Vegetative homeostasis in residents of the Arctic zone with different types of interhemispheric asymmetry of cerebral energy exchange

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Abstract.

Purpose of the study - to reveal the relationship of autonomic homeostasis with interhemispheric asymmetry of the brain in young residents of the Arctic zone of the Russian Federation. ***Materials and methods.*** The study of cerebral energy processes and interhemispheric asymmetry was carried out by registering the level of constant potential of the brain and calculating the interhemispheric gradient (Td-Ts) on a 5-channel hardware-software diagnostic complex "NeuroKM" in 63 young people of working age (30-34 years old), born and permanently residing in the Arctic zone. The study of autonomic homeostasis included the study of the frequency parameters of heart rate variability at rest and during exercise - a passive orthostatic test using the VNS-spectrum diagnostic complex (Neurosoft LLC). Statistical data processing was carried out using the SPSS Statistics 26 software. ***Research results.*** In northerners with different types of hemispheric dominance of cerebral energy processes, the sex characteristics of autonomic homeostasis were revealed. At rest, in both study groups, the activity of the parasympathetic division of the autonomic nervous system in the regulation of the heart rhythm predominates. In "left hemispheric" men and "right hemispheric" women, there is an insufficient reactivity of the parasympathetic division of the autonomic nervous system in response to the orthostatic test and an increase in sympathetic activity. In men with right hemispheric asymmetry and women with left hemispheric dominance, a more pronounced vagal activity with normal parasympathetic reactivity in response to load and preservation of the reserve of parasympathetic regulation is observed. ***Conclusion.*** Thus, the most optimal vegetative homeostasis is observed in men with right hemispheric dominance and women with left hemispheric asymmetry of cerebral energy exchange.

Keywords: Arctic, able-bodied population, hemispheric asymmetry, level of constant potential, vegetative homeostasis.

Introduction

The cerebral hemispheres are two symmetrical, but functionally unequal organs, the role of which is to ensure certain functions and interhemispheric interactions [2, 11, 14]. Adaptation to the harsh climatic conditions of the Arctic occurs with the stress of all body systems [7, 8, 9, 10, 12], including the autonomic and central nervous system with changes in neuroenergy metabolism [3, 4], and interhemispheric asymmetry [5, 6].

Relatively recently, a provision has appeared on the dynamic properties of interhemispheric asymmetry due to the interaction between the cortex and the autonomic nervous system. The literature contains information on the right-sided dominance of sympathetic influences in humans [17], as well as on the representation of the sympathetic and parasympathetic nervous systems in the insular cortex of each hemisphere [15]. It has been suggested that the sympathetic and parasympathetic fibers coming from the ventromedial nucleus of the thalamus intersect in such a way that most of the sympathetic fibers are directed to the right insular cortex, and parasympathetic fibers to the left [16]. Consequently, stimulation of the temporal and frontal cortex of the right or left hemisphere leads to the activation of the sympathetic or parasympathetic system [17; 18]. The natural circadian rhythm of the tone of the sympathetic and parasympathetic nervous systems can also affect the dynamic asymmetry [13].

Thus, the interactions between the cerebral cortex and the autonomic nervous system remain poorly understood. All of the above predetermined the conduct of this work, the purpose of which is to identify the features of vegetative homeostasis in residents of the Arctic zone of the Russian Federation (30-34 years old) with different types of hemispheric dominance of cerebral energy processes.

Materials and methods

The basis of this work was the study of cerebral energy processes and heart rate variability in young people of working age (30-34 years old), born and living in the territory of the Arctic zone of the Russian Federation (men -30 people, women-33). Registration and analysis of the level of constant potential (LCP) were carried out using the 5-channel hardware-

software diagnostic complex "Neuro-KM" ("ASTEK", Russia), the analysis of heart rate variability - using the diagnostic complex VNS-spectrum (LLC "Neurosoft") at the same time of the day, with the maximum physical and mental rest of the subjects with the permission of the Ethics Committee of the Institute of Biomedical Research NArFU (protocol № 1 dated January 14, 2019). Functional images of the brain and autonomic indicators were obtained during the same experimental session. All subjects were right-handed. Each participant signed an informed consent form for the examination in accordance with the Declaration of Helsinki, which regulates scientific research.

LCP registration was carried out with non-polarizable silver chloride electrodes applied at five points of the scalp corresponding to the Fz, Cz, Oz, Td and Ts regions according to the international scheme 10-20. The reference electrode was placed on the left wrist. LCP recording was carried out 5-6 minutes after the application of the electrodes. LCP distribution analysis was performed by mapping monopolar constant potential (CP) values and calculating the interhemispheric gradient (Td-Ts). After recording the LCP of the brain, the autonomic regulation of the circulatory system was assessed by the parameters of heart rate variability (HRV) using the VNS-spectrum software and hardware diagnostic complex (Neurosoft, Russia) [1] at rest and during a passive orthostatic test. The duration of the recording in the supine position was 5 minutes. Then, after adaptation of the subjects in a horizontal position for 10 minutes, the head end of the turntable was raised by 60°. After turning the table, the studied HRV parameters were recorded for 5 minutes.

Statistical processing was carried out using the SPSS Statistics26 software package. One-dimensional descriptive statistics were calculated for each of the indicators, and the distributions of features were assessed for normality. The results of nonparametric data processing methods were presented as a median, first and third quartiles (Me (Q1; Q3)). For all the results presented, the differences were considered significant at $p<0.05$. For comparison of groups, the nonparametric Mann-Whitney test was used.

Results and discussion

When assessing the LCP of the brain and calculating the interhemispheric gradient (Td-Ts), 4 study subgroups were formed: 16 males with right hemispheric dominance and 14 with left hemispheric dominance; 18 women with right hemispheric asymmetry and 15 with left hemispheric asymmetry.

Spectral analysis of heart rate variability indicators revealed the following features of autonomic homeostasis in men with different types of hemispheric asymmetry (tab. 1).

Table 1. Indicators of the spectral structure of heart rate variability in men 30-34 years old with different types of hemispheric dominance, living in the Arctic zone

Indicators		Right hemispheric (n=16)	Left hemispheric (n=14)
TP	Background	4248.00(2326.25;6810.25)	4566.50(2654.25; 9729.00)
	Orthotest	3529.50(2527.50; 5655.00)	5183.50(4461.00; 6049.75)
VLF	Background	1311.00(776.50; 1874.50)	1349.00(607.00; 2582.00)
	Orthotest	1544.50(805.50; 2283.25)	1862.00(1512.50; 3147.75)
LF	Background	1196.50(836.00; 3194.25)	1511.50(1151.50; 1959.25)
	Orthotest	1325.50(918.75; 2189.75)	1704.00(1172.00; 2949.50)
HF	Background	1391.00(489.75; 2330.75)	1266.50(775.00; 2369.00)
	Orthotest	648.00(265.00; 1448.25)	690.50(399.75; 1915.25)*
LF/HF	Background	1.15(0.73;1.73)	1.10(0.77;1.55)
	Orthotest	2.45(0.95;3.83)	1.70(1.23; 3.95)**
VLF%	Background	28.00(23.50; 38.25)	31.00(17.00; 46.50)
	Orthotest	35.00(25.75;59.50)	37.00(29.00;52.50)
LF%	Background	35.00(31.00;41.75)	36.00(21.25; 48.00)
	Orthotest	34.50(28.25;47.75)	37.50(28.50;43.50)
HF%	Background	32.00(23.75;40.00)	28.00(24.00;38.75)
	Orthotest	17.00(10.25;34.25)*	20.00(7.75;32.25)**

*Note: * marked statistically significant differences between baseline and orthotest HRV indicators in men of the same group (*p<0,05; ** p<0,01)*

Spectral analysis indices in men with right-hemispheric and left-hemispheric dominance of cerebral energy processes do not have statistically significant differences. The total spectrum power (TR) is within the age norm in both study subgroups. High-frequency fluctuations (HF) both in absolute values and in percentage terms in "right hemispheric" men are slightly higher than in the subgroup of "left hemispheric" men. The power of low frequency waves (LF) in absolute values within the age norm in men with right hemispheric asymmetry and at the upper limit of the norm - with left hemispheric asymmetry. As a percentage, LF was within normal limits in both study groups. Waves of very low frequency (VLF) both in absolute units and in percentage within the age norm in both groups, however, in men with right hemispheric asymmetry of cerebral energy exchange, this indicator has lower values. Spectral analysis data indicate the activity of the parasympathetic division of the ANS in the regulation of heart rhythm in both study subgroups with a more pronounced vagal effect in "right hemispheric" men. The coefficient of vagosympathetic influence LF/HF at rest is within the normal range and does not have statistically significant differences in the groups.

After performing the orthostatic test, the indicators of high-frequency oscillations (HF) significantly decreased in absolute values in the "left hemispheric" men (p=0.019) and in

percentage terms in both subgroups (p=0.041 in the "right hemisphere", p=0.006 in the "left hemisphere"), which indicates a decrease in vagotonic activity in response to orthostatic load in males. In the group of "left hemispheric" men, there is an increase in the total power of the spectrum (TR) due to an increase in the low-frequency (LF) and very low-frequency (VLF) components of the spectrum and a decrease in the high-frequency (HF) due to sympathetic neuro-reflex activity. In men with right-hemispheric activity of cerebral energy exchange, a decrease in the total power of the spectrum is observed against the background of a pronounced decrease in high-frequency oscillations (HF%) and moderate low-frequency (LF%) in the general structure of the spectrum, as well as an increase in the very low-frequency (VLF%) component, which is characteristic of the centralization of regulation heart rate during orthopedic testing. The coefficient of autonomic reactivity K30/15 has statistically significant differences in the subgroups of left and right hemispheric men (p=0.029). In the subgroup of "left-hemispheric" men, K30/15 is equal to 1.06 (1.02; 1.13) - significantly reduced, which indicates the pathological reactivity of the parasympathetic division of the ANS in response to orthostatic load. In "right hemispheric" men, the coefficient of autonomic reactivity K30/15 is within the normal range - 1.16 (1.05; 1.28); this subgroup of subjects showed a normal reactivity of the parasympathetic division with the resistance of the vagus nerve to a stressful situation. The LF/HF index after the orthostatic test, reflecting the adequacy of autonomic support, significantly increased in the group of "left hemispheric" men (p=0.006) and reflects an increase in the activity of the sympathetic part of the ANS in response to exercise. Whereas in men with right-hemispheric dominance of cerebral energy processes, this indicator at rest and after the orthostatic test did not have statistically significant differences, which indicates the preservation of the reserve of parasympathetic regulation in this study group.

When assessing the indicators of heart rate variability in women with different types of dominance of cerebral energy processes, the following features of autonomic regulation of the heart rate were revealed (tab. 2).

Table 2. Indicators of the spectral structure of heart rate variability in women aged 30-34 years with different types of hemispheric dominance, living in the Arctic zone

Indicators	Gender	Right hemispheric (n=18)	Left hemispheric (n=15)
TP	Background	5987.00(5027.75;9439.75)	9990.00(3296.00; 12742.00)
	Orthotest	5808.00(2733.50; 7613.25)	8779.00(3432.00; 11803.00)
VLF	Background	1809.00(1160.75; 2232.25)	2442.00(639.00; 4114.00)
	Orthotest	1749.00(1215.75; 2560.75)	2458.00(1015.00; 5293.00)
LF	Background	1173.50(1188.25; 2631.00)	2494.00(1172.50; 4757.00)
	Orthotest	1581.50(461.75; 3272.25)	2368.00(1133.00; 3175.00)
HF	Background	2545.00(834.00; 5477.75)	4597.00(1618.00; 6706.00)

	Orthotest	1410.50(431.75; 2728.00)	1692.00(930.00; 4678.00)
LF/HF	Background	0.84(0.43;1.10)	0.67(0.51;1.10)
	Orthotest	0.88(0.74;2.43)	1.20(0.71; 1.80)*
VLF%	Background	26.00(17.00; 41.50)	28.00(19.00; 33.00)
	Orthotest	37.00(24.00;52.25)	36.00(22.00;52.00)*
LF%	Background	28.50(23.00;34.50)	31.00(23.00; 42.00)
	Orthotest	28.50(20.75;42.00)	31.00(25.00;36.00)
HF%	Background	39.00(28.00;54.50)	45.00(35.00;50.00)
	Orthotest	29.00(16.25;41.50)	35.00(18.00;42.00)*

*Note: * marked statistically significant differences between baseline and orthotest HRV indicators in women of the same group (*p<0,05; ** p<0,01)*

The values of spectral analysis at rest do not have statistically significant differences in females with different types of hemispheric asymmetry of cerebral energy processes. In women, the values of the total spectrum power (TR) are higher than the normative values for this age group, and the highest indicators are observed in "left hemispheric" women due to the contribution to the total power of the spectrum of high-frequency oscillations (HF). High values of the total spectrum power may be associated with impaired adrenergic reception in women living in northern latitudes under the influence of female sex hormones. Thus, in women at rest, regardless of the type of hemispheric dominance of neurometabolism, the initial vagotonic tone is observed, and the parasympathetic section has a more pronounced effect on the heart rate in "left hemispheric" women.

When conducting a passive orthostatic test, the total power of the spectrum (TP) in females decreases mainly due to the high-frequency component of the rhythm (HF); low frequency oscillation (LF) remains unchanged. The contribution of the very low-frequency component (VLF) to the regulation of the heart rate increases. The K30/15 coefficient in the group of "right hemispheric" women is reduced by 1.17 (1.09; 1.39), which indicates the pathological reactivity of the parasympathetic division of the ANS in response to orthostatic load. In "left hemispheric" women, the K30/15 indicator is closest to the norm of 1.23 (1.10; 1.32), which indicates the normal reactivity of the parasympathetic section with the resistance of the vagus nerve to stress stimuli.

The indicator of autonomic support (LF/HF) in response to orthostatic load significantly increased in the subgroup of "left hemispheric" women (p=0.023) relative to rest, however, there were no significant differences in this indicator when assessing the orthostatic test between the groups. It should be noted that the value of Q3=2.43 in the subgroup of "right hemispheric" women is higher than that of "left hemispheric" women (Q3=1.80), therefore, autonomic support of heart rate regulation in women with right hemispheric asymmetry is due to a more pronounced

activation of the sympathetic section ANS with preservation of the reserve of vagotonic regulation in response to stress in both groups.

Conclusion. Thus, the results of this study indicate the presence of gender differences in vegetative homeostasis in individuals with different types of hemispheric asymmetry of cerebral energy processes. The most optimal autonomic homeostasis is observed in men with right hemispheric dominance and women with left hemispheric asymmetry of neurometabolism. At rest, in all subjects, regardless of the type of hemispheric domination of cerebral energy processes, the activity of the parasympathetic division of the autonomic nervous system in the regulation of the heart rhythm predominates, which is consistent with the provision on the adaptive-trophic protective action of the vagus nerves on the heart, and is one of the factors of individual stability. a healthy organism to the unfavorable climatic conditions of the Arctic zone. However, in "left hemispheric" men and "right hemispheric" women, there is an insufficient reactivity of the parasympathetic division of the autonomic nervous system in response to an orthopedic test and an increase in sympathetic neuro-reflex activity. In men with right hemispheric asymmetry and women with left hemispheric dominance, a more pronounced vagal activity with normal parasympathetic reactivity in response to load and preservation of the reserve of parasympathetic regulation is observed.

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