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ADAPTATION STATUS OF MILITARY PERSONNEL IN THE ARCTIC UNDER NUTRITIONAL OPTIMIZATION WITH A FOOD PRODUCT CONTAINING BIOLOGICALLY ACTIVE SUBSTANCES

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Introduction. Prolonged stay in the Far North imposes significant stress on the body's adaptive mechanisms responsible for maintaining homeostasis. In this context, the nutrition of military personnel based on a scientifically ground system that ensures optimal intake of essential nutrients, including micronutrients, plays an important role in the acclimatization process. Proper dietary provision preserves and strengthen the health of military personnel, preventing the development of chronic adaptive stress.
Objective. Assessment of the adaptation state of military personnel in the Arctic following inclusion of a natural product rich in dietary and biologically active substances in their diet.
Materials and methods. The study was conducted in June–July 2022 in the Arctic, involving healthy and practically healthy male military personnel (n = 60; mean age 37.3 ± 3.1 years). The median duration of professional activity was 7.0 [5; 9] years. The subjects were divided into the following groups. The main group (n = 30) received 10.0 g of a plant protein product (PPP) incorporated into the main dinner meal for 21 days, whereas the comparison group (n = 30) was provided with a standard ration. The formulation of the PPP was developed considering the living conditions. The PPP included: chokeberry (aronia), flax seeds, carrots, broccoli, seaweed, and chicken eggshell. The amount of macro- and microelements, dietary fiber, and minor biologically active substances included in the PPP was calculated. The assessment of the body's adaptation state was performed by analyzing leukograms. A complete blood count was performed using an automated hematology system (Abbott, USA). The types of non-specific adaptive reactions of the body, levels of reactivity, and adaptation status in the main group prior to and following administration of the PPP, as well as in the comparison group at baseline and on day 22 of the experiment, were determined using L. Garkavi's method. Statistical processing of the initial data was performed using the IBM SPSS Statistica 6.1 software package.
Results. In individuals of the main group, a decrease in leukocyte counts from 6.52 ± 0.61 to (6.3 ± 0.47) × 10^9/L was detected, along with an increase in the number of eosinophils, monocytes, lymphocytes, and the percentage of band neutrophils. At baseline, in 2 (6.7%) participants from the main group, the type of adaptive reaction was classified as "enhanced activation," while in 14 (46.7%) individuals it was defined as "training" and "calm activation." By the end of the 22-day observation period, 28 (93.3%) subjects from the main group demonstrated the body's adaptive reactions classified as "enhanced activation," except for 2 (6.7%) individuals whose adaptive reaction type was assessed as "calm activation." Prior to PPP intake, the level of body reactivity was assessed as high and medium in the majority of subjects. After 22 days, only one person in the main group had a medium level of reactivity, while all others were assessed as having a high level with the "enhanced activation" type of adaptive response. In individuals with the "calm activation" type, the level of reactivity was statistically significantly high in all cases. Following the PPP course in the main group, adaptation was assessed as being within a physiological norm in all servicemen. The comparison group, conversely, showed an increase in the proportion of individuals in a pre-nosological state.
Conclusions. It was established that in the absence of extreme cold exposure (as the study was conducted in the Arctic during the summer period), the non-specific adaptive mechanisms of the body in individuals of the main group and the comparison group were predominantly assessed as "training" (46.7–56.7%) and "calm activation" (36.7–43.3%), corresponding to high and medium levels of body reactivity. Nutritional optimization with the inclusion of PPP in the subjects of the main group contributed to stimulating metabolic processes in the body, a positive shift in lymphopoiesis (manifested in an increase in the proportion of individuals with the "enhanced activation" type of non-specific adaptive reaction to 93.3% in the main group), and the restoration of the adaptation state to the physiological norm.

Keywords: Arctic; contract military personnel; plant protein product; diet; efficacy; adaptation state

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СОСТОЯНИЕ АДАПТАЦИИ ВОЕННОСЛУЖАЩИХ В АРКТИКЕ ПРИ ОПТИМИЗАЦИИ ПИТАНИЯ ПРОДУКТОМ, СОДЕРЖАЩИМ ПИЩЕВЫЕ И БИОЛОГИЧЕСКИ АКТИВНЫЕ ВЕЩЕСТВА

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Введение. Пребывание в условиях Крайнего Севера приводит к напряжению адаптационных реакций организма, обеспечивающих поддержание гомеостаза. В связи с этим продовольственное обеспечение военнослужащих с учетом научно обоснованной системы адекватного питания, предусматривающей доведение до оптимального уровня в рационах незаменимых пищевых веществ, в том числе микронутриентов, играет важную роль в процессе акклиматизации, сохранении и укреплении здоровья контингента, а также предупреждении синдрома хронического адаптивного напряжения.
Цель. Оценка состояния адаптации военнослужащих в Арктике при включении в рацион питания натурального продукта, содержащего пищевые и биологически активные вещества.
Материалы и методы. Исследование проведено июне–июле 2022 г. в Арктике с участием здоровых и практически здоровых военнослужащих-мужчин (n = 60; средний возраст 37,3 ± 3,1 года). Медианная длительность профессиональной деятельности составила 7 [5; 9] лет. Испытуемые были разделены на группы: основная (n = 30) (в течение 21 сут во время ужина принимали по 10,0 г продукта из растительно-белкового сырья (ПРБС), внесенного во второе блюдо); группа сравнения (n = 30) (питание по стандартному рациону). Рецептура ПРБС разработана с учетом условий обитания. В состав продукта из растительно-белкового сырья включены: черноплодная рябина, семена льна, морковь, брокколи, морская капуста и скорлупа куриных яиц. Включение в состав пищевых ингредиентов в ПРБС макро- и микроэлементов, пищевых волокон, минорных биологически активных веществ проведено расчетным методом. Оценка состояния адаптации организма проведена при анализе лейкограмм. Общеклинический анализ крови выполнен с использованием автоматизированной гематологической системы Abbott (США). Типы неспецифических адаптационных реакций организма, уровни реактивности организма, состояние адаптации в основной группе до и после приема ПРБС и в группе сравнения до начала и на 22-й день эксперимента определяли по методике Л.Х. Гаркави. Статистическая обработка исходных данных проведена с использованием пакета прикладных программ IBM SPSS Statistica 6.1.
Результаты. У лиц основной группы выявлены снижение числа лейкоцитов с 6,52 ± 0,61 до (6,3 ± 0,47)×10^9/л, возрастание количества эозинофилов, моноцитов, лимфоцитов и процентного содержания палочкоядерных нейтрофилов. До начала исследования у 2 (6,7%) участников из основной группы тип адаптационной реакции был определен как «повышенная активация», у 14 (46,7%) лиц — как «тренировка» и «спокойная активация». В конце наблюдения через 22 дня у 28 (93,3%) испытуемых из основной группы адаптационные реакции организма оценивали как «повышенную активацию», за исключением 2 (6,7%) лиц, у которых тип адаптационной реакции оценили как «спокойную активацию». Уровень реактивности организма до приема ПРБС у большинства испытуемых оценивался как высокий и средний; через 22 дня лишь у одного человека из основной группы уровень реактивности оказался средним, у всех остальных оценивался как высокий при типе адаптационной реакции «повышенная активация», а при типе адаптационной реакции «спокойная активация» уровень реактивности организма статистически значимо определен на высоком уровне у всех участников. После курса приема ПРБС в основной группе у всех военнослужащих адаптация оценивалась как физиологическая норма, в группе сравнения, наоборот, было отмечено нарастание доли лиц в донозологическом состоянии организма.
Выводы. Установлено, что при отсутствии влияния на организм экстремального холода (исследование проводилось в Арктике в летнее время) неспецифические адаптационные реакции организма лиц основной группы и группы сравнения оценивали как «тренировка» у 46,7–56,7% и «спокойная активация» у 36,7–43,3% при высоких и средних уровнях реактивности организма. Оптимизация питания пищевым продуктом из растительно-белкового сырья у испытуемых основной группы способствовала стимулированию метаболических процессов в организме, позитивной динамике лимфопоэза (возрастание доли лиц до 93,3% в основной группе с типом неспецифической адаптационной реакции «повышенная активация») и восстановлению состояния адаптации до физиологической нормы.

Ключевые слова: Арктика; военнослужащие по контракту; продукт из растительно-белкового сырья; рацион питания; эффективность; состояние адаптации

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Финансирование: исследование выполнено без спонсорской поддержки.

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INTRODUCTION

State interests in the development of the Arctic zone of Russia necessitate a permanent military presence as part of the strategic deterrent forces[1,2]. Under changing living conditions, significant alterations occur in the functional state of the human body, with physiological functions being reorganized to a new adaptive level [1]. Even permanent residence in the Far North among indigenous small-numbered peoples is associated with stress on the body's adaptive mechanisms responsible for homeostasis maintenance [2, 3]. It, therefore, can be expected that prolonged deployment of healthy military personnel in this area, in the course of their professional activity, may have a negative impact on the body's adaptation status and overall resistance [4].

Human activities in northern environments lead to an increase in the body's energy and plastic requirements, including vitamins and minerals[3]. In this context, the adequate nutrition of military personnel based on a scientifically ground system that ensures the intake of essential nutrients, including micronutrients, plays an important role in the acclimatization of servicemen, preserving their health and preventing chronic adaptive stress.

The conducted analysis of combined-arms and naval rations showed a reduced content of vitamins A, C, B_1, B_2, and niacin, as well as a calcium deficiency [5, 6]. The study by Kirichenko et al. emphasized the regular (course-based) introduction of vitamins and minerals into the diet of military personnel during autumn–winter periods [7]. A number of studies [8–11] proposed food products possessing therapeutic and prophylactic properties, the formulations of which were developed based on local raw materials, both plant- (northern berries) and protein-based (from animal husbandry and fishing). For example, the development of food products aimed at enhancing the body's adaptive capacity takes into account the pathogenesis of the predominant diseases observed among populations residing in northern regions [9]. At the same time, the technological and resource constrains associated with the production of such products from raw materials and berries limit their widespread application [8–11]. Consequently, the creation of food products that contribute to the prevention of diseases associated with the specific conditions of professional activity in the North remains a pressing issue.

The aim of this study was to assess the adaptation status of military personnel in the Arctic following the inclusion of a natural food product containing dietary and biologically active substances in the diet.

MATERIALS AND METHODS

The study, conducted in June–July 2022 in the Arctic, involved healthy and practically healthy male contract military personnel (n = 60; mean age 37.3 ± 3.1 years). The median duration of professional activity of the participants was 7.0 [5; 9] years.

In order to assess the effectiveness of the tested plant protein product (PPP) on their adaptation state, the subjects were divided into the following groups:

- Group 1 (main, n = 30) received 10.0 g of the PPP as part of the main course during dinner for 21 days;
- Group 2 (comparison, n = 30) received a standard ration.

The inclusion criteria were healthy and practically healthy military personnel who provided their voluntarily consent to participate in the study, who had not taken vitamin and mineral complexes or dietary supplements, and who had not traveled on leave to other regions of the country over the previous six months.

The basic food ration included products delivered during the navigation period, such as canned vegetables, vegetables and fruits heat-dried according to norm No. 1, as well as products delivered to regions of the Far North[4]. Water supply was provided using melted snow or ice, characterized by low mineralization. The living and working conditions of the participants were identical. Prior to the onset of the study, no vitamin or specialized food products were included in the diet.

Based on the results of previous studies assessing hemogram parameters in military personnel [12, 13], as well as data on insufficient iodine supply in the human body under northern conditions [14, 15], a formulation of PPP was developed. The product includes the following ingredients: chokeberry, flax seeds, carrots, broccoli, kelp (seaweed), and chicken egg shell. The primary processing method for the ingredients was low-temperature drying [16] (Certificate of Conformity UAEC No. RU D-RU.PA03.B.69039/24).

The inclusion of macro- and microelements and dietary fiber in the PPT composition was carried out by calculation [17]. The presence of minor biologically active substances in the composition of the finished product was assessed without determining their quantitative values based on the data from [18–22].

At present, the food package composition for the Arctic ration has not been specified. The nutrition of contract military personnel is organized in accordance with the norms approved in Decree No. 946[5]. In the present study, norm No. 1 (combined-arms ration) was used, taking into account additional products supplied

1 Decree of the President of the Russian Federation dated February 27, 2023 No. 126 "On Amendments to the Strategy for the Development of the Arctic Zone of the Russian Federation and Ensuring National Security for the Period up to 2035.

2 On Approval of the Maritime Doctrine of the Russian Federation / Decree of the President of the Russian Federation dated 31.07.2022 No. 512.

3 Methodological Recommendations MP 2.3.1.0253-21 «Norms of physiological requirements for energy and nutrients for various population groups of the Russian Federation».

4 Decree of the Government of the Russian Federation dated 29.12.2007 No. 946 «On food supply for military personnel and certain other categories of persons, as well as on the supply of feed (products) for regular animals of military units and organizations in peacetime» (as amended on 18.09.2020, No. 1484).

5 Ibid.

in the regions of the Far North and the Arctic zone (canned fish, butter, cookies, condensed milk, canned green peas, squash caviar, dried fruits). The energy value of this ration (norm No. 1) is 4466.7 ± 230.7 kcal, including proteins — 165.5 ± 6.7 g, fats — 158.6 ± 16.1 g, and carbohydrates — 587.9 ± 29.4 g [6]. According to several authors, ration No. 1 provides only 45.3% of the recommended intake of vitamin A, 75.0% of vitamin C, 70.0% of vitamin B_1, 45.0% of vitamin B_2, and 77.5% of niacin, while the calcium deficit reaches 31.4% relative to the standards established by MR 2.3.1.2432-05[6]. For this reason, correction of the standard diet to compensate for deficiencies in essential micronutrients were proposed in [5–7] .

In this work, we approached the task of optimizing the nutrition of contract military personnel by introducing micronutrients in the diet based on determining the clinical signs of their deficiency [12, 13], taking into account data on iodine status in the population of the North [14, 15]. Individuals in the main group receiving the PPP additionally received macro- and microelements, including all vitamins (specifically C, K, and A), minerals (the highest doses of Ca, I, Fe, Se, Cr, Mn), and dietary fiber (Table 1).

The maintenance of the body's adaptive capacity and antioxidant defense system also depend on the presence of minor biologically active food substances [23] contained in plant protein products. In addition to a wide spectrum of vitamins and minerals, the composition of vegetable and berry powders includes biologically active substances such as choline, carotenoids, phytosterols, anthocyanins, lutein, zeaxanthin, beta-cryptoxanthin, organic acids, pectin, and tannins (from chokeberry). Flax seeds are rich in polyunsaturated and free fatty acids, monoacylglycerides, diacylglycerides, tocopherols, sterols, phospholipids, waxes, carotenoids, polysaccharides, and phenolic acids. Carrots are a source of polyacetylenes, falcarinol, pyrrolidine, beta-carotene, and organic acids. Broccoli contains alpha- and beta-carotene, lutein, zeaxanthin, lycopene, glucoraphanin, and phenolic compounds, and kelp contains beta-carotene, fucoxanthin, fucoidans, and alginic acid.

To assess the status of body adaptation, the leukograms of participants were analyzed in the main group before and after administration of vegetable and berry powders, and in the comparison group at baseline and on day 22 of the experiment. Blood sampling was carried out in the morning after an overnight fast into vacuum tubes (LabVac) at the Taimyr Interdistrict Hospital. Within 3 h, the samples were transported to the Central Research Laboratory of Krasnoyarsk State Medical University for performing a complete blood count using an automated hematology analyzer (Abbott, USA).

The status of body adaptation was assessed in three stages according to the method developed by Garkavi [24]. First, the type of non-specific adaptation reactions of the body was determined based on the relative lymphocyte count as a criterion indicator. The following reaction types were identified: "training reaction" — 20–27.5%; "calm activation reaction" — 28–34%; "heightened activation reaction" — 34.5–44%; "overactivation reaction" — over 40–44%.

The second stage involved the assessment of the proportions of monocytes, eosinophils, basophils, band neutrophils, and the total leukocyte count, as well as the levels of body response[7]: high, medium, low, and very low.

At the third, final stage, the adaptation state was assessed: physiological norm, pre-nosology, or disease. To that end, for each type of adaptation response, the number of individuals with different levels of body reactivity was determined. For the "calm activation" and "heightened activation" reaction types, the adaptation state was assessed as "physiological norm" (healthy) with a high or medium reactivity level, and as "pre-nosology" with a low reactivity level. For the "training" adaptation reaction type, with a high reactivity level, the adaptation state was classified as normal; with a medium reactivity level – "pre-nosology"; with a low reactivity level – "disease." For the "overactivation" and "stress" reaction types, with a high reactivity level, the adaptation state was assessed as a manifestation of pre-nosology, and for the others — as "disease"[8].

Statistical processing of the initial data was performed using the IBM SPSS Statistica 6.1 software package (USA). The normality of distribution was determined using the Kolmogorov–Smirnov test. For parametric data, mean values and their standard deviations (M ± SD) were calculated; for non-parametric data, the median (M_e) and interquartile range [Q_1; Q_3] were calculated. The statistical significance of differences at $p < 0.05$ for parametric indicators in dependent samples was calculated using Student's t-test, and for non-parametric indicators, using the Wilcoxon test. The statistical significance of differences in assessing the effectiveness of vegetable and berry powder intake was determined using Pearson's chi-squared test (χ^2).

RESULTS AND DISCUSSION

When assessing the effectiveness of incorporating vegetable and berry powders into the diet of individuals in the main group, statistically significant differences

6 MR 2.3.1.2432-08 «Norms of physiological requirements for energy and nutrients for various population groups of the Russian Federation» for individuals working in the Far North. Moscow: Federal Center for Hygiene and Epidemiology of Rospotrebnadzor; 2009.

7 Khursa RV, Eryomina NM, Korzun NN. Screening methods for assessing body adaptation in outpatient practice: educational and methodological manual. Minsk: BSMU; 2018.

8 Ibid.

Table 1. Daily intake of macro- and microelements from the plant protein product

Nutrient	Consumption parameters	
	consumed dose	% of daily dose
Proteins, g	1.22	1.12
Fats, g, including	1.22	2.22
SFAs, 10% of kcal	1.08	0.3
PUFAs, 6–10% of kcal	7.13	1.95–3.24
Omega-6, 5–8% of kcal	1.674	0.57–0.92
Omega-3, 1–2% of kcal	5.4	0.15–0.074
Carbohydrates, g	4.43	0.84
Vitamins		
A, µg retinol equivalent	70.1	7.8
E, mg tocopherol equivalent	0.27	1.8
C, mg	15.0	15.0
B_1, mg	0.061	4.1
B_2, mg	0.032	1.8
B_5, mg	0.21	4.2
B_6, mg	0.066	3.3
B_9, µg	4.2	0.84
B_{12}, µg	0.012	0.4
Biotin, µg	0.424	0.85
K, µg	11.34	9.45
PP, mg niacin equivalent	0.224	1.12
D, µg	0.39	2.9
Minerals		
F, mg	0.21	5.25
I, µg	31.91	21.3
Cu, mg	0.052	5.2
Zn, mg	0.31	2.5
Fe, mg	0.7	7.0
Mn, mg	0.121	6.05
Cr, µg	2.45	6.13
Se, µg	4.61	6.6
Mg, mg	16.4	3.9
P, mg	37.52	5.36
Na, mg	15.49	1.2
Ca, mg	684.03	68.4
K, mg	126.71	3.62
Dietary fiber, g	1.43	5.72–7.12

Table compiled by the authors based on their own data

Note: SFA — saturated fatty acids; PUFA — polyunsaturated fatty acids.

Table 2. Dynamics of blood leukogram parameters in the examined individuals over the observation period

Leukogram parameters	Reference values	Observation period			
		Baseline		Day 22	
		General group $n = 30$	Comparison group $n = 30$	General group $n = 30$	Comparison group $n = 30$
Leukocytes, × 10⁹/L[1]	3.9–10.6	6.52 ± 0.61	6.5 ± 0.47	6.3 ± 0.47*	6.55 ± 0.65
Band neutrophils, %[2]	1–6	0.4 [0.2–0.8]	0.7 [0.5–0.8]	0.6 [0.5–0.8]*	0.8 [0.45–0.8]
Basophils, %[2]	0–1	0.51 [0.3–0.8]	0.4 [0.2–0.65]	0.6 [0.4–0.8]	0.4 [0.2–0.75]
Eosinophils, %[2]	1–5	2.95 [1.9–3.9]	2.7 [1.7–3.55]	3.65 [2.8–4.1]*	2.8 [1.55–3.55]
Monocytes, %[1]	2–10	6.05 ± 1.88	6.6 ± 1.35	6.7 ± 1.14*	6.68 ± 1.75
Lymphocytes, %[2]	28–45	28.2 [25.1–31.9]	27.6 [25.6–29.25]	39.5 [37.4–41.2]*	26.9 [25.6–27.65]

Table compiled by the authors based on their own data

Note: [1] — data presented as arithmetic means and standard deviations (M ± SD); [2] — data presented as median and interquartile range (M_e [Q_1; Q_3]); * — differences are statistically significant in dependent groups, $p < 0.05$.

were revealed within the reference intervals for a number of parameters, namely: a decrease in leukocyte count from 6.52 ± 0.61 to (6.3 ± 0.47) × 10^9/L, an increase in the number of eosinophils (from 2.95 to 3.65%), monocytes (from 6.05 ± 1.88 to 6.7 ± 1.14%), and lymphocytes (from 28.2 to 39.5%). At the same time, an increase in the ratio of band neutrophils was noted, recorded at the level of the lower limit of the physiological norm, while the proportion of basophils in the subjects remained unchanged. These changes are likely associated with the enrichment of vitamin and mineral status in the participants following the intake of vegetable and berry powders (in particular, B_9, B_{12}, 25-OH-vitamin D, Fe, Ca) and the modulation of metabolic processes, manifested in the functional properties of leukocytes [25].

In the comparison group, the analyzed parameters did not show statistically significant differences over the observation period (Table 2).

Prior to the study, in 2 (6.7%) subjects from the main group, the type of adaptation reaction was classified as “heightened activation” (as the lymphocyte proportion reached 35.0–37.5%), in 14 (46.7%) individuals — as “training” (lymphocyte proportion within 20–27.5%) and “calm activation” (lymphocyte proportion within 28–34%). Following the 22-day observation period, 28 (93.3%) subjects from the main group showed the body’s adaptation reactions assessed as “heightened activation,” except for 2 (6.7%) individuals, whose adaptation reaction type was assessed as “calm activation.” These types of adaptation reactions are characterized by specific patterns in the thymic-lymphatic (immune) and endocrine subsystems of the body, corresponding to the upper range of physiological norm, where anabolic processes prevail over catabolic processes. This profile most likely represents a morphological equivalent of the participants’ adaptation to constantly acting extreme environmental factors [24].

In the comparison group, the type of adaptation reaction at baseline was assessed as “training” in 17 (56.7%) participants and as “calm activation” in 13 (43.3%) individuals. At the end of the observation period, the proportion of individuals whose adaptation reaction type was assessed as “training” increased to 19 (63.3%), while the number of individuals with the “calm activation” type decreased to 11 (36.7%).

When characterizing the levels of body response in the examined individuals over the observation period across different types of non-specific adaptation reactions, it was found that, prior to intake of vegetable and berry powders, all individuals, except for one (1.7%) participant showed the reactivity at high and medium levels. In the main group, with the “heightened activation” type, a low reactivity level was recorded in only one person. At baseline, among participants in the main group with the “training” type of adaptive reaction, reactivity levels were assessed as high in 5 (35.7%) individuals and medium in 9 (64.3%) individuals ($p = 0.001$). Meanwhile, among those with the “calm activation” type, a high level of body reactivity was statistically significantly determined in 2 (14.3%) subjects, and a medium level in 12 (85.7%) participants. For the “heightened activation” reaction type, in one participant from the main group at baseline, the reactivity level was assessed as medium, and in one, as low.

Over the 22-day observation period, only one individual in the main group exhibited a medium reactivity level, whereas others a high level of reactivity

Table 3. Characteristics of body reactivity levels during the observation period under different types of non-specific adaptation reactions, %

Body reactivity level	Group and observation period			
	General		Comparison	
	Baseline	Day 22	Baseline	Day 22
non-specific adaptation reactions of the body in the "training" state				
High	35.7	0	58.8	36.8
Medium	64.3	0	41,2	63.2
	p = 0.001		*p* = 0.002	
non-specific adaptation reactions of the body in the "calm activation" state				
High	14.3	100.0	15.4	9.1
Medium	85.7	0	84.6	90,9
	p = 0.001		–	
non-specific adaptation reactions of the body in the "heightened activation" state				
High	0	50.0	0	0
Medium	50.0	50.0	0	0
Low	50.0	0	0	0
	p = 0.001		–	

Table compiled by the authors based on their own data

Note: “0” — absence of subjects with a determinable level of body reactivity; “–” — absence of statistically significant differences.

associated with the “heightened activation” adaptation type. Simultaneously, following 22 days, among individuals in the main group with the “calm activation” type, the level of body reactivity was statistically significantly high in all participants.

In the comparison group, conversely, the proportion of individuals with a medium level of body reactivity increased (Table 3).

Optimization of the diet was reflected in the leukogram parameters of individuals in the main group, while no changes in the comparison group were noted. This also influenced the status of body adaptation. Overall, at the beginning of observation, the adaptation state was defined as “pre-nosology” in 30% of individuals in the main group and in 23.34% in the comparison group.

Following the course of vegetable and berry powders in the main group, the adaptation state was assessed as a physiological norm in all military personnel. In the comparison group, conversely, a statistically significant (χ^2 = 12.0; p = 0.001) increase to 40% was noted in the proportion of individuals in a pre-nosological state of the body (see Figure). Based on leukocyte indicators and calculated leukocyte indices, it was previously established that the “pre-nosology” state is characterized by weakening of the humoral and cellular immunity and a decrease in the phagocytic activity of cells [26].

It should be noted that the observation reported in the present paper were obtained during the summer period. It can be assumed that with increasing exposure

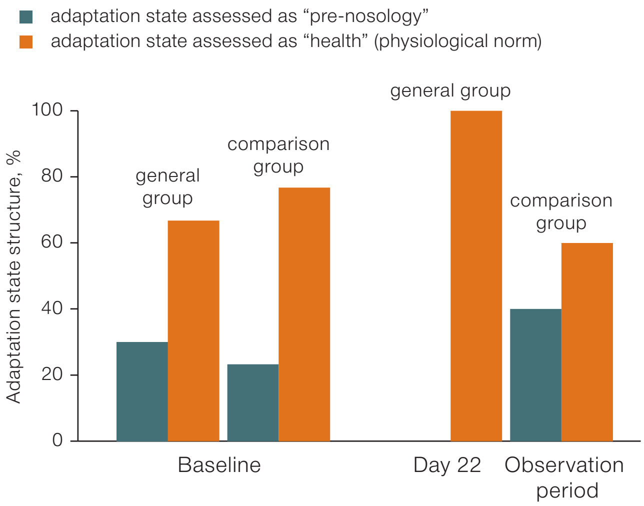

Figure prepared by the authors based on their own data

Fig. **Adaptation state parameters among military personnel during the observation period**

to extreme cold, the body's adaptation response may undergo further changes.

The obtained results demonstrate the potential of multicomponent products developed using cryogenic technology and containing biologically active substances. formulations tailored to specific living conditions. These products can be used for optimizing the nutrition of military personnel and other populations operating in Arctic environments.

CONCLUSION

1. Assessment of the effectiveness of PPP inclusion in the diet of participants in the main group established a statistically significant decrease in total leukocyte count and an increase in the relative proportion of band neutrophils, eosinophils, monocytes, and lymphocytes, all within physiological norm ranges. These changes are associated with the modulation of metabolic processes affecting the functional properties of leukocytes.

2. The non-specific adaptation reactions in the majority of participants in both the main and comparison groups were classified as "training" and "calm activation" with high or medium levels of body reactivity. This is most likely due to the absence of extreme cold exposure during the study, which was conducted in the summer period.

3. Optimization of the diet was reflected in the adaptation status after the PPP course. In the main group, adaptation was assessed as a physiological norm in all military personnel, while in the comparison group, a statistically significant increase in the proportion of individuals in a pre-nosological state was observed.

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