Zabrodina, L., Pryvalova, N., & Matkovskyi, V. (2024).
Monitoring indicators of vegetative and energy
supply of activity in the process of human
adaptation to long-term extreme living conditions.
Ukrainian Antarctic Journal, *22*(1), 106–119.
https://doi.org/10.33275/1727-7485.1.2024.731

Liudmyla Zabrodina[1, *], Nataliya Pryvalova[1], Vasyl Matkovskyi[2]

[1] State Institution "Institute of Neurology, Psychiatry and Narcology of the National Academy of Medical Sciences of Ukraine", Kharkiv, 61068, Ukraine

[2] State Institution National Antarctic Scientific Center, Ministry of Education and Science of Ukraine, Kyiv, 01601, Ukraine

*** Corresponding author:** inpn_zabrodina@ukr.net

Monitoring indicators of vegetative and energy supply of activity in the process of human adaptation to long-term extreme living conditions

Abstract. The study was designed to trace winterers' parameters of vegetative and energetic activity supply over time, arbitrary regulation of mental processes, and evaluation of sleep quality. It also aims to identify a complex of informative criteria for human adaptation to harsh living conditions. To this effect, we created an original model that allows to optimize diagnostics of people's functional state and its dynamics given a variety of factors. We examined ten winterers (seven men and three women) whose mean age was 35.4 ± 2.0 years, and 18–28 records per participant were obtained for everyone. Three options for specific changes of adaptive and compensatory reactions in the participants of the long-term Antarctic expedition were observed. The first included pronounced vasomotor responses of the hypertonic type with preserved functions of the somnogenic mechanisms. In the second option, measured parameters remained almost always within the norm. For the third option, typical were vasomotor responses following the dystonic type, sleep disturbances of varying degrees, and unstable evaluations of health, activity, and mood, with a tendency to decrease. Under unfavorable changes in the vasomotor responses during the wintering season, the signs of maladaptive changes in the brain's functional state were clearer. A relatively higher proportion of insufficiently adaptive productivity changes as a result of decreasing functional state was seen in the winterers with the first variety of adaptation dynamics. In the people with the second variety, a sufficient level of adaptation is often reached by a compensatory reaction type. As for the third variety, the subjects had the least representation of the stable reaction type and significant compensatory and exhaustive types. Thus, the results allow us to identify a complex of informative parameters that permits evaluating the quality and dynamics of human adaptation to long-term extreme life conditions. The data have to be considered to forecast work productivity in extreme conditions, study the quality and duration of adaptation, and plan measures to prevent the disruption of adaptive-compensatory mechanisms in the wintering team.

Keywords: winterers, functional state, vegetative parameters, motor parameters

1 Introduction

The problem of human adaptation to the extreme conditions of a long stay at an Antarctic station has not lost its relevance today. This is due to the specifics of the life of winterers, which is influenced by numerous negative factors, such as the inversion of the seasons, the peculiarities of photoperiodicity,

the shift of time zones, extreme heliogeophysical influences, hypodynamia, sensory deprivation, etc., which lead to disorders of the functioning of various body systems with pronounced individual manifestations (Sukhorukov & Zabrodina, 2011/2012; Moiseyenko, 2014; Sandal et al., 2018). Disturbances in the psycho-emotional sphere may complicate the course of adaptive processes in the conditions of Antarctica, the occurrence of desynchronosis, manifestations of hypoxia and oxidative stress, which form the symptom complex of the so-called "Antarctic syndrome" (Sandal et al., 2006; Moiseyenko, 2014; Shylo et al., 2017). Therefore, the issue of assessing the human body's adaptive reserves and determining informative markers of a possible disruption of adaptive mechanisms still needs to be solved. The quality of the adaptation process can be determined by the degree of tension of the cardiovascular system's regulatory mechanisms and autonomic reactions (Jarczok et al., 2020). Various stressful situations cause instability of the vegetative nervous system (VNS) functioning due to the increased tone of its sympathetic department. Adrenaline is released, peripheral resistance of blood vessels grows, heart rate increases, and so do the minute volume of blood and arterial pressure (Convertino, 2009; Zadorozhnja & Gavrilenko, 2017). Disturbances of night sleep, observed in winterers at various stages of the expedition, put quite a heavy load on the regulatory systems that ensure adaptation. Night sleep disorders negatively influence the quality of daytime functioning and lead to the symptoms of asthenia and chronic stress (Shylo et al., 2017). Thus, it is expedient to conduct a comprehensive study of the functional state of the vegetative support systems in winterers using monitoring of cardiovascular system indicators and evaluating the quality of night sleep in the conditions of a long Antarctic expedition.

In addition, it is important to study the effect of changes in indicators of vegetative support activity on daily changes in the functional state of the brain and, accordingly, on mental performance in real time. Most often, the method of recording an electroencephalogram (EEG) is used to assess the functional state of the central nervous system (CNS). However, it may be impractical for everyday use due to the cost of the study, its complexity, and the need for technical support and maintenance. Thus, the search for simpler methods for permanently fixing biometric data, which can be used for prediction and/or early diagnosis to prevent the development of pathological conditions due to excessive load, remains urgent (Williams, 2003).

Changes in the functional state of the CNS under the influence of various factors lead at the psychological level to changes in energy supply and arbitrary regulation of motor and cognitive processes (in particular, to changes in the speed of work and its stability during the performance of various motor, intellectual and cognitive programs, disturbances of current control over activities), correlated both with the general level of activation and with the level of activity of the higher cortical regulatory systems of the brain (Boller & Grafman, 2001).

With this in mind, a suitable modification of the serial motor reaction (tapping) research methodology can be used to monitor the functional state. Previously, in medical diagnostics tapping was used to assess the motor capabilities of patients with Parkinson's disease, ataxia, and Alzheimer's disease and to assess the dynamics of recovery after the consequences of brain injuries and strokes (Barut et al., 2013; Hubel et al., 2013; Sundqvist et al., 2016; Lan & Yeo, 2019). Our modification of the tapping method (Zabrodina et al., 2021; Pryvalova et al., 2023) allowed to evaluate the dynamic characteristics of motor functions (stability reaction time, reaction asymmetry, their dynamics under conditions of arbitrary acceleration). The method can be used to study the qualitative features of subtle changes in the functional activity of subcortical non-specific brain systems and the nature of their interaction with the higher regulatory systems, the patterns of interhemispheric interaction, to determine common features and differences in the dynamics of the brain's func-

tional state in healthy subjects and patients with various forms of psychoneurological pathologies. This is extremely important for a timely diagnosis of the development of pathological conditions and processes of their compensation.

Therefore, a comprehensive study of the dynamics of brain regulatory systems in winterers, using long-term monitoring of vegetative support indicators, serial motor reactions, and evaluation of night sleep quality, can provide valuable insights into human adaptation in the Antarctic expedition. This research has the potential to not only enhance our understanding of human adaptation to extreme conditions but also contribute to developing strategies to mitigate their adverse effects.

This study aimed to monitor indicators of vegetative and energy supply of activity, arbitrary regulation of mental processes, and evaluation of night sleep quality in participants of Ukrainian Antarctic expeditions during wintering. The ultimate goal was to identify a comprehensive set of informative criteria for human adaptation to challenging living conditions.

2 Materials and methods

Ten winterers (seven men and three women) were examined. The subjects are 27 to 48 years old (the mean age is 35.4 ± 2.0 years). All participants signed the informed consent form before being enrolled in the study (approved by the Ethics committee of the State Institution "Institute of Neurology, Psychiatry and Narcology of the National Academy of Medical Sciences of Ukraine", record № 1 of January 14, 2022, according to Declaration of Helsinki).The study was conducted in the morning 2–3 times a month throughout the wintering period, which made it possible to obtain from 18 to 28 examinations for each winterer. The functional state of the brain's regulatory systems was monitored using a set of methods for which copyright registration certificates were obtained (Zabrodina et al., 2021).

The diagnostic complex included the measurement of blood pressure and heart rate. Based on the obtained data on systolic arterial pressure (SAP), diastolic arterial pressure (DAP) and heart rate (HR), integral indicators were calculated, such as Kerdo's vegetative index (KVI), which assesses the peculiarities of vegetative regulation; Robinson index (RI), which reflects the state of functioning of the cardiovascular system; the cardiovascular endurance indicator (CEI) and the circulatory efficiency coefficient (CEC) (Zadorozhnja & Gavrilenko, 2017). The formulas used to calculate these integral indicators and the normative data of selected indicators of the cardio-vascular and vegetative nervous systems for young people in a calm state are shown in Table 1.

For the quick diagnostics of peculiarities of current state, subjects completed a standard test using a 5-point scale to assess health, activity, and mood, where 1 point corresponded to the lowest and 5 points to the highest rating. The quality of night sleep was determined using the night sleep quality scale, which included the following indicators: length of time to fall asleep (from "instant-

Table 1. Formulas for calculation and normative data of the indicators of the cardiovascular system and vegetative nervous system

Indicator	Formula	Normative data
Robinson index (RI), c.u.	RI = HR × SAP/100	≤85
Kerdo's vegetative index (KVI), c.u.	KVI = (1 − DAP/HR) × 100	(−10)–(+10)
Cardiovascular endurance indicator (CEI), c.u.	CEI = HR/(SAP − DAP)	12–16
Circulatory efficiency coefficient (CEC), c.u.	CEC = HR × (SAP − DAP)	2500–3000

Note: c.u. – conventional units

ly" – 5 points, to "very long" – 1 point); sleep duration (from "very long" – 5 points, to "very short" – 1 point); number of night awakenings (from "no" – 5 points, to "very often" – 1 point); the number of dreams (from "no" – 5 points, to "very often" – 1 point); sleep quality (from "excellent" – 5 points, to "very bad" – 1 point); quality of morning awakening (from "excellent" – 5 points, to "very bad" – 1 point). A score of fewer than 19 points for all assessments corresponds to insomnia; 19–21 points – borderline state; more than 22 points is the norm, and the maximum total score is 30 points.

In our computer modification of tapping, motor programs were performed at different speed modes (usual and accelerated) by pressing the space bar with the forefingers of the right and left hands (a total of 4 tasks of 2 minutes each), which makes it possible to obtain an informative set of performance indicators. Performance indicators are determined: the number of clicks for every 6 seconds of work and the average indicator for the time of each task; indicators of unevenness (the difference in productivity between adjacent 6-second intervals and the average indicator for the time of each task), which make it possible to assess the speed and stability of work; asymmetry of all indicators (the difference between the indicators of performance of tasks with the right and left hand, separately for the usual and accelerated mode of operation and the degree of their reliability); the effect of arbitrary acceleration (the difference between performance indicators in usual and accelerated mode of operation, separately for the left and right hands and the degree of their reliability). In addition, the changes of all indicators in the dynamics over the entire observation period were studied, considering the reliability of these changes. Further data processing included the compression of primary information and its statistical transformations in search of relationships between primary indicators. The standardized examination procedure and the use of a systematic methodology for processing the obtained results make it possible to determine individual indicators of the dynamics of the functional state, which include changes in the speed and stability of the response, asymmetry of the response, and the type of response to arbitrary acceleration. Integral criteria allow to characterize changes in the specified parameters in connection with the influence of various factors in the dynamics, which makes it possible to assess the adaptive capabilities of healthy subjects (Zabrodina et al., 2021; Pryvalova et al., 2023). For processing of all obtained quantitative indicators and evaluating the significance of intergroup differences, non-parametric statistical methods were used (Wilcoxon-Mann-Whitney criterion $p \leq 0.05$) applying the software package Statistica ver. 10.

3 Results

3.1 Dynamics of the cardiovascular system and vegetative nervous system indicators

The analysis of the individual features of the dynamics of indicators of the cardiovascular and vegetative nervous systems as well as indicators of the current state and the quality of night sleep, allowed the evaluation of recovery processes. As a result, three options for specific changes of adaptive and compensatory reactions in the participants of the long-term Antarctic expedition (respectively, three groups of subjects) were identified. The data are presented in Table 2.

As seen from Table 2, in the winterers of the first group, a pronounced vasomotor response of the hypertensive type was observed. An increase in blood pressure manifested this, both systolic (147.24 ± 2.65 mm Hg) and diastolic (95.02 ± ± 1.79 mm Hg), as well as an increase in heart rate (82.98 ± 1.55 beats/min).

The analysis of integral vegetative indicators determined a significant increase in the Robinson index (123.53 ± 4.09 c.u.) and the efficiency coefficient of blood circulation (4374.36 ± 161.47 c.u.). These data displayed a change in the hemodynamic system's functional capabilities and increased energy consumption during blood flow. In the win-

terers of the first group, high negative values of Kerdo's vegetative index were also determined (−15.05 ± 1.67 c.u.), which indicated a possible exhaustion of the sympathoadrenal system. However, the value of the endurance coefficient of the cardiovascular system (16.31 ± 0.45 c.u.) had only a slight, non-critical excess of the normative limit.

The analysis of changes in indicators of the quality of night sleep in winterers of the first group did not identify significant disorders. All the main indicators were within 3−4 points, and according to the overall total score, 22 points and above corresponded to the norm's lower limit. These winterers also had satisfactory health, activity, and mood ratings of 3−4 points. Sufficient restorative sleep could compensate for the pronounced vasomotor reaction and prevent the formation of decompensation and the critical deterioration of the health of these winterers.

In winterers of the second group, changes in almost all selected parameters of the cardio-vascular and vegetative nervous systems remained within the norm. However, the endurance coefficient was slightly increased (17.70 ± 0.49 units). It may indicate some stress on the functional capabilities of the cardiovascular system due to the development of fatigue. In these winterers, the indicators of night sleep also practically did not go beyond the norm. Still, in comparison with the first group, it is possible to note a statistically significant $p \leq 0.05$ prolongation of the process of falling asleep (3.24 ± 0.10 points), which was compensated by a sufficient duration of sleep (3.68 ± 0.12 points) and did not significantly in-

Table 2. Indicators of the cardiovascular system and vegetative nervous system, current state, and night sleep quality for three variants of the dynamics of adaptive-compensatory reactions in winterers

Indicator	Winterers' group			Reliability of the differences between groups ($p \leq 0.05$)		
	Group 1 $n = 50$	Group 2 $n = 69$	Group 3 $n = 140$	1 & 2	2 & 3	1 & 3
SAP	147.24 ± 2.65	116.04 ± 1.14	127.32 ± 1.11	0.00	0.00	0.00
DAP	95.02 ± 1.79	73.75 ± 0.89	80.31 ± 0.69	0.00	0.00	0.00
HR	82.98 ± 1.55	72.44 ± 0.91	81.00 ± 0.99	0.00	0.00	0.40
RI	123.53 ± 4.09	83.83 ± 1.13	104.06 ± 1.86	0.00	0.00	0.00
KVI	−15.05 ± 1.67	−3.33 ± 2.15	−0.22 ± 1.41	0.00	0.74	0.00
CEI	16.31 ± 0.45	17.70 ± 0.49	18.23 ± 0.53	0.05	0.84	0.03
CEC	4374.36 ± 161.47	3057.01 ± 68.00	3811.20 ± 74.77	0.00	0.00	0.00
Health	3.92 ± 0.08	3.88 ± 0.08	3.46 ± 0.06	0.70	0.00	0.00
Activity	3.80 ± 0.08	3.49 ± 0.09	3.09 ± 0.07	0.01	0.00	0.00
Mood	3.62 ± 0.11	3.85 ± 0.08	3.51 ± 0.06	0.08	0.00	0.51
Time to fall asleep	4.18 ± 0.08	3.24 ± 0.10	3.55 ± 0.07	0.00	0.01	0.00
Duration of sleep	3.62 ± 0.15	3.68 ± 0.12	2.76 ± 0.10	0.88	0.00	0.00
Night awakenings	3.92 ± 0.09	4.50 ± 0.07	3.71 ± 0.09	0.00	0.00	0.34
Sleep quality	3.60 ± 0.12	3.79 ± 0.08	3.42 ± 0.07	0.11	0.00	0.29
Dreams	3.60 ± 0.09	4.06 ± 0.08	3.82 ± 0.06	0.00	0.01	0.04
Well-being in the morning	3.76 ± 0.11	3.82 ± 0.08	3.25 ± 0.07	0.62	0.00	0.00
Total evaluation of sleep quality	22.62 ± 0.43	23.06 ± 0.28	20.55 ± 0.30	0.71	0.00	0.00

Notes: $p \leq 0.05$ reliability between-group differences according to the non-parametric Mann-Whitney's test; n − number of observations

fluence its quality. Indicators of the current state also had satisfactory values; only the activity indicator (3.49 ± 0.09 points) slightly decreased compared to the first group (Table 2).

In winterers of the third group, a dystonic type of vasomotor reactions was determined with unstable blood pressure and an increase in manifestations of tachycardia. There were frequent disturbances of night sleep and decreased health, activity, and mood evaluations. The amplitude of fluctuations in blood pressure indicators exceeded the fluctuations of similar indicators in the second group of subjects statistically significantly $p \leq 0.05$, but also statistically significantly $p \leq 0.05$ did not reach the level of indicators of the first group. However, fluctuations in heart rate (81.00 ± 0.99 beats/min) practically coincided with the indicators of the first group. It negatively influenced the functionality of the cardiovascular system and led to a decrease in its endurance. According to the Robinson index (104.06 ± 1.86 c.u.) and the efficiency coefficient of blood circulation (3811.20 ± 74.77 c.u.), the functional reserves of the cardiovascular system in winterers of the third group are reliably ($p \leq 0.05$) higher than in winterers of the first group and significantly ($p \leq 0.05$) lower than in winterers of the second group (Table 2).

A distinguishing feature of the winterers of the third group were disorders of night sleep of a varying degree, namely, a decrease in the duration of sleep (2.76 ± 0.10 points), frequent night awakenings (3.71 ± 0.09 points), a decrease in the quality of sleep (3.42 ± 0.07 points), deterioration of well-being in the morning (3.25 ± 0.07 points). The total evaluation of the quality of night sleep was less than 21 points, corresponding to the marginal level between insomnia and the norm. According to the scales of health, activity, and mood, these winterers also had significantly lower scores by $p \leq 0.05$ (Table 2), which could be an indicator of the most significant (compared to others) influence of emotiogenic brain systems on the adaptive and compensatory reactions.

3.2 Dynamics of indicators of serial motor reactions

The tables below present the features of serial motor reactions for the entire observation period.

The group average maximum and minimum values of mean work productivity in usual (Table 3) and accelerated (Table 4) modes for the entire observation period and the range of changes of these indicators were determined in each group.

The presented data shows that in both modes of operation, the maximum productivity does not differ between the examined groups. At the same time, the minimum productivity is significantly lower in the subjects of Group 1, as well as the average difference between the maximal and minimal productivity especially in the accelerated mode. A significant decrease in the energy resources on certain days can be considered one of the indicators of insufficient stability of the functional state (Moiseyenko et al., 2016; Sandal et al., 2018).

Table 3. Indicators of the average work productivity of the subjects in the usual mode

Winterers' group	Right hand			Left hand		
	max	min	difference	max	min	difference
Group 1	23.52 ± 0.87	5.60 ± 0.14[1, 3]	16.43[1, 3]	20.75 ± 0.40	5.40 ± 0.13[3]	15.35[3]
Group 2	21.63 ± 0.40	8.65 ± 0.22[1]	12.98[1]	21.50 ± 0.27	4.70 ± 0.49[2]	13.80
Group 3	21.82 ± 0.52	10.06 ± 0.25[3]	11.64[3]	20.17 ± 0.23	10.19 ± 0.16[2, 3]	7.98[3]

Notes: [1] – $p \leq 0.05$ reliability of differences between groups 1 and 2; [2] – $p \leq 0.05$ reliability of differences between groups 2 and 3; [3] – $p \leq 0.05$ reliability of differences between groups 1 and 3; differences according to the non-parametric Mann-Whitney's test

We determined the maximum and minimum values of mean work unevenness in the usual (Table 5) and accelerated (Table 6) modes for the entire observation period and the range of changes of these indicators in each group.

According to the data, this indicator is low for all subjects in the usual mode. At the same time, under load conditions, this indicator increases significantly, mainly in subjects of Group 1, more when working with the left hand. The same effect is observed in subjects from Group 3, but more so when working with the right hand.

Figure 1 shows the percentage of cases of significant dominance of productivity of the right or left hand in different work modes during the entire observation period.

From these data, it can be seen that in Group 2, in the usual mode of work, there is a significant dominance of the right-hand productivity or the absence of such dominance. In contrast, in the conditions of arbitrary acceleration, the dominance of the right-hand productivity increases significantly, whereas significant differences in the unevenness indicator are absent (Fig. 2). These re-

Table 4. Average work productivity of the subjects in the accelerated mode

Winterers' group	Right hand			Left hand		
	max	min	difference	max	min	difference
Group 1	43.83 ± 1.22	19.78 ± 0.37[1, 3]	24.05[1, 3]	37.55 ± 1.33	18.25 ± 0.32[1, 3]	19.30[1, 3]
Group 2	39.33 ± 0.74	27.90 ± 0.48[1]	11.43[1]	36.37 ± 0.88	26.08 ± 0.33[1]	10.28[1]
Group 3	38.58 ± 2.19	26.15 ± 0.53[3]	12.45[3]	31.81 ± 1.38	25.00 ± 0.42[3]	7.42[3]

Notes: [1] – $p \le 0.05$ reliability of differences between groups 1 and 2; [2] – $p \le 0.05$ reliability of differences between groups 2 and 3; [3] – $p \le 0.05$ reliability of differences between groups 1 and 3; differences according to the non-parametric Mann-Whitney's test

Table 5. Average work unevenness of the subjects in the usual mode

Winterers' groups	Right hand			Left hand		
	max	min	difference	max	min	difference
Group 1	1.89 ± 0.37	0.24 ± 0.12	1.61	1.13 ± 0.20	0.29 ± 0.10	0.84
Group 2	2.07 ± 0.73	0.51 ± 0.16	1.56	2.63 ± 0.85	0.61 ± 0.15	2.02
Group 3	2.19 ± 0.51	0.45 ± 0.12	1.66	2.71 ± 0.54	0.48 ± 0.13	2.23

Table 6. Average work unevenness of the subjects in the accelerated mode

Winterers' groups	Right hand			Left hand		
	max	min	difference	max	min	difference
Group 1	5.55 ± 4.57	0.37 ± 0.12	5.18[1]	7.42 ± 3.51[1, 3]	0.48 ± 0.11	6.95[1, 3]
Group 2	3.48 ± 1.21	0.88 ± 0.21	2.60[1, 2]	3.73 ± 1.31[1]	0.75 ± 0.16	2.65[1]
Group 3	5.65 ± 2.06	0.62 ± 0.17	4.23[2]	4.40 ± 1.35[3]	0.55 ± 0.15	3.85[3]

Notes: [1] – $p \le 0.05$ reliability of differences between groups 1 and 2; [2] – $p \le 0.05$ reliability of differences between groups 2 and 3; [3] – $p \le 0.05$ reliability of differences between groups 1 and 3; differences according to the non-parametric Mann-Whitney's test

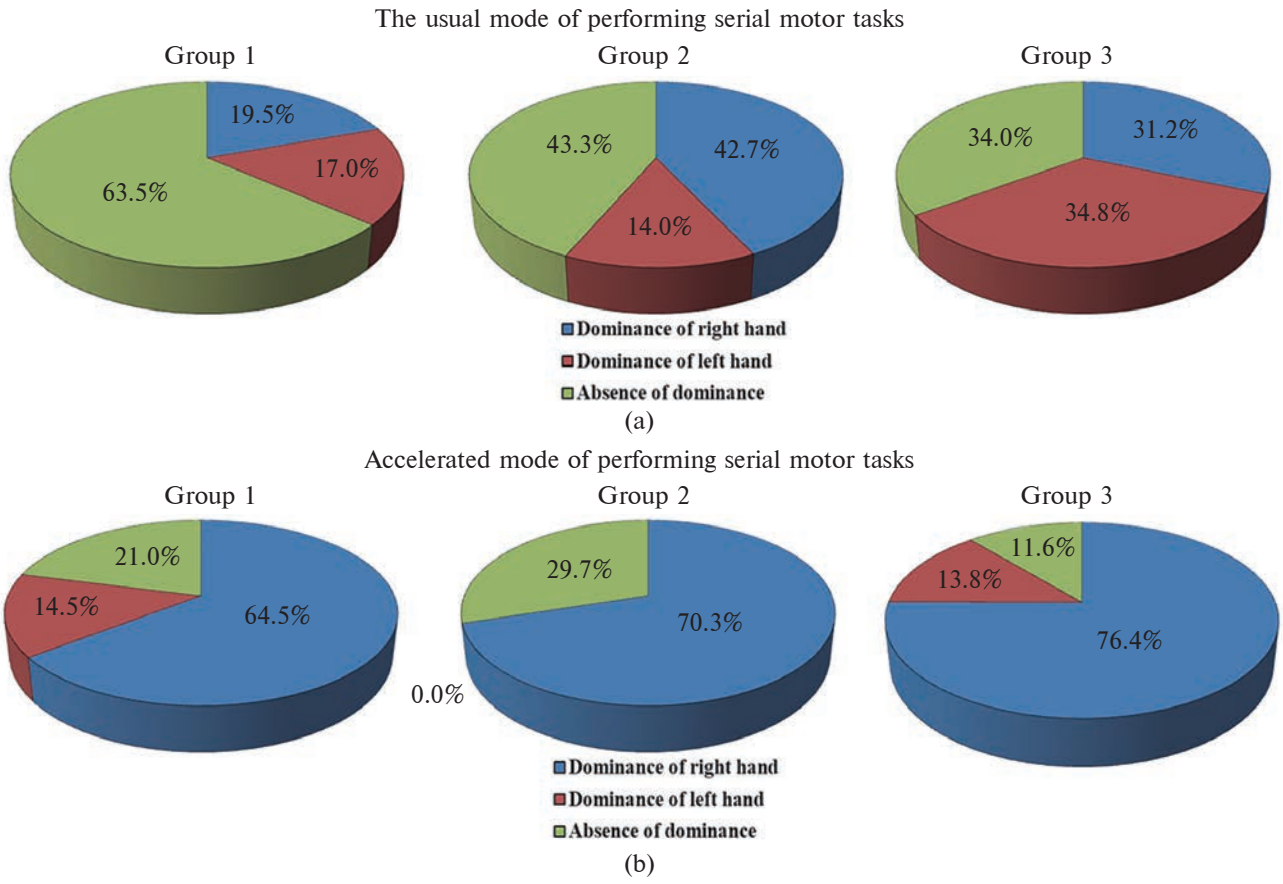

Figure 1. The percentage of cases of significant dominance of the productivity of the right or left hand in different work modes

sults may indicate the optimal functioning of arbitrary regulation of the functional state.

Individuals of Group 3 in the usual mode do not have significant dominance of the right-hand productivity, although it appears in the accelerated mode also without significant differences in the unevenness index.

At the same time, subjects of Group 1 are characterized by the absence of a persistent, significant asymmetry of productivity in the usual mode of work; in the accelerated mode of work, the dominance of the right-hand productivity is observed less often than in others. In addition, in this mode of work, the number of cases of inversion of productivity asymmetry with a significant dominance of the left hand increases in these subjects. It is also accompanied by greater instability in completing tasks.

The instruction of arbitrary acceleration leads to a significant increase in work productivity in all subjects. At the same time, under these conditions, increasing work instability of with both hands was observed in Group 1 (mainly in the left hand). This effect is the least pronounced in Group 3 (Fig. 3).

Our findings underscore the significant role of acceleration in destabilizing the functional state of the subjects in Group 1.

The analysis of the study results made it possible to determine several types of dynamics of the productivity indicator in subjects. The first type of work productivity dynamics is adaptive. It was characterized by an improvement in the functional state of brain regulatory systems, evidenced by a significant increase in work productivity in all

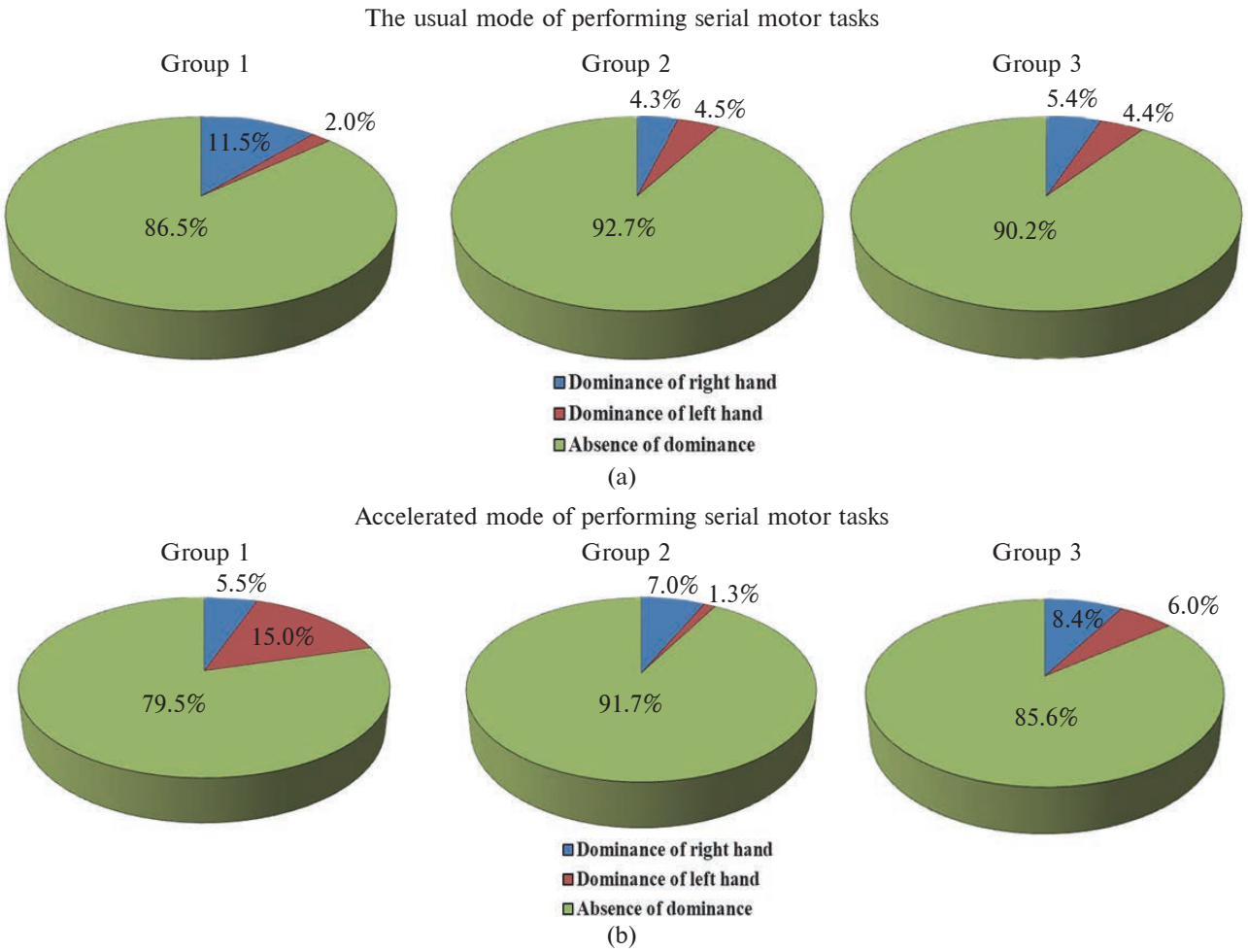

Figure 2. Percentage of cases of significant dominance of the unevenness of the work of the right or left hand in different modes

modes of its performance or mainly in the mode of arbitrary acceleration. The second type is stable, in which there were no significant changes in work productivity in all work modes. The third type is compensatory, in which productivity was significantly reduced in the usual mode but stable or increased under acceleration conditions. The fourth type was characterized by an impairment of the functional state of the brain regulatory systems, which was manifested by a significant decrease in productivity in all work modes. The fifth type is exhaustion, with an increase or stability of productivity in the usual mode and its decrease in acceleration conditions (Pryvalova et al., 2023).

An analysis of productivity indicators changes in subjects over the entire observation period was carried out.

From the data presented in Figure 4, it can be seen that there is no dominance of changes that indicate an improvement or sufficient stability of the functional state during the entire wintering period (a total of 1 and 2 types of response) in all subjects. The adaptive type of response is represented almost equally in all groups. At the same time, a relatively large part of insufficiently adaptive changes in productivity dynamics with a decrease in functional status is observed in the examined Group 1; in subjects from Group 2, a sufficient level of adap-

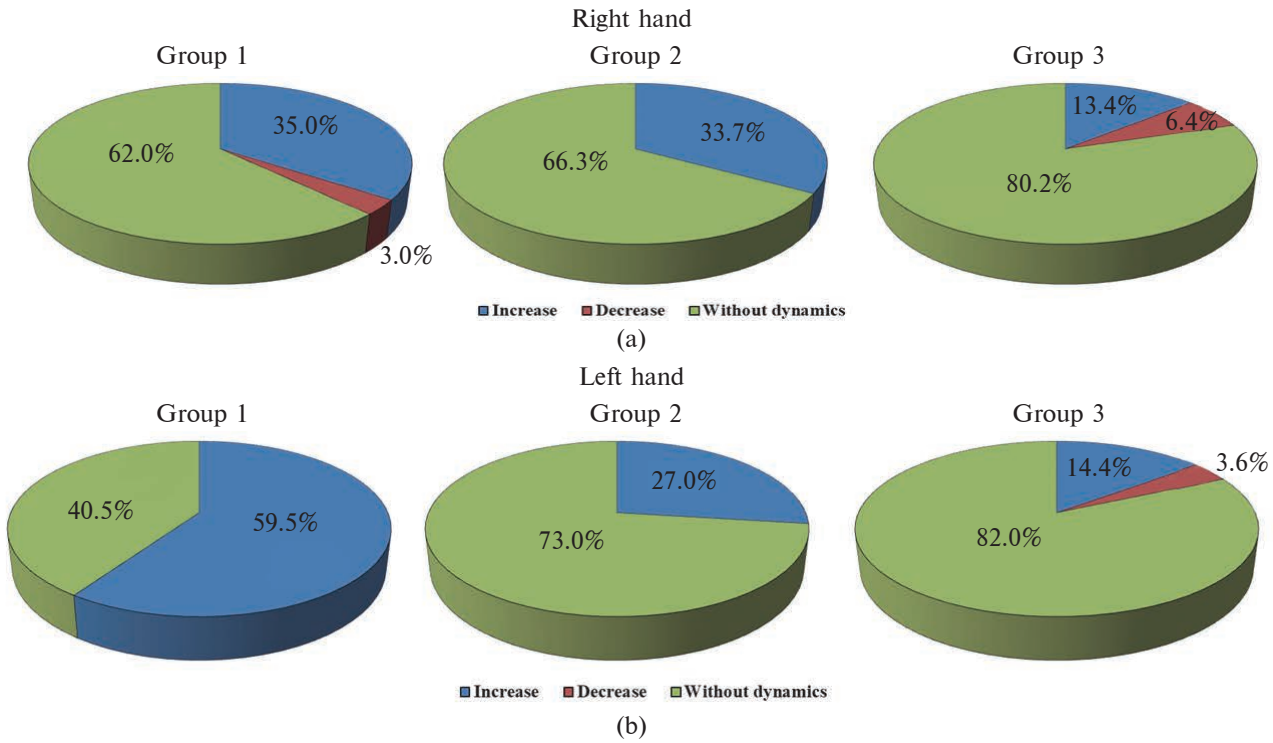

Figure 3. The percentage of cases of the impact of acceleration on work unevenness

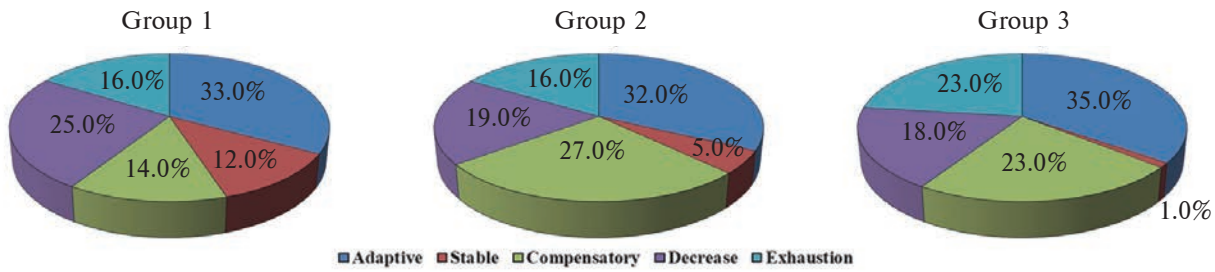

Figure 4. The percentage of the number of different types of productivity dynamics in the subjects throughout the observation period

tation is often achieved due to the compensatory type of response, and subjects in Group 3 are characterized by the smallest representation of the stable type and the significant representation of the compensatory type and exhausting type of response.

4 Discussion

Long-term monitoring of the indicators of the functional activity of the vegetative support systems in the participants of the wintering detachment made it possible to determine the options for forming vasomotor reactions of varying degrees of expressiveness (Williams, 2003; Convertino, 2009). Based on the analysis of changes in individual primary and integral indicators of vegetative support, the quality of night sleep, health, activity, and mood, the following variants of the features of changes of adaptive reactions in winter residents were determined: the first with pro-

nounced reactions of the hypertensive type with the preservation of the functioning of somnogenic mechanisms, which contributed to restraining the development of decompensation processes; the second – vasomotor reactions and indicators of the quality of night sleep practically did not go beyond the permissible normative values as well as evaluations of health, activity, and mood; the third – vasomotor reactions of the dystonic type, disorders of night sleep of varying degrees of expressiveness, unstable with a tendency to decrease the evaluations of health, activity, and mood; this variant could be defined as an option with a high cost of adaptation.

The analysis of the research results allows to determine informative indicators of the functioning of a non-specific brain system at all levels of the organization, including the features of interhemispheric asymmetry and interhemispheric integration at the level of higher regulatory systems: productivity and unevenness of work with the right and left hands and the nature of their significant changes under conditions of load (arbitrary acceleration) in persons with different features of changes of adaptive reactions.

It is shown that with a more favourable type of vegetative response, the range of changes in productivity and instability indicators in dynamics is insignificant both in the usual mode of operation and under load conditions. The effect of arbitrary acceleration is perceptible when working with the right and left hand; in the first case, it is somewhat more pronounced. At the same time, there is a persistent clear dominance of right-handed work performance or the absence of such dominance in the usual mode. In contrast, under conditions of acceleration upon activation of the frontal cortex of the brain's left hemisphere, which is responsible for the arbitrary regulation of mental processes, the dominance of right-handed work productivity significantly increases while maintaining its stability. Such indicators of the performance of serial motor reactions and their correlations testify to the pronounced influence of the brain's cortical regulatory systems on the dynamics of the functional state in accordance with the tasks that are performed, which allows for maintaining the appropriate level of adaptation both under usual or load conditions.

At the same time, the more unfavourable changes in the indicators of the vegetative response were observed during wintering, i.e., the greater the price of adaptation correlated with significant maladaptive changes in the functional state of the brain, namely, pronounced instability of work (as evidenced by a significant range of changes in its productivity and unevenness indicators), as well as the absence of persistent, significant productivity asymmetry both in usual and accelerated work mode with an increase in the number of cases of inversion of asymmetry in accelerated work mode. The obtained data may indicate preservation, but the reduction of cortical regulatory influences on subcortical systems of non-specific activation under load conditions, a decrease in the level of interhemispheric interaction processes, which is a sign of an insufficient level of adaptation.

Several types of dynamics of the productivity indicator were determined, and their ratio was shown in all subjects for the entire wintering period. It was found that there was no dominance of changes indicating an improvement or sufficient stability of the functional state during wintering in all winterers. At the same time, a relatively larger part of insufficiently adaptive changes in productivity in dynamics with a decrease in functional state is observed in subjects with the first variant of adaptation dynamics. In subjects with the second variant, a sufficient level of adaptation is often achieved due to a compensatory type of response, and subjects with the third variant of adaptation dynamics are characterized by the least representation of the stable type and a significant representation of the compensatory and exhausting type of response.

Thus, the research made it possible to determine a set of informative indicators that allows for a comprehensive assessment of the quality and dynamics of human adaptation to long-term extreme conditions of life. These data can be taken into account to predict the effectiveness of work in

extreme conditions for further study of the quality and duration of adaptation and for the development of measures aimed at preventing the breakdown of adaptive and compensatory mechanisms in participants of the wintering detachment.

5 Conclusions

An original model both during the day and for longer periods of monitoring parameters of vegetative and energetic supply of activity, arbitrary regulation of mental processes, and evaluation of sleep quality together with a standardized algorithm for data processing was created.

Monitoring of the indicators of the functional activity of the vegetative support systems in the participants of the wintering detachment permits to determine three options for specific changes of adaptive and compensatory reactions depending on the type and expressiveness of vegetative reactions and the degree of preservation of the functioning of somnogenic mechanisms.

It was shown that parameters of tapping, such as productivity and unevenness of work with the right and left hands and the nature of their changes under conditions of arbitrary acceleration, may be informative indicators of the stability of the brain's functional state in persons with different features of changes of adaptive reactions. Under unfavorable changes in the vegetative parameters during the wintering season, the signs of maladaptive changes in the brain's functional state were more clear (unstable capacity to work, the absence of persistent, significant productivity asymmetry both in usual and accelerated work mode with frequent manifestations of inversion of asymmetry under load condition).

Several types of dynamics of the productivity indicator such as adaptive, stable, compensatory, decrease and exhaustion, in all subjects for the entire wintering period were determined. Relationship between percentage of representation of these types and variants of dynamics of adaptation in winterers groups was identified. It was found that there was no dominance of changes indicating an improvement or sufficient stability of the functional state during wintering in all winterers.

The results of the research made it possible to determine a set of informative indicators for a comprehensive assessment of the quality and dynamics of human adaptation to long-term extreme conditions of life.

Author contributions. L.Z.: conceptualization, methodology of research of parameters of vegetative supply over time, and evaluation of sleep quality, writing – original & draft. N.P: conceptualization, methodology of research of parameters of energetic activity supply over time and arbitrary regulation of mental processes, writing – original & draft. V.M.: investigation, creating a database. All authors have read and agreed to the published version of the manuscript.

Acknowledgments. The current study was performed in the framework of the State Special-Purpose Research Program in Antarctica for 2011–2025.

Informed consent. Written informed consent was obtained for anonymized patient information to be published in this article.

Conflict of Interest. The authors declare no conflict of interest.

References

Barut, Ç., Kiziltan, E., Gelir, E., & Köktürk, F. (2013). Advanced analysis of finger-tapping performance: a preliminary study. *Balkan Medical Journal, 30*(2), 167–171. https://doi.org/10.5152%2Fbalkanmedj.2012.105

Boller, F., & Grafman, J. H. (Eds.). (2001). *Handbook of Neuropsychology* (2nd ed.) Introduction (Section 1) and Attention (Section 2). Elsevier.

Convertino, V. A. (2009). Status of cardiovascular issues related to space flight: implications for future research directions. *Respiratory Physiology & Neurobiology*, 169, Supplement, S34–S37. https://doi.org/10.1016/j.resp.2009.04.010

Hubel, K. A., Reed, B., Yund, E. W., Herron, T. J., & Woods, D. L. (2013). Computerized measures of finger tapping: effects of hand dominance, age, and sex. *Perceptual and Motor Skills, 116*(3), 929–952. https://doi.org/10.2466/25.29.pms.116.3.929-952

Jarczok, M. N., Jarczok, M., & Thayer, J. F. (2020). Work stress and autonomic nervous system activity. In T. Theorell (Ed.), *Handbook of socioeconomic determinants of occupational health* (pp. 625–656). Springer, Cham. https://doi.org/10.1007/978-3-030-31438-5_27

Lan, B. L., & Yeo, J. H. W. (2019). Comparison of computer-key-hold-time and alternating-finger-tapping tests for early-stage Parkinson's disease. *PLoS ONE, 14*(6), e0219114. https://doi.org/10.1371/journal.pone.0219114

Moiseyenko, Ye. V. (2014). Peculiarities of human adaptation to Antarctic conditions. *Science and Education, 8*, 133–137.

Moiseyenko, Y. V., Sukhorukov, V. I., Pyshnov, G. Y., Mankovska, I. M., Rozova, K. V., Miroshnychenko, O. A., Kovalevska, O. E., Madjar, S.-A. Y., Bubnov, R. V., Gorbach, A. O., Danylenko, K. M., & Moiseyenko, O. I. (2016). Antarctica challenges the new horizons in predictive, preventive, personalized medicine: preliminary results and attractive hypotheses for multi-disciplinary prospective studies in the Ukrainian "Akademik Vernadsky" station. *EPMA Journal*, *7*, 11.

Pryvalova, N. M., Zabrodina, L. P., Bovt, Y. V, & Sukhorukov, V. V. (2023). Monitoring of asthenic disorders in patients with psychoneurological pathology. *Ukrainian newsletter of psychoneurology, 31*(3 (116), 46–52. https://doi.org/10.36927/2079-0325-V31-is3-2023-8 (In Ukrainian)

Sandal, G. M., Leon, G. R., & Palinkas, L. (2006). Human challenges in polar and space environments. *Reviews in Environmental Science and Bio/Technology*, 5, 281–296. https://doi.org/10.1007/s11157-006-9000-8

Sandal, G. M., van deVijver, F. J. R., & Smith, N. (2018). Psychological hibernation in Antarctica. *Frontiers in Psychology*, *9*, 2235. https://doi.org/10.3389/fpsyg.2018. 02235

Shylo, O. V., Lutsenko, D. G., Danylenko, K. M., Babiychuk, G. O., & Moiseyenko, Ye. V. (2017). Methods of studying the dynamics of some sleep quality indexes in Antarctic winterers. *Ukrainian Antarctic Journal, 16*, 188–200. https://doi.org/10.33275/1727-7485.16.2017.77 (In Russian)

Sukhorukov, V. I., & Zabrodina, L. P. (2011/2012). Features of electrical activity of human brain during prolonged staying in Antarctica. *Ukrainian Antarctic Journal, 10/11*, 365–369. https://doi.org/10.33275/1727-7485.10-11.2012.324 (In Russian)

Sundqvist, M., Johnels, J. Å., Lindh, J., Laakso, K., & Hartelius, L. (2016). Syllable repetition vs. finger tapping: aspects of motor timing in 100 healthy adults. *Motor Control, 20*(3), 233–254. https://doi.org/10.1123/mc.2014-006

Williams, D. R. (2003). The biomedical challenges of space flight. *Annual Review of Medicine*, 54, 245–256. https://doi.org/10.1146/annurev.med.54.101601.152215

Zabrodina, L. P., Mishchenko, T. S., Bovt, Yu. V., & Pryvalova, N. M. (2021). *Certificate of copyright registration for the work "Comprehensive study including the Tapping test and questionnaires to determine the disturbance of night sleep and daytime functioning".* Ukraine. No. 105714, date of registration 06.23.21. State Enterprise "Ukrainian Intellectual Property Institute".

Zadorozhnja, V. Yu., & Gavrilenko, O. Yu. (2017). Cardiovascular system reaction features of students with different type of blood circulation autoregulation. *Bulletin of Zaporizhzhya National University. Biological Sciences*, (2), 56–66.

Received: 16 April 2024
Accepted: 30 July 2024

Людмила Забродіна[1], *, Наталія Привалова[1], Василь Матковський[2]

[1] Державна установа Інститут неврології, психіатрії та наркології Національної академії медичних наук України, Харків, 61068, Україна
[2] Державна установа Національний антарктичний науковий центр Міністерства освіти і науки України, Київ, 01601, Україна

*** Автор для кореспонденції:** inpn_zabrodina@ukr.net

Моніторинг показників вегетативного та енергетичного забезпечення діяльності в процесі адаптації людини до тривалих екстремальних умов життя

Реферат. Метою роботи було вивчення динаміки показників вегетативного та енергетичного забезпечення діяльності, довільної регуляції психічних процесів та самооцінки якості нічного сну в учасників зимувального загону та визначення комплексу інформативних показників, які дозволяють всебічно оцінити якість і динаміку адаптації людини до тривалих екстремальних умов життєдіяльності. Для виконання завдань дослідження було створено оригінальну модель, яка дозволяла оптимізувати діагностику функціонального стану людини

та його динаміки в умовах дії різних чинників. Було проведено обстеження 10 зимівників (сім чоловіків та троє жінок), середній вік яких складав 35.4 ± 2.0 років, та отримано результати від 18 до 28 обстежень для кожного. Було визначено три варіанти динаміки адаптивно-компенсаторних реакцій учасників зимувального загону. Перший характеризувався виразними вегето-судинними реакціями за гіпертонічним типом на тлі збереження функціонування сомногенних механізмів; при другому всі досліджені показники практично не виходили за межі нормативних значень; для третього були типовими вегето-судинні реакції за дистонічним типом, порушення нічного сну різного ступеня виразності, нестабільні з тенденцією до зниження оцінки самопочуття, активності та настрою. На тлі неадаптивних змін вегетативного реагування під час зимівлі стають виразнішими ознаки негативної динаміки функціонального стану мозку, особливо у обстежених з першим варіантом динаміки адаптації. У осіб з другим варіантом достатній рівень адаптації часто досягається за рахунок компенсаторного типу реагування. Особи з третім варіантом динаміки адаптації характеризуються найменшою представленістю стабільного типу на тлі домінування компенсаторного і виснажливого типу реагування. Таким чином, результати обстеження дозволили визначити комплекс інформативних показників, які дозволяють оцінити якість і динаміку адаптації людини до тривалих екстремальних умов життєдіяльності. Ці дані необхідно враховувати для прогнозу ефективності роботи в екстремальних умовах, для подальшого вивчення якості та тривалості адаптації та при плануванні заходів, спрямованих на запобігання зриву адаптивно-компенсаторних механізмів у учасників зимувального загону.

Ключові слова: зимівники, функціональний стан, вегетативні показники, моторні показники