ASSESSMENT OF MICRONUTRIENT LEVELS IN THE MILITARY PERSONNEL SERVING IN VARIOUS CLIMATIC ZONES OF RUSSIA

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The lack of vitamins and minerals in the body contributes to the development of acquired deficient conditions. The study was aimed to assess micronutrient levels in the military personnel serving in various climatic zones of Russia. Plasma levels of vitamins (D based on 25(OH)D, B_{12}, B_9) and minerals (K, Na, total and ionized Ca, P, Mg, Fe), working and nutritional conditions were determined in servicemen in the Arctic (n = 54), Subarctic (n = 57), and temporary climate (n = 58) zones. The 25(OH)D levels were 24.06 ± 6.95, 21.5 ± 12.1(p_{1-2} = 0.003), and 27.2 ± 15.2 (p_{1-2} = 0.423, p_{1-3} = 0.032) ng/ml; deficiency and insufficiency were revealed in 82.3, 86.5, and 63.8% of military personnel. The cobalamin levels were 96.46 ± 20.6, 111.7 ± 59.4 (p_{1-2} = 0.046), and 125.7 ± 63.2 (p_{1-2} = 0.002, p_{1-3} = 0.334) pmol/L; the values below 148 pg/mL were reported for 100.0, 73.6, and 67.2% of surveyed individuals. The folate levels were 3.4 ± 0.4, 3.52 ± 1.54 (p_{1-2} = 0.657), and 6.49 ± 6.21 (p_{1-2} = 0.001, p_{1-3} = 0.009) ng/mL; the decreased levels were reported for 89.8, 81.3, and 44.8% of military personnel. The ionized calcium levels were decreased in 29.4, 50.0, and 67.2% of surveyed individuals, while the iron levels were decreased in 2.0, 1.9, and 3.4%. Elevated potassium (23.5, 29.6, and 8.6%), sodium (32.7 and 27.6% of individuals serving in the Subarctic and temporary climate zones) and total calcium (42.6% of individuals serving in the Subarctic zone) levels were reported. In the Arctic zone, the servicemen worked indoors and outdoors (heavy labour), while in the Subarctic and temporary climate zones they worked indoors (hard labour). In the Arctic zone, meals were organized consisting of the delivered canned foods (general military ration, 4466.7 ± 230.7 kcal/day), while in other zones it was homemade food with the disturbed eating pattern, inadequate consumption of fresh vegetables and fruits. The study updates the directions for prevention of health problems in the military personnel serving in the extreme habitat and working conditions: estimation of body's vitamin and mineral balance; optimization of the diet with the vegetable protein food products; raising awareness about the issues of individual diet and the use of vitamin and mineral supplements; developing formulations of multicomponent food products for adjustment of body's vitamin and mineral balance.

Keywords: Arctic, Subarctic, temperate climate zone, male military personnel, vitamins, minerals

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Compliance with ethical standards: the study was approved by the Ethics Committee of the Privolzhsky Research Medical University (protocol № 4 of 14 March 2022), it was carried out in accordance with the ethical principles stipulated in the Declaration of Helsinki of the World Medical Association; all servicemen submitted the informed consent to participation in the study.

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ОЦЕНКА СОДЕРЖАНИЯ МИКРОНУТРИЕНТОВ В ОРГАНИЗМЕ ВОЕННОСЛУЖАЩИХ, ПРОХОДЯЩИХ СЛУЖБУ В РАЗЛИЧНЫХ КЛИМАТИЧЕСКИХ ПОЯСАХ РОССИИ

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Недостаток витаминов и минералов в организме способствует развитию приобретенных дефицитных состояний. Цель исследования — оценка содержания микронутриентов в организме военнослужащих, проходящих службу в различных климатических поясах России. У военнослужащих в арктическом (n = 54), субарктическом (n = 57) и умеренном (n = 58) поясах в плазме крови определяли витамины (D по 25 ОН витамина D, B_{12}, B_9), минеральные вещества (K, Na, Ca общий и ионизированный, P, Mg, Fe), оценивали условия работ и питания. Значения 25 ОН витамина D составили 24,06 ± 6,95, 21,5 ± 12,1(p_{1-2} = 0,003) и 27,2 ± 15,2 (p_{1-2} = 0,423, p_{1-3} = 0,032) нг/мл; дефицит и недостаточность выявлены у 82,3, 86,5 и 63,8% военнослужащих. Уровни кобаламина составляли 96,46 ± 20,6, 111,7 ± 59,4 (p_{1-2} = 0,046) и 125,7 ± 63,2 (p_{1-2} = 0,002, p_{1-3} = 0,334) пмоль/л; значения ниже 148 пмоль/л были определены у 100,0, 73,6 и у 67,2% обследованных. Фолаты составляли 3,4 ± 0,4, 3,52 ± 1,54 (p_{1-2} = 0,657) и 6,49 ± 6,21 (p_{1-2} = 0,001, p_{1-3} = 0,009) нг/мл; снижение их уровня имело место у 89,8, 81,3 и 44,8% военнослужащих. Уровень ионизированного кальция был снижен у 29,4, 50,0 и 67,2% обследованных, железа — у 2,0, 1,9 и 3,4%. Повышался уровень уровень калия (у 23,5, 29,6 и 8,6%), натрия (у 32,7 и 27,6% проходящих службу в Субарктике и умеренном поясе) и общего кальция (у 42,6% проходящих службу в Субарктике). В Арктике военнослужащие выполняли работы в помещениях и на открытой территории (тяжелый труд), в Субарктике и умеренном поясе — в помещениях (напряженный труд). В Арктике организовано питание завозными консервированными продуктами (общевойсковой паек, 4466,7 ± 230,7 ккал/сутки), в иных условиях — домашнее с нарушениями режима, недостаточным потреблением свежих овощей и фруктов. Исследование актуализирует направления профилактики нарушений здоровья у военнослужащих, проходящих службу в экстремальных условиях обитания и труда: оценка витаминно-минерального баланса организма; оптимизация питания продуктами белково-растительного происхождения; повышение осведомленности по вопросам индивидуального питания и приема витаминно-минеральных препаратов; разработка рецептур многокомпонентных продуктов питания для коррекции витаминно-минерального баланса организма.

Ключевые слова: Арктика, Субарктика, умеренный климатический пояс, военнослужащие-мужчины, витамины, минеральные вещества

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The need to ensure national security in the Arctic zone (Arctic and Subarctic) of the Russian Federation (RF) determines the permanent presence of military personnel being part of the strategic deterrence forces aimed to prevent aggression against the RF and its allies. The presence of military personnel is also related to the increase of conflict potential in the Arctic, the need to develop the Northern Sea Route as a globally competitive national transport communication system [1, 2]. The Arctic zone is characterized by extreme weather and climatic conditions, underdeveloped infrastructure, both transport and social [3, 4].

The human body's need for micronutrients (vitamins and minerals) increases when working in such conditions [5–7]. Insufficient intake of vitamins and minerals contributes to the development of acquired deficient conditions, such as B_{12} and/or folate deficiency, iron deficiency anemia [8–10]. Vitamin D deficiency manifests itself in the negative impact on the human calcium, magnesium, and phosphate metabolism, immune status, and mental health [11–14]

The study was aimed to estimate micronutrient levels in the military personnel serving in various climatic zones of Russia.

METHODS

The study was carried out in three climatic zones in the Krasnoyarsk Territory: Arctic (group 1), Subarctic (group 2), and temporary climate (continental climate) (group 3) zones. Inclusion criteria: submitted informed consent, no contraindications for serving in the regions of Far North (for the Arctic and Subarctic zones), health group 1 or 2, similar duties performed by military personnel residing in all climatic zones. Exclusion criteria: acute disorder or exacerbation of chronic disease, self-administration of vitamin and mineral supplements within a month before inclusion in the study or during the period of monitoring.

The study involved male military personnel. The samples were large: 54 (group 1), 57 (group 2), and 58 (group 3) individuals. The age of military personnel serving in the Arctic was 35.7 ± 0.57 years, in the Subarctic it was 34.2 ± 0.9 years ($p_{1–2}$ = 0.156), and in the temporary climate zone it was 35.6 ± 0.79 years ($p_{1–3}$ = 0.452, $p_{2–3}$ = 0.241).

When conducting a routine check-up in summer, plasma levels of vitamin D, B_{12} (cobalamin), B_9 (folic acid), and minerals (potassium, sodium, total and ionized calcium, inorganic phosphorus, magnesium, iron) were determined in the military personnel.

The body's vitamin D status was characterized by 25(OH) D, the intermediate product of its transformation, the levels of which were determined using the AB SCIEX QTRAP 5500 mass spectrometer (SCIEX; Germany). Assessment criteria: < 10 ng/mL — severe deficiency, 10–20 ng/mL — deficiency, 20–30 ng/mL — insufficiency, 30–100 ng/mL — optimal levels [15, 16].

The cobalamin levels were determined using the ARCHITECT i2000 automated immunoassay analyzer (Abbott; USA). The normal range was 25–165 pmol/L. Furthermore, the total serum cobalamin levels < 148 pmol/L were considered as vitamin B_{12} deficiency: with this value the B_{12} deficiency diagnosis sensitivity was 97% [17].

The folic acid levels were determined by tandem mass spectrometry using the AD SCIEX QTRAP 5500 system (SCIEX; Germany). The reference range was 5.0–9.0 ng/mL [9].

The total calcium, inorganic phosphorus, magnesium, iron levels were assessed using the AU 5800 analyzer (Beckman Coulter; USA). The potassium, sodium, ionized calcium levels were determined with the AVL9180 electrolyte analyzer (Roche; USA).

The working regime was assessed.

In the Arctic, catering was provided in accordance with the standard No. 1 (general military ration) with provision of addition food supplies in the regions of Far North [18]. Food was brought during the navigation season for the whole year. Vegetables and fruit were canned or dried. Meltwater obtained from snow was used for cooking. The eating pattern and the rate of food consumption were assessed in the Subarctic and temporary climate zones (questionnaire survey).

Primary data were entered in the MS Excel spreadsheet (Microsoft; USA). The spreadsheet was processed using the Statistica 6.1 software package (StatSoft; USA). The sample distributions were tested for normality: the distributions for vitamins, potassium, ionized calcium, and iron were non-normal, while the distributions for total calcium, phosphorus, magnesium, and sodium were normal. We determined mean (M) and standard deviation (σ) for parametric, median (Me) and interquartile range (Q_{25}–Q_{75}) for nonparametric data. Significance of differences between various groups of servicemen was determined using the Student's t-test for independent parametric (normally distributed) data and the Mann–Whitney U test for nonparametric (non-normally distributed) data for the probability $p \leq 0.05$.

RESULTS

The average 25(OH)D levels were within the range considered to indicate insufficiency. Furthermore, the lowest value was reported for individuals of group 2: it was significantly lower compared to the values of groups 1 and 3 (by 11.9 and 26.5%, respectively). The differences between the values of groups 1 and 3 were non-significant.

The average vitamin B_{12} levels were within the reference range. The lowest values that were significantly different from the data obtained for groups 2 and 3 were reported in group 1: these were 15.8 and 30.3% lower, respectively. The differences in the indicators determined in the individuals serving in the Subarctic and temporary climate zones were non-significant.

The average B_9 levels were within normal only in members of group 3. This indicator was significantly higher (by 90.9 and 84.4%, respectively), than in groups 1 and 2. In individuals of groups 1 and 2, the average values were below the reference range and showed no significant differences. However, the upper limit of the deviation from the mean in group 1 indicated the absence of individuals with optimal levels of this vitamin, while in group 2 it indicated the presence of such individuals (Table 1).

Plasma levels of potassium were within normal in members of all three groups. Furthermore, the differences between the values of groups 1 and 3 were non-significant, and the highest value that significantly differed (by 6.1 and 4.3%, respectively) was reported for members of group 2.

The sodium levels of group 1 were within the reference range, while the values of groups 2 and 3 were above the upper end of normal range (146.86 and 146.95 mmol/L). The average levels of groups 2 and 3 were significantly higher than that of group 1 (by 2.6 and 2.0%).

Based on the deviation from the mean, the magnesium levels were slightly above the upper end of normal range only in group 2, the levels of other groups were within normal. The average magnesium level of group 2 was the highest: it was significantly higher compared to the values reported for groups 1 (by 9.6%) and 2 (by 7.1%). The value of group 3 was also 2.4% higher than that of group 1.

The ionized calcium levels were the same in groups 2 and 3, however, these significantly differed from the level of group 1

Table 1. Plasma levels of vitamins in the military personnel serving in various climatic zones (M ± σ)

Vitamins, reference ranges	Groups monitored, abs.		
	1	2	3
25(OH)D, 30.0–100 ng/mL	24.06 ± 6.95	21.5 ± 12.1 0.003*	27.2 ± 15.2 0.423**/0.032***
Cobalamin 25.0–165.0 pmol/L	96.46 ± 20.6	111.7 ± 59.4 0.046*	125.7 ± 63.2 0.002**/0.334***
Folic acid, 5.0–9.0 ng/mL	3.4 ± 0.4	3.52 ± 1.54 0.657*	6.49 ± 6.21 0.001**/0.009***

Note: * — significance of differences between values of groups 1 and 2; ** — significance of differences between values of groups 1 and 3; *** — significance of differences between values of groups 2 and 3.

(were 2.6% lower). The deviations from the mean indicated the presence of individuals with the decreased body's levels of ionized calcium in each group.

The lowest total calcium level was reported for group 1: it was significantly lower, than in groups 2 and 3 (by 16.8 and 7.3%, respectively). The value of group 3 was higher, than the value of group 1, but significantly lower, than the value of group 2. The upper end of the deviation from the mean of group 2 indicated the presence of individuals with the blood total calcium levels higher than normal.

The average inorganic phosphorus levels were within normal in all the studied groups. Furthermore, the lowest value was reported for group 1, group 3 ranked second. The value of group 2 was 45.0% higher, than the value of group 1 (p = 0.001), and 11.5% higher, than the value of group 3 (p = 0.001).

The iron levels were within normal in all the groups; the lowest value was reported for members of group 1: significant differences from the values of groups 2 and 3 were 25.7 and 12.0%, respectively. The value of group 2 was higher, than the value of group 3 (Table 2).

It was found out that there were individuals with severe vitamin D deficiency in groups 2 and 3. In general, the proportions of individuals with optimal levels of this vitamin among military personnel serving in the Arctic and Subarctic zones showed minor differences, but were 1.9–2.4 lower than that among those serving in the continental climate. As for cobalamin and folic acid levels, members of group 3 seemed to be the most prosperous: the proportion of individuals with the B_{12} levels below 148 pg/mL was lower (by 32.8 and 6.4%, respectively), and the values for B_9 were 45.0 and 36.5% lower, than in other groups.

In groups 1 and 2, individuals were found with the potassium levels higher than normal. As for excess sodium, groups 2 and 3 stood out. The differences in the proportions of individuals with various magnesium levels turned out to be interesting. Thus, it was lower than normal in almost a fifth of group 1, individuals with the magnesium levels higher than normal were found in group 2, while in group 3 there were individuals with the magnesium levels on the lower end of normal. Significant differences were revealed, when assessing individual ionized calcium levels: the proportions of individuals with low ionized calcium levels in the Subarctic and temporary climate zones were 1.7 and 1.5 times higher than the proportion in the Arctic zone. Given the fact that the ionized calcium level was on the lower end of normal range in a fifth of group 3 (1.15 mmol/L), the greatest imbalance was found in this group. Excess total calcium levels were reported for group 2; there were minor proportions of individuals with low iron levels in each group, while individuals with low phosphorus levels were found in group 3 only (Table 3).

The work order of male military personnel serving in the Arctic zone envisaged the indoor day duty with a 2-day interval (hard labour). During intervals between the indoor tasks they were engaged in activities in an open area for 4–5 h (hard labour). The work order in the Subarctic and temporary climate zones represented the 5–6-day (unofficially) indoor work with the unregulated timing; Sunday was a day off. Sometimes, Saturday was made a day off.

In the Arctic, meals were organized in accordance with the standard established for such conditions [18], no vitamin supplementation was provided. In the Subarctic and temporary climate zones, individual homemade meals and meals at public

Table 2. Plasma levels of minerals in the military personnel serving in various climatic zones (M ± σ for parametric and Me (Q25–Q75) for nonparametric data)

Minerals, reference ranges	Groups monitored, abs.		
	1	2	3
Potassium, 3.5–5.1 mmol/L	4.6 (4.1–5.1)	4.8 (4.55–5.15) 0.015*	4.7 (4.6–4.8) 0.415**/0.023***
Sodium, 136–145 mmol/L	140.5 ± 2.59	144.1 ± 2.76 0.001*	143.3 ± 3.65 0.001**/0.246***
Magnesium, 0.66–1.03 mmol/L	0.83±0.07	0.91 ± 0.13 0.001*	0.85 ± 0.1 0.001**/0.004
Ionized calcium, 1.15–1.35 mmol/L	1.18 (1.14–1.2)	1.16 (1.12–1.2) 0.043*	1.15 ((1.1–1.8) 0.033**/0.339***
Total calcium, 2.02–2.6 mmol/L	2.2 ± 0.06	2.57 ± 0.21 0.001*	2.36 ± 0.14 0.001**/0.001
Inorganic phosphorus, 0.7–1.8 mmol/L	0.8 ± 0.04	1.16 ± 0.21 0.001*	1.04 ± 0.17 0.001**/0.01***
Iron, 9.5–30 μmol/L	17.4 (14.56–19.26)	20.05 (16.35–25.92) 0.001*	18.4 (13.8–22.7) 0.035**/0.011***

Note: * — significance of differences between values of groups 1 and 2; ** — significance of differences between values of groups 1 and 3; *** — significance of differences between values of groups 2 and 3.

Table 3. Characteristics of the vitamin and mineral levels being outside the normal range in the comparison groups (%)

Indicators	Groups monitored		
	1	2	3
Vitamins			
25(OH)D: Severe deficiency Deficiency Insufficiency Optimal levels	 0 29.4 52.9 17.7	 5.8 46.1 34.6 13.5	 3.4 39.7 24.1 32.8
Cobalamin, < 148 pg/mL	100	73.6	67.2
Folic acid, lower than normal	89.8	81.3	44.8
Minerals			
Potassium, higher than normal	23.5	29.6	8.6
Sodium, higher than normal	0	32.7	27.6
Magnesium	19.6 (lower than normal)	7.4 (higher than normal)	6.9 (low end of normal range)
Ionized calcium, lower than normal	29.4	50	44.8 and 22.4 (low end of normal range)
Total calcium	0	42.6% (higher than normal)	0
Phosphorus, lower than normal	0	0	1.7
Iron, lower than normal	2	1.9	3.4

catering enterprises were organized (96.0% had lunch). The frequency of meals was as follows: lunch and dinner in 52.7%, breakfast, lunch, and dinner in 47.3%. Fresh vegetables, greens, fruits were consumed no more than three times per week. Some respondents noted that they sometimes used vitamin supplements on their own, and preference was given to the vitamin D-containing formulations.

DISCUSSION

It is well known that the changes in blood composition and erythrocyte characteristics occur under conditions of the Far North: erythrocyte counts increase, hemoglobin levels decrease, and iron deficiency anemia develop in response to cold exposure and hypoxia that disturb pulmonary ventilation [19, 20]. Furthermore, an important role in hematopoiesis is played by vitamins B_{12} and B_9 (interrelated vitamins), as well as iron [21–23]. It should be noted that all the earlier reported studies were performed under extreme cold exposure. Our study was conducted in summer, which ruled out the effects of extremely low temperatures. Furthermore, the available literature provides no comparative analysis of the indicators we have assessed in individuals performing activities in three climatic zones, as well as in individuals engaged in outdoor and indoor activities, who have different eating patterns.

In our study, plasma cobalamin levels of males of three groups were within the reference range. However, according to the literature data, the cobalamin levels were decreased in a significant proportion of individuals, with predominance in the Arctic [17]. Furthermore, low folic acid levels were revealed in the significant proportion of individuals, with predominance in the Far North.

The findings suggest that nutrition plays a role in supplying the body with the above vitamins. Thus, the energy value of the general military ration used by military personnel in the Arctic is 4466.7 ± 230.7 kcal/day. Vegetables are represented by canned potatoes, carrots, cabbage (including sauerkraut), beets, onions, pickled tomatoes, and cucumbers. The ration includes fruit and berry juices (apple, grape, plum), canned vegetables (green peas, squash caviar), dried fruits (apples, plums, grapes, apricots). However, some authors note that the possible deficit of vitamins in the described rations is among pressing issues of food supply. According to the research data, even the short-term physical exertion combined with low temperature of the environment and sub-caloric diet can result in body's vitamin C deficiency. Disturbances of the vitamin C, vitamin B and mineral complex metabolism can occur under exposure to low temperatures [6, 7]. Our study revealed vitamin B_9 and B_{12} deficiency in all groups of military personnel. The data on vitamin B_9 insufficiency in the military personnel serving in the Subarctic and temporary climate zones suggest inadequate consumption of fresh plant foods.

Iron, plasma levels of which were within normal in all surveyed individuals, is also required for normal hematopoiesis. However, individuals with low iron levels were found in each group, which suggested the increased body's demand for this mineral.

Thus, the causes of erythropoiesis disorders occurring under conditions of the Far North can include cobalamin and folic acid insufficiency, as well as probable high demand for iron.

The climatic factors of the Far North are characterized by low ultraviolet solar radiation that contributes to body's vitamin D insufficiency [24, 25]. In our study, vitamin D deficiency and insufficiency were found in 82.3 and 86.5% of individuals serving under such conditions, respectively. It is interesting that the proportion in the Subarctic was larger, than in the Arctic. Furthermore, the proportion of individuals with vitamin D severe deficiency and deficiency was 1.8 times higher in the Subarctic. Apparently, this was associated with working environment: in the Arctic military personnel spent much time outdoors, while in the Subarctic they were engaged in indoor activities.

In the temporary climate zone 67.2% of surveyed individuals also had insufficient vitamin D, which was probably due to indoor activities.

The fact attracted attention that vitamin D deficiency was detected in summer in all three climatic zones.

It is well-known that vitamin D status of the body is strongly associated with the phosphate, calcium, and magnesium metabolism [26, 27]. Magnesium contributes to activation of vitamin D that regulates calcium and phosphate homeostasis. All the enzymes that metabolize vitamin D need magnesium engaged in the enzymatic reactions occurring in the liver and kidney as a co-factor [14]. Our findings suggest low magnesium levels in a fifth of individuals serving in the Arctic, as well as low ionized calcium levels in a third; low ionized calcium levels or the levels on the lower end of the normal range were determined in a half of assessed individuals serving in the Subarctic and temporary climate zones. Furthermore, imbalance of blood potassium and sodium levels was revealed in the Subarctic and temporary climate zones, while imbalance of potassium levels was revealed in the Arctic. Perhaps, magnesium deficiency contributed to the potassium level imbalance, and the decreased magnesium levels were associated with severe emotional stress [28]. The possible causes of such deficiency include the low mineral content drinking water obtained from melt snow. The water contained minimal amounts of iron, zinc, copper, molybdenum essential for human body functioning and engaged in biological processes [29].

Thus, our study updates the directions for prevention of health problems in the military personnel serving in the extreme working conditions:

– the need to estimate body's vitamin and mineral balance in both extreme habitat conditions (Arctic, Subarctic zones) and the temporary climate zone;

– optimization of the diet with the vegetable protein/plant food products with high content of bioactive substances (for catering organized in the Arctic) and raising the military personnel awareness about the issues of individual diet (to increase body's vitamin content) and the use of vitamin and mineral supplements containing cobalamin, folic acid, vitamin D;

– developing formulations of multicomponent food products for adjustment of body's vitamin and mineral balance in extreme habitat conditions.

CONCLUSIONS

1. In the Arctic and Subarctic, vitamin D deficiency and insufficiency in summer were diagnosed in 82.3 and 86.5% of male military personnel. The indoor working conditions determined the vitamin D deficiency severity in both Subarctic and temporary climate zones (vitamin D severe deficiency and deficiency were revealed in 51.9 and 43.1% vs. 29.4% among individuals in the Arctic working in the open areas). 2. In the Far North, the body's demand for vitamins B_9 and B_{12} is increased, which is indicated by cobalamin deficiency found in 100.0% of military personnel in the Arctic and 73.6% in the Subartic zone, as well as by folic acid deficiency (in 89.8 and 81.3%, respectively, vs. 67.2 and 44.8% in the temporary climate zone). This represents the risk factor of erythropoiesis disorder. 3. Imbalance of minerals in the military personnel serving in three studied climatic zones is characterized by low ionized calcium levels (in 29.4, 50.0, and 67.2%, respectively), decreased iron levels (in 2.0, 1.9, and 3.4%), increased potassium levels (in 23.5, 29.6, and 8.6%), excess sodium in the Subarctic and temporary climate zones, excess total calcium in the Subarctic.

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