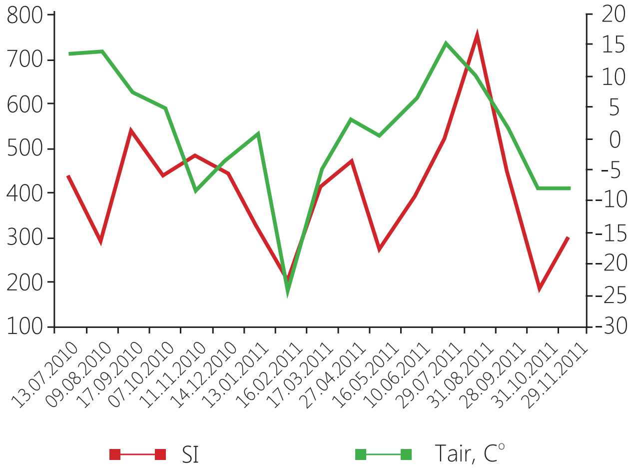

Figure 16

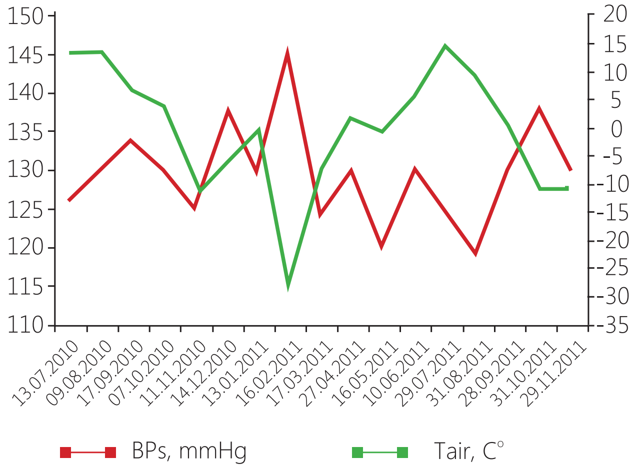

Figure 14

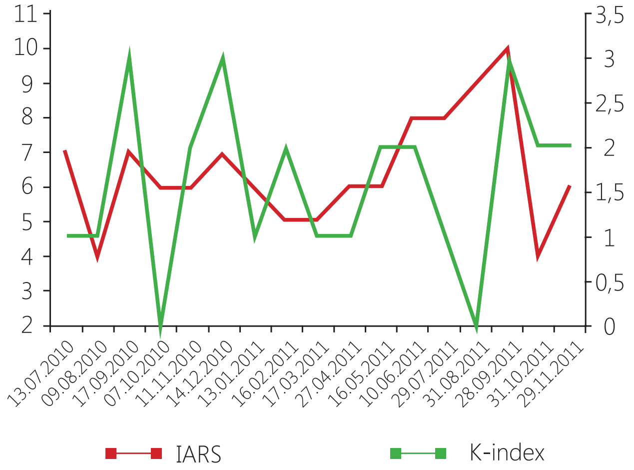

Figure 17

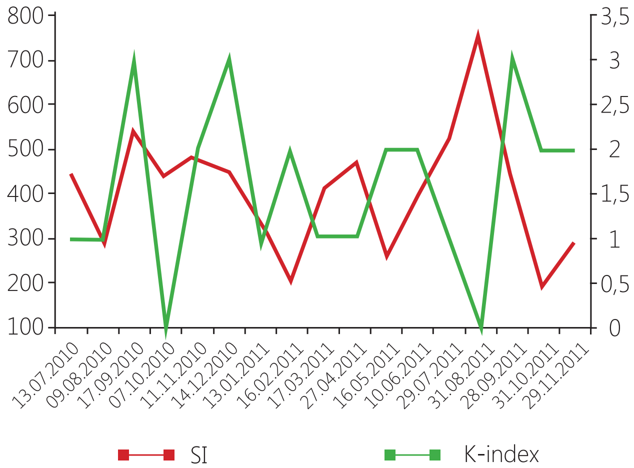

Figure 15

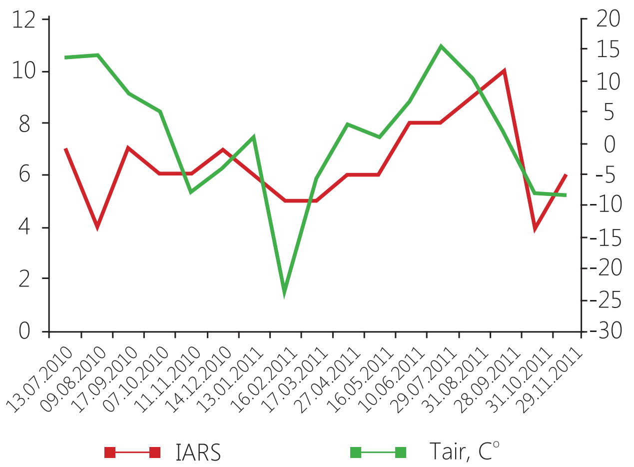

Figure 18

Figures 13–18. Indicators of the dynamics of some physiological characteristics, depending on the air temperature and the K-index at the time of the study in the sympathotonic male (subject Z-v)

In general, it can be stated that the critical periods for the functional state in the male individuals we have surveyed are time intervals characterized by positive ambient temperatures and transitional spring-summer and autumn-winter periods of the year, caused by the transition of the temperature curve through zero point. The presence of certain negative shifts in the physiological characteristics that cause a decrease in the functional state of the subjects is noted. But still the highest peaks of the studied characteristics, which indicate the disruption of adaptation, are observed just under the synergistic action of the temperature factor (whatever it is – a positive air temperature or a transitional period of the year) and a perturbed magnetic field. Moreover, certain differences in the dynamics of some cardiovascular system characteristics in young men of the Magadan Region, depending on the initial type of autonomic regulation, have been revealed. In the above discussed vagotonic subject, the level of BPS does not change in response to the dynamics of the ambient temperature during the year, and in the normotonics under examination, the changes in the perturbation of the Earth's magnetic field do not affect the systolic blood pressure level. In this case, the subject with sympathicotonic tendency in the heart rhythm regulation shows no stable characteristics, which do not respond to changes in environmental parameters. It is worthy to mention that positive air temperatures, especially in the combined action of the disturbed magnetic field, are stress factors for the normotonic and vagotonic subjects, whereas negative ambient temperatures are stressful for the sympathotonics.

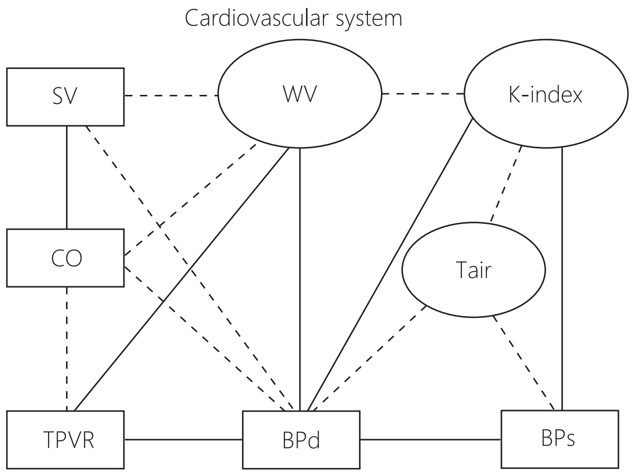

Figure 19. Correlation of the climatic-heliomagnetic characteristics with the main indicators of the cardiovascular system

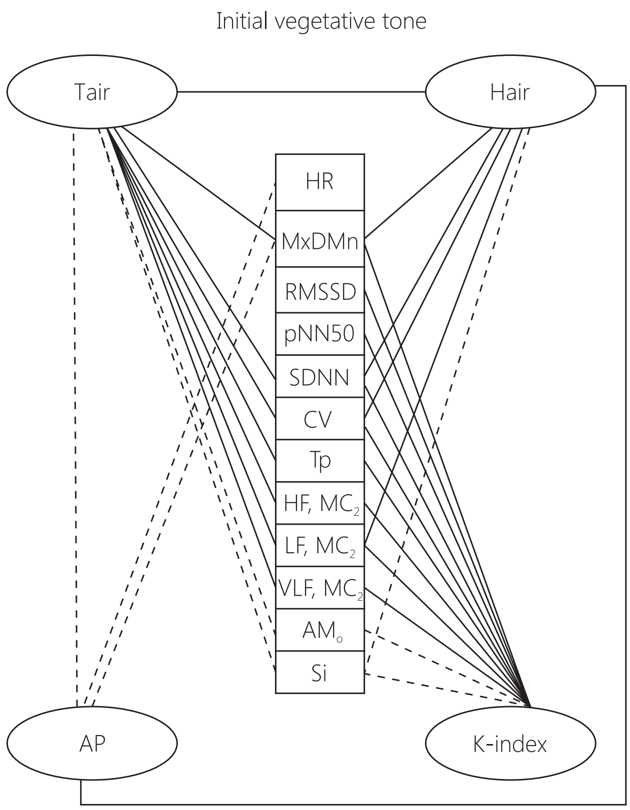

Figure 20. The correlation pleiad of climatic-heliomagnetic characteristics with the main indicators of heart rate variability

Our correlation analysis has revealed the main directions of the meteorological heliomagnetic factors' effect on the analyzed functional status physiological characteristics of the men we have involved in the survey. So, there is an increase in the level of systolic and diastolic blood pressure in response to the voltage of the Earth's magnetic field, which was discovered earlier in other studies [14]. There is also a tendency of a rise of the BPS and BPD levels in response to the low air temperatures effects, that in a combination with the wind velocity effect leads to an elevation of vascular tone, resulting in an increase in diastolic blood pressure. In addition, high values of wind velocity induce a decrease in the stroke volume and cardiac output (CO). The effect of the exogenous abiotic factors on HRV structures is manifested in the activation of such a modulation of the heart rhythm, which is characterized by the predominance of the autonomic nervous system parasympathetic division. It is known that the dominance of parasympathetic influences provides metabolism with energy, as well as the body reactions responding to external disturbances more efficiently, than sympathicotonia [15, 16]. In addition, any abiotic-nature perturbation causes the activation of the sympathetic vascular center, which may demonstrate the marker ability of this index regarding the meteorological and heliophysical factors dynamics. The systemic structure of the correlation relationships of the external respiration parameters indicates a general tendency of the organism's orientation to support the strategy of economizing applied to the functional systems reserves in the process of its adaptation to the negative influence of environmental factors, manifested by a decrease in bronchial patency within physiological norms. On the contrary, the gas exchange system in this aspect acts as a system aimed at eliminating effects produced by the heliophysical and meteorological factors. Thus, one can see an in-

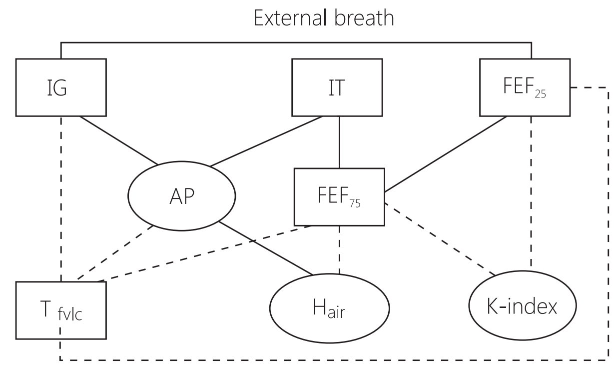

Figure 21. The correlation pleiad of climatic-heliomagnetic characteristics with the main indicators of the function of external respiration

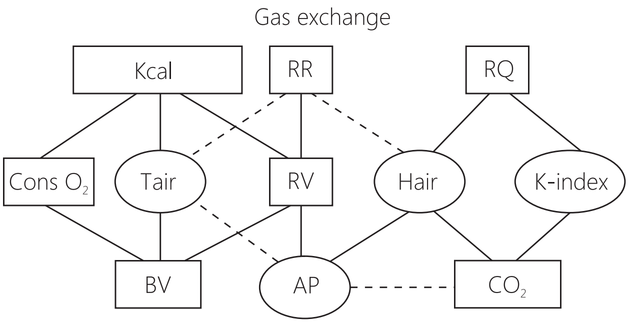

Figure 22. The correlation pleiad of climatic-heliomagnetic characteristics with the main indicators of gas exchange

crease in the respiratory and cardiac output, reflecting to some extent a change in the oxygen transport and ventilatory function of the organism in response to the positive air temperatures influence, as well as an increase in the energy expenditure of the organism. In addition, it should be noted that there is a transition to the preferential oxidation of carbohydrates in the body, caused by the disturbed magnetic field action.

Statement on ethical issues

Research involving people and/or animals is in full compliance with current national and international ethical standards.

Conflict of interest

None declared.

Author contributions

The authors read the ICMJE criteria for authorship and approved the final manuscript.

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