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Pre-clinical diagnostics of health by blood indices in workers in the Arctic zone of Russia

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ABSTRACT

Introduction. Pre-clinical diagnostics is aimed at assessing human health for timely implementation of health-improving and preventive measures.

Goal. To substantiate an algorithm for pre-clinical diagnostics of the health by clinical signs and laboratory blood parameters in workers in the Arctic zone of Russia. **Materials and methods.** We analyzed three thousand seven hundred seventy four blood samples in military personnel in the Arctic ($n=51$) and Subarctic ($n=60$): general clinical, biochemical (blood lipids, vitamins B₉, B₁₂, D), minerals (total and ionized Ca, K, Na, Mg, P, Fe). The groups were divided into two (up to 40 and over 40 years) and duration of work (up to 5 and up to 10 years). We assessed the adaptive reactions and nonspecific resistance of the body.

Results. An extensive blood test indicated the risk of developing B₉ and B₁₂ deficiency and iron deficiency anemia, hypotonic dehydration, and provided information about nonspecific resistance and the state of the body's adaptive reactions. The presence and type of dyslipidemia was established; according to C-reactive protein — the risk of cardiovascular diseases; according to liver enzymes — the risk of iron deficiency and transferrin production. Determination of vitamins and minerals reflected the need depending on the duration of work in extreme conditions. The increase in changes and the duration of work indicated a adverse impact of regional conditions on the human body.

Limitations. Military personnel of health groups I–II who arrived in the conditions of the North from other regions and who have no contraindications for occupational activity there.

Conclusion. The need for differentiated implementation of preventive measures in various volumes in groups with different duration of work has been determined. The need for conducting research among workers during annual medical examinations regardless of age was proven, which will reduce the risk of developing diseases in the North.

Keywords: military personnel; Arctic zone; laboratory blood parameters; pre-clinical conditions; detection algorithm

Compliance with ethical standards. The study was conducted in compliance with the ethical standards of the Helsinki Declaration of the World Medical Association. The conclusion of the Ethics Committee of the Privolzhsky Research Medical University was received, protocol No. 4 dated March 14, 2022. Each participant in the study gave informed voluntary written consent to participate in the study and the publication of personal medical information in anonymized form in the journal "Hygiene and Sanitation".

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Донорологическая диагностика по показателям крови здоровья работающих в Арктической зоне России

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РЕЗЮМЕ

Введение. Донорологическая диагностика ориентирована на оценку здоровья человека для своевременного проведения оздоровительных и профилактических мероприятий.

Цель исследования: обосновать алгоритм донорологической диагностики по клинико-лабораторным показателям крови здоровья работающих в Арктической зоне России для проведения профилактических мероприятий.

Материалы и методы. Анализировали 3774 образца крови военнослужащих в Арктике ($n = 51$) и Субарктике ($n = 60$): общеклинический, биохимический (липиды крови, витамины B₉, B₁₂, D), минералы (Ca общий и ионизированный, K, Na, Mg, P, Fe). Группы были разделены на подгруппы по возрасту (до 40 и старше 40 лет) и длительности службы (до 5 лет и до 10 лет). Оценили адаптационные реакции и неспецифическую резистентность организма.

Результаты. Расширенный анализ крови указывал на риск развития B₉- и B₁₂-дефицитных и железодефицитных анемий, гипотонической дегидратации, дал информацию о неспецифической резистентности и состоянии адаптационных реакций организма. Установлены наличие и тип дислипидемий; по С-реактивному белку — риск болезней системы кровообращения; по ферментам печени — риск дефицита железа и продукции трансферрина. Определение витаминов и минералов отражало потребность в них в зависимости от продолжительности работ в экстремальных условиях. Нарас-

тание изменений с увеличением длительности работ свидетельствовало о негативном влиянии условий региона на организм человека.

Ограничения исследования. Военнослужащие I–II групп здоровья, прибывшие из других регионов для прохождения службы в Арктике и Субарктике и не имеющие противопоказаний для профессиональной деятельности в этих условиях.

Заключение. Определена необходимость дифференцированных профилактических мероприятий в различных объёмах в группах военнослужащих с различной продолжительностью пребывания в условиях Арктики и Субарктики. Доказана целесообразность проведения исследований среди работающих при ежегодной диспансеризации независимо от возраста, что снизит риск развития болезней в условиях Севера.

Ключевые слова: военнослужащие; Арктическая зона; лабораторные показатели крови; донозологические состояния; алгоритм выявления

Соблюдение этических стандартов. Исследование проведено с соблюдением этических норм Хельсинкской декларации Всемирной медицинской ассоциации. Получено заключение Комитета по этике ФГБОУ ВО «ПИМУ» Минздрава России (протокол № 4 от 14.03.2022 г.). Каждый участник дал информированное добровольное письменное согласие на участие в исследовании и публикацию персональной медицинской информации в обезличенной форме в журнале «Гигиена и санитария».

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Introduction

Occupational safety involves the prevention and mitigation of hazards, and the minimization of harm to workers' health¹. The employer must ensure the implementation of measures aimed at preventing threats to the life and/or health of employees resulting from exposure to harmful and/or hazardous occupational factors, including physical factors such as air temperature, air velocity, humidity and thermal radiation².

The legislation of the Russian Federation prioritizes one of the most important principles of public health protection in the country — the priority of prevention, including through the early detection of diseases³ (preventive medical examinations and regular health check-ups⁴). Preclinical diagnosis of the health of people working in the extreme conditions of Russia's Arctic region is crucial for development of methods of preventive and personalized medicine, which ensure healthy longevity, as well as adaptation to climate change⁵.

Preclinical diagnostics are aimed at assessing the health of healthy individuals [1]. Dynamic monitoring of the status of the body's adaptive reserves and its main functions differs fundamentally from the system of medical monitoring currently in place in our country, which is focused on the diagnosis of diseases. The aim of the study is to justify an algorithm for preclinical diagnosis based on clinical and laboratory blood analyses to assess the health of workers in the Arctic region of Russia for the purpose of carrying out preventive measures.

Materials and methods

We analyzed the results of clinical and laboratory tests on blood samples ($n = 3,774$), selected by random sampling, from

contracted military personnel (CMP) in health groups I–II during medical examinations in the summer period — 51 people from the Arctic and 60 people from the Subarctic. All military personnel were informed about the research and gave their voluntary consent.

Before being deployed to the specified areas, the CMP participants underwent a medical examination and were found to have no medical contraindications for service in those conditions. The subjects were divided into two age groups: Group 1 — up to 40 years of age, and Group 2 — 40 years of age and over. In addition, the servicemen were categorized according to length of service: up to 5 years and up to 10 years. Living conditions and occupational hygiene conditions were assessed⁶.

A complete blood count with a white blood cell differential⁷ was performed using an Abbott automated hematology system (USA). C-reactive protein (CRP) was measured on a Cobas Integra 400 Plus analyzer (Roche Diagnostics; Switzerland). The lipid profile was assessed based on total cholesterol (TC), triglycerides (TG), and high-density (HDL) and low-density (LDL) lipoproteins (AU5800 analyzer, USA). Mineral levels (K, Na, total and ionized Ca, Fe, Mg, P) were determined using the AU5800 and AVL9180 analyzers (USA). To analyze vitamin B₉ levels, the AD SCIEX QTRAP 5500 HPLC-MS system (Germany) was used; for vitamin B₁₂ levels, the ARCHITECT® i2000 system (Abbott Laboratories, USA); and for vitamin D, the AB SCIEX QTRAP 5500 mass spectrometer (SCIEX, Germany). The level of vitamin D in the body was assessed based on 25(OH)D₃ calcitriol — an intermediate product of its metabolism.

The percentage of lymphocytes was used to assess the state of the body's non-specific adaptive responses (NSAR) [2]. Using complete blood counts, the following leucocyte ratio indices were calculated: N/L — neutrophils to lymphocytes, L/N — lymphocytes to neutrophils, L/M — lymphocytes to monocytes, L/E — lymphocytes to eosinophils, NML — neutrophils to monocytes, MML — monocytes to lymphocytes, GI (Garkavi index) — lymphocytes to the percentage of segmented neutrophils, and the immunoresistance index (IRI — eosinophils and lymphocytes to monocytes). These data provide an indication of the body's non-specific resistance.

¹ Labour Code of the Russian Federation (as amended by Federal Law No. 311-FZ of 2 July 2021), Art. 209.15

² Federal Law No. 426-FZ of 28 December 2013 'On the Special Assessment of Working Conditions (as amended on 28 December 2022).

³ Federal Law No. 323-FZ of 21 November 2011 (as amended by Federal Law No. 323-FZ of 8 August 2024 and Federal Law No. 554-FZ of 28 December 2024) 'On the Fundamentals of the Protection of Citizens' Health in the Russian Federation'

⁴ Order of the Ministry of Health of the Russian Federation of 27 April 2021 No. 404n 'On the Approval of the Procedure for Conducting Preventive Medical Examinations and Health Screening for Certain Groups of the Adult Population' (as amended by Orders of the Ministry of Health of the Russian Federation No. 44n of 1 February 2022, No. 515n of 28 September 2023, and No. 378n of 19 July 2024).

⁵ On the Approval of Priority Areas for Scientific and Technological Development and the List of Key Science-Intensive Technologies: Decree of the President of the Russian Federation No. 529 of 18 June 2024.

⁶ Guidelines for the Hygienic Assessment of Factors in the Working Environment and Work Process. Criteria and Classification of Working Conditions. R 2.2.2006–05.

⁷ Kishkun, A.A. *Guide to Laboratory Research Methods*. Moscow: 'GEOTAR-Media', 2007. 779 pp.

Таблица 1 / Table 1

Blood parameters in military personnel in dependence on the age and duration of work**Показатели крови военнослужащих в зависимости от возраста и продолжительности трудовой деятельности**

Показатель крови, норма Blood index, norm	Группы наблюдения, абс. вел. Observation groups, abs. value		<i>p</i>
	1	2	
	35.1 ± 1.1*	41.3 ± 0.89	
	4.2 ± 0.3**	7.1 ± 0.76	0.001
Эритроциты, 4.7–6.1 · 10 ¹² /л Erythrocytes, 4.7–6.1 · 10 ¹² /L	4.94 ± 0.43	4.98 ± 0.31	0.68
Гемоглобин, 140–180 г/л Hemoglobin, 140–180 g/L	156.9 ± 0.9	154.6 ± 3.9	0.041
Гематокрит, 42–52% Hematocrit, 42–52%	45.4 ± 3.03	46.0 ± 2.7	0.47
Средний объём эритроцита, 80–94 фл Mean corpuscular volume, 80–94 fl	90.2 ± 3.0	89.1 ± 3.87	0.62
Средняя концентрация гемоглобина в эритроците, 330–370 г/л Average concentration of erythrocyte hemoglobin, 330–370 g/L	336.2 ± 3.7	334.0 ± 3.52	0.008
Среднее содержание гемоглобина в эритроците, 27–31 пг Average hemoglobin content in erythrocyte, 27–31 pg	28.0 ± 1.16	29.1 ± 1.38	0.001
Распределение эритроцитов по величине, 11.5–14.5% Distribution of erythrocytes by size, 11.5–14.5%	12.1 ± 0.44	12.4 ± 0.53	0.068
Средний объём тромбоцитов, 8.9–9.5 фл Mean platelet volume, 8.9–9.5 fl	9.14 ± 0.25	9.33 ± 0.23	0.008
Тромбоциты, 130–400 · 10 ⁹ /л Platelets, 130–400 · 10 ⁹ /L	241,8 ± 33,04	237,3 ± 26.75	0.59
Лейкоциты, 3.9–10.6 · 10 ⁹ /л Leukocytes, 3.9–10.6 · 10 ⁹ /L	6.49 ± 0.53	6.8 ± 0.8	0.16
Нейтрофилы Neutrophils:			
палочкоядерные, 1–6% band neutrophils, 1–6%	45.2 ± 3.05	0,4 (0.2–0.9)	0.37
сегментоядерные, 40–72% segmented, 40–72%	0,3 (0.2–0.6)	44.14 ± 4.4	0.32
Эозинофилы, 1–5% Eosinophils, 1–5%	3.9 (3.4–4.)	2.5 (1.9–3.4)	0.001
Базофилы, 0–1% Basophils, 0–1%	0.7 (0.1–1.0)	0.5 (0.3–0.7)	0.658
Моноциты, 2–10% Monocytes, 2–10%	6.5 ± 2.05	5.9 ± .,06	0.289
Лимфоциты, 18–45% Lymphocytes, 18–45%	27.6 (25.2–31.2)	26.9 (24.2–31.2)	0.396

Примечание. Здесь и в табл. 3: для параметрических показателей $M \pm \sigma$; для непараметрических показателей $Me (Q_1; Q_3)$; * – возраст; ** – стаж.

Note: Here and in Table 3: for parametric indices: $M \pm \sigma$; for nonparametric indices: $Me (Q_1; Q_3)$; * – age; ** – length of service.

The results obtained were entered into a database, and the analysis was carried out using the Russian-language version of the APSS Statistica 6.1 program. For parametric indicators, means (M) and standard deviations ($\pm \sigma$) were calculated; for non-parametric indicators, medians (Me) with lower and upper quartiles ($Q_1; Q_3$) were calculated. The proportion (%) of deviations from the reference limits was determined. The statistical significance of intergroup differences for parametric indicators was assessed using the Student's *t*-test, and for non-parametric indicators using the Mann–Whitney *U* test, at a probability level of $p < 0.05$.

Results

The military personnel's work schedule was organized in cycles: the first day involved mental work with high psycho-emotional stress; the second day was for rest; and the third day involved working for 5–6 hours in an open area. Intense mental work was assessed as second-degree harmful (class 3.2), and physical labour as heavy and as second-degree harmful (class 3.2); the overall assessment of the work in terms of harmfulness and danger was third-degree harmful (class 3.3). Living conditions met the requirements for an organized group; the diet consisted of tinned and freeze-dried vegetables and fruit, delivered during the summer supply period, with a daily calorie intake of $4,466.7 \pm 230.7$ kcal for a macronutrient-balanced diet⁸.

⁸ On the provision of food to military personnel and certain other categories of persons, as well as on the provision of feed (food) for service animals of military units and organisations in peacetime: Decree of the Government of the Russian Federation No. 946 of 29 December 2007 (as amended by Decree No. 1484 of 18 September 2020).

In the Arctic, blood parameters (except for band neutrophils) in both groups were within the reference ranges. However, in Group 2, compared with Group 1, hemoglobin levels, the mean concentration and proportion of eosinophils were lower, whilst the mean hemoglobin content per erythrocyte and the mean platelet volume were higher (Table 1).

In Group 1, 30% of those examined had a reduced red blood cell count, whilst in Group 2 this figure was 6.7%. A reduced hematocrit was observed in 20% of those examined in Group 1; in Group 2, this parameter was within the normal range. The mean corpuscular volume was elevated in 10% of military personnel in Group 1 and in 6.7% in Group 2. The proportion of individuals with a reduced percentage of band neutrophils reached 100% and 80% in Groups 1 and 2, respectively. In Group 2, individuals with a reduced mean hemoglobin concentration in red blood cells were identified (20.1%); in Group 1, there were no deviations from the norm. In 20.1% of those examined in Group 2, the mean hemoglobin concentration in red blood cells was elevated, whilst in Group 1 it was reduced in 20% of cases. Furthermore, in Group 2, 13.4% of those examined had a reduced count of segmented neutrophils, whereas this was within the normal range in Group 1.

Based on the average lipid profile values, the upper limit of triglycerides (TG) in Group 1 exceeded the upper reference limit and fell within the 'moderately elevated' range, whilst in Group 2 it was assessed as high. HDL levels were high and within the normal range. Total cholesterol (TC) was assessed as high in both groups. The upper limit of LDL-C in Group 1 fell within the 'elevated' range, as did that in Group 2. Lipid atherogenicity in Group 1 was within the normal range, whilst in Group 2 it exceeded the normal range (Table 2).

Таблица 2 / Table 2

Blood lipid spectrum indices**Показатели липидного спектра крови**

Липиды крови Blood lipids	Группы наблюдения Observation groups		p
	1	2	
Триглицериды, 0.15–1.7 ммоль/л Triglycerides, 0.15–1.7 mmol/L	1.7 (1.67–1.87)	1.71 (1.65–1.82)	0.04
Общий холестерин, 3.5–5.2 ммоль/л Total cholesterol, 3.5–5.2 mmol/L	6.5 (6.0–6.9)	6.3 (5.67–7.0)	0.33
Липопротеиды, в том числе: Lipoproteins, including:			
низкой плотности low density	4.2 (3.8–5.52)	4.43 (3.8–4.9)	0.058
высокой плотности high density	1.65 ± 0.35	1.22 ± 0.22	0.001
Коэффициент атерогенности, до 3,5 у. е. Atherogenicity coefficient, up to 3.5 c. u.	3.07 ± 0.65	4.37 ± 1.38	0.001

In Group 2, triglycerides (TG) were above normal in 60% of subjects, and in Group 1 in 40%; total cholesterol (TC) was above normal in 93.4% of those examined in Group 2 and in 90.9% in Group 1. High LDL-cholesterol levels were found in 60% of those examined in Group 2 and 36.4% in Group 1. Also in Group 1, normal HDL levels were observed in 36.7%, and low levels in 13.3%. In Group 1, the proportion of individuals with elevated HDL-C reached 72.7%, whilst no cases of low HDL-C were identified.

The proportions of individuals with normal C-reactive protein (CRP) levels were 59.1% and 20% in Groups 1 and 2, respectively. In Group 1, 13.6% of participants were found to have moderate and high levels of C-reactive protein. In Group 2, the proportions of participants with these same levels of C-reactive protein were 26.7% and 66.7%.

The mean values of the indicators characterizing liver function (ALT, AST, total bilirubin) were within the normal range. However, ALT exceeded the reference ranges in 36.4% of those examined in Group 1 and in 49% in Group 2; AST exceeded the reference ranges in 40% and 45.5% of those in Groups 1 and 2, respectively. Total bilirubin was elevated in 20% and 27.5% of those examined in Groups 1 and 2, respectively. Blood levels of 25(OH)D₃ in military personnel with shorter service and younger age (Group 1) were higher. In Groups 1 and 2, vitamin D deficiency was observed in 28.6% and 46.7% of those examined, respectively, whilst vitamin D insufficiency was observed in 71.4% and 53.3%, respectively. In these same groups, blood levels of vitamin B₁₂ were assessed as insufficient in 30% and 66.7% of participants, respectively. Vitamin B₉ deficiency was identified in 86.3% of individuals in Group 1 and in 93.3% in Group 2. In 19% of individuals in Group 1, the level of ionized calcium in the blood was below normal. Inorganic phosphorus levels were within the normal range but lower than in Group 2: 0.81 ± 0.04 and 0.84 ± 0.04 mmol/L ($p = 0.041$) respectively; a similar trend was

observed for magnesium: 0.73 ± 0.06 and 0.78 ± 0.08 mmol/L ($p = 0.038$) in Groups 1 and 2, respectively.

A comparative assessment of lipid metabolism parameters in CMP with varying lengths of stay in the Subarctic revealed that the mean TG values showed no statistically significant differences; however, in Group 1 they fell within the reference range, whilst in Group 2 the upper limit fell within the 'elevated' range. Cholesterol in Group 1 was within the normal range, but the upper limit fell within the 'borderline high' zone. In Group 2, this parameter was assessed as borderline high. The mean HDL-C values in both groups were within the normal range, but the lower limits fell within the 'low' range. Statistically significant differences were found for LDL-C and triglycerides. In Group 1, the upper limit of triglycerides exceeded the normal range, whilst in Group 2 it fell within the 'high' range (Table 3).

In terms of individual lipid profile parameters, 94% of service personnel in Group 1 had triglyceride levels within the normal range. In Group 2, 53.3% of those examined had normal TG levels, 33.3% had moderately elevated levels, and 13.3% had elevated levels. The proportions of individuals with normal blood lipid levels in Groups 1 and 2 were 55.6% and 41.2% respectively; those with borderline-high at 22.2% and 23.5%, and high at 22.2% and 35.3%. Normal LDL-C levels were found in 8% of those examined in Group 1, elevated levels in 50%, and high levels in 42%. In Group 2, LDL-C levels were elevated in 50% and high in 50%. The proportions of individuals with normal HDL-C levels in Groups 1 and 2 reached 50% and 58% respectively. Furthermore, in Group 1, 33.3% of those examined had elevated HDL-C and 16.7% had reduced levels, whilst in Group 2, 42% of individuals had reduced levels. In 40% of individuals in Group 1, AC (atherogenic coefficient) was within the normal range, whilst in the remainder it was elevated; in Group 2, these proportions were 25.1% and 75%, respectively.

Таблица 3 / Table 3

Blood lipid indices in military personnel in dependence on age and duration of service in the Subarctic**Показатели липидов крови у военнослужащих в зависимости от возраста и продолжительности службы в Субарктике**

Липиды крови Blood lipids	Группы наблюдения, абс. вел. Observation groups, abs. value		p
	1	2	
	35.1 ± 1.1*	41.3 ± 0.89	0.001
Триглицериды, 0.15–1.7 ммоль/л Triglycerides, 0.15–1.7 mmol/L	0.76 (0.44–1.22)	0.82 (0.59–1.18)	0.216
Общий холестерин, 3.5–5.2 ммоль/л Total cholesterol, 3.5–5.2 mmol/L	4.83 (4.3–5.64)	5.24 (4.71–6.43)	0.152
Липопротеиды, в том числе: Lipoproteins, including:			
низкой плотности low density	3.93 (3.69–4.79)	4.52 (4.44–5.3)	0.007
высокой плотности high density	1.11 ± 0.26	1.09 ± 0.21	0.758
Коэффициент атерогенности, до 3,5 у. е. Atherogenicity coefficient, up to 3.5 c. u.	3.54 ± 1.2	4.32 ± 0.16	0.012

Таблица 4 / Table 4

Leukocyte indices in military personnel, conventional units
Лейкоцитарные индексы военнослужащих, усл. ед.

Лейкоцитарные индексы Leukocyte indices	Группы наблюдения, $M \pm \sigma$ Observation groups, $M \pm \sigma$		<i>p</i>
	1	2	
ИСНЛ, 2.47 ± 0.21 ISNL, 2.47 ± 0.21	1.34 ± 0.22	1.35 ± 0.15	0.746
ИСЛН, 0.52 ± 0.04 ISLN, 0.52 ± 0.04	0.88 ± 0.09	0.69 ± 0.16	0.116
ИСЛМ, 5.34 ± 0.59 ISLM, 5.34 ± 0.59	4.4 ± 0.44	3.9 ± 0.87	0.045
ИСНМ, 11.83 ± 1.31 ISNM, 11.83 ± 1.31	5.78 ± 1.09	5.67 ± 0.66	0.544
ИСЛЭ, 8.73 ± 1.26 ISLE, 8.73 ± 1.26	21.2 ± 13.9	20.1 ± 10.5	0.708
ИСМЛ, $0.1-0.3$ ISML, $0.1-0.3$	0.24 ± 0.04	0.26 ± 0.04	0.27
Индекс Гаркави, $0.3-0.5$ Harkavi index, $0.3-0.5$	0.89 ± 0.27	0.69 ± 0.08	0.018
Индекс иммунорезистентности, $5.2 (Q_1-Q_3: 3.8-6.5)$ Immunoresistance index, $5.2 (Q_1-Q_3: 3.8-6.5)$	4.9 ± 0.67	4.3 ± 0.77	0.14

The mean values for liver function parameters were within the reference ranges. However, ALT levels exceeded these ranges in 5.6% of service personnel in Group 1 and in 13.8% in Group 2; AST was above the normal range in 11.1% and 6.7% of individuals in Groups 1 and 2 respectively, whilst total bilirubin was elevated in 27.8% and 17.2% of those examined, respectively.

Leucocyte indices, with the exception of the ISML and immunoresistance, differed from normal values in CMP personnel in all groups. Specifically, the values for ISNL, ISLM and ISNM were lower than normal. ISLN, ISLE and IG were above the normal range. Statistically significant differences in these parameters between the groups were identified for ISLM and IG (Table 4).

Discussion

In the North, the effects of the cold lead to a reduction in pulmonary ventilation and oxygen consumption – the development of polar hypoxia – resulting in a decrease in hemoglobin levels, an increase in red blood cell count, and the development of iron deficiency [3–5]. However, our study, conducted in the summer, showed that the blood parameters of military personnel remained within normal limits, with the exception of band neutrophils.

In the Arctic, a general clinical blood test of military personnel in Group 1 revealed a reduced red blood cell count and a low hematocrit, reduced hemoglobin concentration in red blood cells and an increased mean corpuscular volume, indicating a risk of developing hypotonic hyperhydration due to a possible disturbance in water-electrolyte balance. Such changes could have developed as a result of using low-mineral water from melted snow for domestic and drinking purposes via the water supply system [6, 7]. Our results from the analysis of mineral substances in blood plasma confirmed an insufficient supply of macro- and micronutrients to the body. Signs of iron-deficiency anemia were also detected (a decrease in the mean hemoglobin content per erythrocyte, and an increased mean corpuscular volume of up to 100 fl), which is characteristic of normocytic anemia during the regenerative phase of iron-deficiency anemia⁹.

In individuals in Group 2, signs of hypotonic dehydration (an increase in mean corpuscular volume) were also observed, but the mean hemoglobin concentration in red blood cells was elevated. Such signs are characteristic of hypochromic anaemia, as well as vitamin B₁₂ and/or folate-deficiency anaemia^{10,11},

and lipid metabolism disorders. Deficiencies of vitamins B₁₂ and B₉ were also identified in our study. The increase in mean platelet volume may have been due to the impact of adverse environmental conditions on the body [8]. Studies by other authors have also noted iron deficiency as an important factor influencing platelet levels and condition, emphasizing the key role of this element in regulating metabolism [9]. In the subjects we examined, C-reactive protein levels were elevated or high in some cases; this is a marker of inflammation in the atherosclerotic process and indicates a risk of developing cardiovascular diseases [10].

When adapting to northern conditions, the metabolism shifts from a typical carbohydrate-based type to a lipid-based one, which contributes to the development of dyslipidemia [4, 11–13]. Our observations also confirmed these changes, but in Group 1 there was a significant proportion of individuals with elevated HDL-C levels. In other words, during the initial period, the mobilization of the body's adaptive potential prevented the development of such changes [14, 15].

In Group 2, there was an increase in the proportion of individuals with elevated levels of triglycerides (TG), LDL-C and HDL-C (including a decrease in the proportion of individuals with high HDL-C levels), which led to an increase in the atherogenicity of blood lipids to levels above the norm.

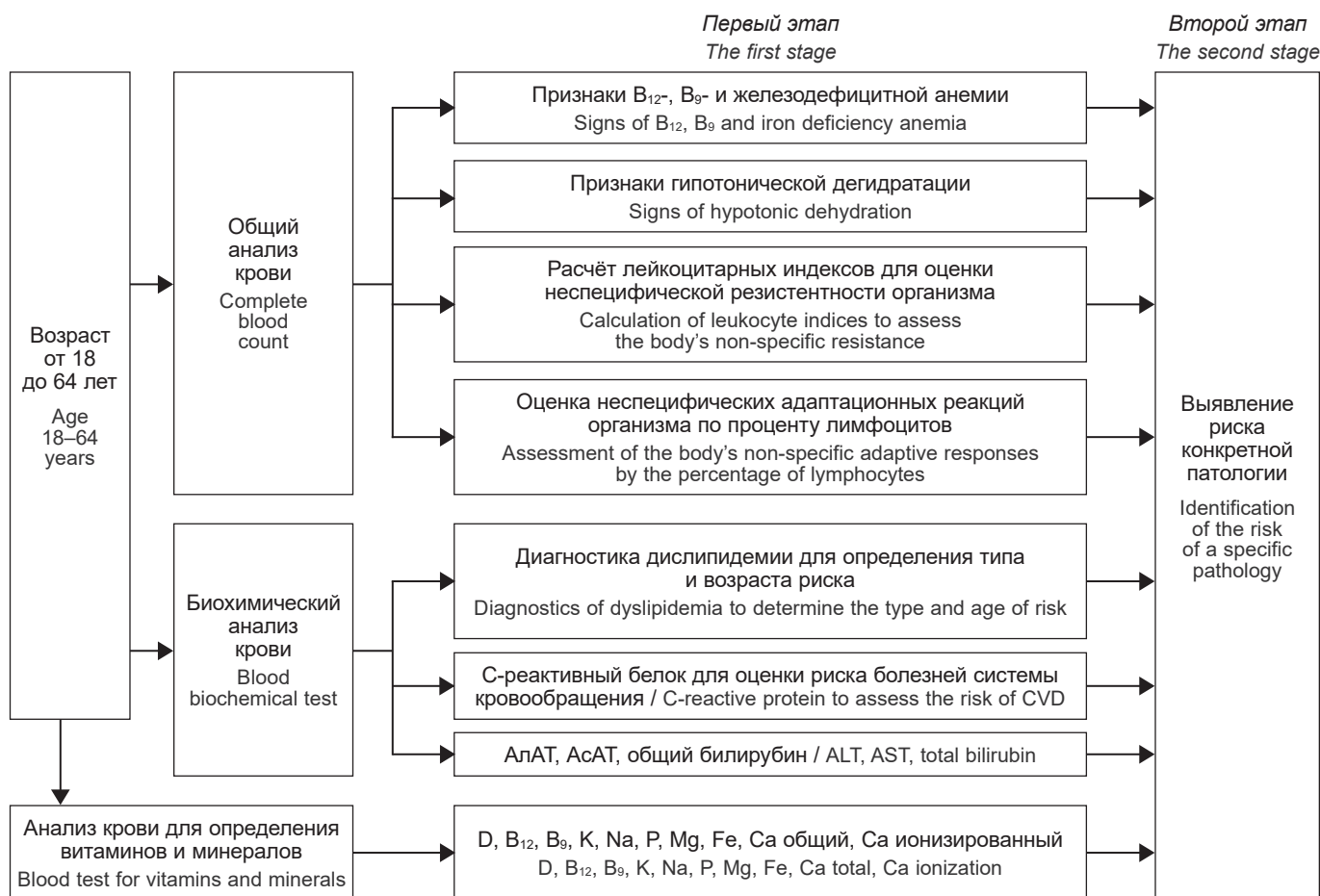
Those who had spent less time in the Arctic had better indicators of vitamin D status. However, their levels of inorganic phosphorus and magnesium were lower. The data suggest that, during the process of adaptation to Arctic conditions, the body's requirement for minerals becomes higher than that of the more adapted members of the CMP.

In the Subarctic, statistically significant differences were observed for triglycerides (TG) and total cholesterol (TC) (these levels increased) and high-density lipoprotein (HDL) (which decreased), leading to an increase in the atherogenicity of blood lipids. When assessing humoral and cellular immunity, the body's susceptibility to allergies, the severity of inflammation and intoxication based on leucocyte indices, the following characteristics were identified. Thus, the ISML, which indicates the severity of inflammatory processes [16], was within the normal range in both groups in our study. The IG was above normal, indicating a high level of the body's immune defense [17]. However, in individuals in Group 2, the IG was statistically significantly lower, which is likely due to the prolonged negative impact of environmental factors on the body. The IIR was within the reference range; consequently, the body's adaptive reserves were sufficient [18, 19]. The ISNL reflects the ratio of non-specific to specific components of resistance, which was below the reference value in each group. Thus, in the military personnel examined, these components

⁹ Iron-deficiency anemia. Clinical guidelines. Russian Ministry of Health, 2021.

¹⁰ Folate-deficiency anemia. Clinical guidelines. Ministry of Health of Russia, 2021.

¹¹ Vitamin B₁₂-deficient anemia. Clinical guidelines. Ministry of Health of Russia, 2024.



Алгоритм донозологической диагностики по показателям крови здоровья работающих в условиях Арктической зоны.

Algorithm for preclinical diagnostics of health of workers in the Arctic zone based on blood parameters.

of resistance were balanced and corresponded to a sufficiently high level [20–23]. The ISLN indicated a negative impact of working conditions and the environment on the humoral and cellular components of resistance. In individuals who had spent less time in the Subarctic, the ISLN was higher, which can be interpreted as a strain on the body's adaptive mechanisms during this period.

In individuals with shorter service records, the ISLM was higher, which corresponded to greater bodily reactivity [24–26]. In individuals in Group 2, lower indicators suggested a tendency towards reduced immune defense [27]. The ISNM revealed a reduction in phagocytic activity of cells [28, 29]. The ISLE exceeded the reference value, indicating sensitization of the military personnel in Groups 1 and 2 [23].

In both the Arctic and the Subarctic, changes in liver enzyme function were detected in some military personnel, consistent with iron deficiency and impaired protein synthesis⁷. Iron deficiency can lead to impaired production of transferrin – the main iron carrier in blood plasma. These findings also confirmed the risk of developing iron-deficiency anemia.

Currently, during medical check-ups for young people in the Far North, blood tests are carried out on a differentiated basis depending on age¹², but changes in bodily functions under northern conditions are not taken into account.

The data obtained during this study have enabled the development of an algorithm for preclinical health assessment of workers in the Arctic region based on blood parameters (see **figure**). A key component of the algorithm is the annual screening of all individuals, regardless of age, as part of routine medical check-ups.

In the first stage, health risks are identified based on findings from general and biochemical blood tests, as well as the measurement of vitamin and mineral levels. Based on these data, in accordance with a supplementary list of tests^{7,8,9} [7], as well as indicators of non-specific resistance and the body's adaptive responses, it is possible to identify signs of the development of a specific pathology and prescribe corrective therapy.

Conclusion

Blood tests, carried out according to the expanded protocol we proposed, made it possible to identify subclinical changes in the health of military personnel in the Arctic zone of the Russian Federation. The results showed an increase in these changes with longer periods of service, indicating the negative impact of the conditions in this region on the body. The need for preventive, tailored measures has been established, the scope of which within each group is determined by the duration of service in extreme conditions. Furthermore, the tests proposed in this study must be carried out as part of the annual medical check-ups for service personnel regardless of age, which will enable health improvement measures to be implemented and reduce the risk of developing diseases caused by living conditions in the North.

¹² Order of the Minister of Defense of the Russian Federation No. 285 of 20 May 2021 'On Establishing the Procedure for Medical Examinations and Health Check-ups for Servicemen of the Armed Forces of the Russian Federation'

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