ASSESSMENT OF THE VITAMIN D, CALCIUM AND PHOSPHORUS SUFFICIENCY IN INDIVIDUALS DEPLOYED IN ARCTIC

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Inadequate ultraviolet insolation is one of the the key prerequisites for the pathogenesis of body's vitamin D insufficiency in the North. The study was aimed to assess the body's vitamin D, calcium and phosphorus sufficiency in the contract servicemen deployed in Arctic. The contract servicemen deployed on the Cape Chelyuskin and Dixon Island were surveyed (n = 51). The serum levels of 25(OH)D, the intermediate of the vitamin D conversion, along with the ionized calcium, total calcium, and inorganic phosphorus levels, were determined in June. Three degrees of the vitamin D sufficiency were revealed in the military, who had been deployed in Arctic for 5.9 ± 0.4 years: deficiency (in 29.4%), insufficiency (in 52.9%), and optimal levels (in 17.7%). However, the optimal levels revealed were close to the lower limit of normal range. Low ionized calcium levels were found in 29.4% of blood samples (15.5 ± 0.6 ng/mL). A total of 70.6% of samples that were within normal range were close to the lower limit of normal range based on Q_{25} (1.16 mmol/L) and were within the lower half of normal range (1.15–1.35 ng/mL) based on Q_{75} (1.22 mmol/L). The measured total calcium and inorganic phosphorus levels were close to the lower limits of reference ranges (2.29 ± 0.009 and 0.83 ± 0.006 mmol/L, respectively). In general, the reduced ionized calcium levels associated with vitamin D insufficiency were revealed, which were indicative of impaired calcium metabolism. The vitamin D deficiency results from the total calcium and inorganic phosphorus concentrations that are close to lower limits of reference ranges. Further negative changes in the body's vitamin D, phosphorus and calcium sufficiency should be expected during polar night. The study actualizes the year-round replenishement of the vitamin D and mineral deficiency in the military.

Keywords: Arctic, contract servicemen, vitamin D, total calcium, ionized calcium, inorganic phosphorus

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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; the informed consent was submitted by all study participants.

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ОЦЕНКА ОБЕСПЕЧЕННОСТИ ВИТАМИНОМ D, КАЛЬЦИЕМ И ФОСФОРОМ ЛИЦ, ПРОХОДЯЩИХ СЛУЖБУ В УСЛОВИЯХ АРКТИКИ

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Неадекватная ультрафиолетовая инсоляция является одним из ключевых условий в патогенезе развития D-витаминной недостаточности организма на Севере. Целью работы было оценить насыщенность организма витамином D, кальцием и фосфором военнослужащих, проходящих службу по контракту в Арктике. В исследовании участвовали военнослужащие, проходящие службу по контракту, работающие на мысе Челюскин и острове Диксон (n = 51). В июле определяли содержание в сыворотке крови 25-ОН — промежуточного продукта превращения витамина D, уровень кальция ионизированного и общего, фосфора неорганического. В летний период года у военнослужащих, работающих в Арктике 5,9 ± 0,4 года, выявлено три уровня обеспеченности витамином D: дефицит (у 29,4%), недостаточность (у 52,9%) и оптимальный, но в нижней зоне границы нормы, уровень (у 17,7%). Низкое содержание ионизированного кальция определено в 29,4% проб крови (15,5 ± 0,6 нг/мл). В 70,6% проб, входящих в границы нормы, по Q_{25} были близки к нижней границе нормы (1,16 ммоль/л), по Q_{75} (1,22 ммоль/л) — в нижней половине зоны нормы (1,15–1,35 нг/мл). Общий кальций и фосфор неорганический выявлены на уровне нижней зоны референтных границ (соответственно 2,29 ± 0,009 и 0,83 ± 0,006 ммоль/л). В целом на фоне недостаточной насыщенности организма витамином D выявлено снижение содержания ионизированного кальция, что свидетельствует о нарушении кальциевого обмена. Его дефицит обусловлен концентрацией и общего кальция и неорганического фосфора, находящихся в нижних зонах референтных значений. В период полярной ночи следует ожидать более негативные изменения D-витаминной и фосфорно-кальциевой насыщенности организма. Исследование актуализирует проведение в течение всего года восполнение дефицита D и минеральных веществ у военнослужащих.

Ключевые слова: Арктика, военнослужащие по контракту, витамин D, кальций общий, кальций ионизированный, фосфор неорганический.

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Arctic is a region with extreme environmental conditions that adversely affect body's functional state by reducing its reserve capacity, complicate the daily routine and implementation of the people's professional activity [1]. This climate zone is characterized by inadequate ultraviolet insolation being the key prerequisite for the pathogenesis of body's vitamin D insufficiency [2–6].

Table 1. Serum levels of 25(OH)D and minerals in individuals of the study group (abs.)

№	Studied parameter, reference range	M ± *m*	Me	Q_{25}–Q_{75}
1	25(OH)D, 30–100 ng/mL	24,1 ± 0,9	24	17,9–28,7
2	Ionized calcium, 1.15–1.35 mmol/L	1,2 ± 0,005	1,18	1,14–1,2
3	Total calcium, 2.02–2.6 mmol/L	2,2 ± 0,009	2.2	2,14–2,24
4	Inorganic phosphorus, 0.7–1.8 mmol/L	0,8 ± 0,006	0,83	0,79–0,85

Vitamin D serves a number of important functions in the human body; the receptors susceptible to the effects of this vitamin are found in many cells of the body. The vitamin affects both innate and adaptive immunity; it has been found that the vitamin plays a certain role in regulation of neurohormonal effects on the brain development, maintaining cognitive function, memory, and behavior associated with mental disorders [7, 8]. It has been shown that low vitamin D levels are associated with the increased risk of a number of cancer types and infectious diseases, cardiovascular disorders, diabetes mellitus of both types, tuberculosis, bronchial asthma, reproductive dysfunction, mental disorders, complications of pregnancy [9–11]. The vitamin D deficiency exacerbates the severity of autoimmune disorders [12, 13] and affects the incidence of infectious and inflammatory diseases [14–19]. A correlation between the vitamin D deficiency and the increase in hospital admissions of elderly people has been determined [20]. Vitamin D plays an important role in the mechanisms of oxidative stress and damage to tissues and cells of the body [21, 22]. On the one hand, the vitamin D system is regulated by epigenetic mechanisms, and on the other hand it is involved in regulation of epigenetic events [23].

It is well-known that the vitamin D sufficiency is closely related to the calcium and phosphate metabolism [24–26].

The study was aimed to assess the vitamin D, calcium and phosphorus sufficiency in the contract servicemen deployed in Arctic.

METHODS

The study that was carried out in summer (July) involved males (n = 51), the contract servicemen who were deployed in the Arctic zone of Russia, on the Cape Chelyuskin and Dixon Island.

The age of individuals in the study group was 35.3 ± 0.6 years. The total enlistment period of the individuals in the study group was 12.8 ± 0.76 years, the servicemen had been doing their duty in Arctic for 5.9 ± 0.36 years. The median value was 6 years; the interquartile ranges were 4–7 years. The servicemen were engaged in professional activities in shifts: they worked one day on and one or two days off. On the working days the time spent in an open area was 3–7 h. On the days off, except those in summer, the time spent in an open area was minimal due to weather conditions.

Meals were provided by the canteens at the military units in accordance with the food ration № 1 taking into account additional food items distributed in the regions of the Far North according to regulatory documents.

The body's vitamin D sufficiency was judged by the levels of 25(OH)D, the intermediate of the vitamin D conversion, in blood samples. Identification was performed by tandem mass spectrometry using the AB SCIEX QTRAP 5500 mass spectrometer (SCIEX; Germany). The body's vitamin D sufficiency was distinguisged based on the 25(OH)D levels: severe deficiency (5–10 ng/mL), deficiency (10–20 ng/mL), insufficiency (20–30 ng/mL), optimal levels (30–100 ng/mL) [24, 27].

The ionized calcium and total calcium levels were determined. The ionized calcium represented a metabolically active form (free calcium); the total calcium represented a biologically inactive form, it was linked to proteins and other molecules. The ionized calcium levels were assessed by ion-selective potentiometry using the AVL9180 electrolyte analyzer. The total calcium and inorganic phosphorus levels were determined using the helium–neon laser operating in a fully automatic mode in the AU5800 hematology analyzer (Abbott; USA).

The reference ranges were 2.02–2.6 mmol/L for the total serum calcium concentration, 1.15–1.35 mmol/L for the ionized calcium, and 0.7–1.8 mmol/L for inorganic phosphorus [28].

Statistical processing of primary data was performed using the Statistica 6.1 software package (StatSoft; USA). The mean and standard error of the mean (M ± m), median values and quartile deviations (Q_{25}–Q_{75}) were calculated. Primary data were tested for normality using the Kolmogorov–Smirnov test, significance of differences for parametric samples was calculated using the Student's t-test for the probability of $p < 0.05$.

RESULTS

The 25(OH)D levels in the study group were within the range estimated as “close to optimal” (Table 1). However, the Q_{25} value showed that there were individuals, whose levels of this vitamin corresponded to deficiency.

The average ionized and total calcium levels and average inorganic phosphorus levels were within reference ranges.

When assessing the 25(OH)D levels based on individual data, three cohorts of subjects were distinguished showing different body levels of 25(OH)D (Table 2). The bulk of the group showed 25(OH)D deficiency of insufficient 25(OH)D levels. The levels of this vitamin in the cohort with deficiency were significantly lower (by 1.6 times; p = 0.001) than in the cohort where the 25(OH)D levels were estimated as insufficient, and 2.2 lower than in the cohort with optimal levels (p = 0.0001). The 25(OH)D levels in the cohort 2 were 1.3 times lower than in the group 3 (p = 0.001).

Table 2. Characteristics of the study group, 25(OH)D levels

№	Estimated levels	Abs., M ± *m*, ng/mL	Me	Q_{25}–Q_{75}	Share of the group, %
1	Severe deficiency	–	–	–	0
2	Deficiency	15,5 ± 0,6	16,2	14,0–16,7	29,4
3	Insufficiency	25,4 ± 0,6	25,25	23,3–28,6	52,9
4	Optimal levels	34,1 ± 0,8	34,8	31,7–35,25	17,7

Table 3. Characteristics of the study group, ionized calcium levels

№	Estimated levels	Abs., M ± *m* mmol/L	Me	Q_{25}–Q_{75}	Share of the group, %
1	Low levels	1,12 ± 0,003	1,125	1,12–1,14	29,4
2	Normal levels	1,195 ± 0,005	1,2	1,16–1,22	70,6

The average ionized calcium level based on Q_{25} was 1.14 mmol/L, i.e. it was beyond the lower limit of normal range (1.15–1.35 mmol/L). The average value of Q_{75} (1.2 mmol/L) showed that this value was just above the median (1.18 mmol/L). As for individual data, almost one third of the study group showed low levels of this mineral; these were significantly (by 6.7%) lower (p = 0.001) than in the cohort with normal levels (Table 3). In individuals with normal levels of ionized calcium, the Q_{25} value exceeded the lower limit of normal range just by 0.01.

The individual total calcium levels varied between 2.1 and 2.27 mmol/L. The median value was 2.2 mmol/L, and the interquartile range (Q_{25}–Q_{75}) was 2.14–2.24 mmol/L. Furthermore, individual blood levels of this mineral in subjects of the study group were close to the lower limit of reference range.

Inorganic phosphorus was within normal range. Individual levels varied between 0.77–0.9 mmol/L, the median value was 0.83 ng/mL, and the interquartile range (Q_{25}–Q_{75}) was 0.79–0.85 ng/mL. Blood levels of this mineral in subjects of the study group were also close to the lower limit of reference range.

Thus, the reduced levels of ionized calcium associated with the body's vitamin D insufficiency were revealed, which were indicative of the calcium metabolism disorder [28]. Deficiency of this vitamin resulted in low total calcium and inorganic phosphorus concentrations that were close to the lower limits of reference ranges.

DISCUSSION

The values of vitamin D insufficiency in the population vary significantly depending on the country, gender, and season [29, 30]. Vitamin D deficiency and insufficiency is common in the Russian Federation [24].

Ultraviolet light plays an important role in regulation of the body's vitamin D sufficiency. Sufficient sunlight exposure of the skin sufrace can ensure 80% of the vitamin D synthesis; not only the number of sunny days, but also the intensity of the exposed body surface UVB irradiation is important [2].

Artic is a zone of severe ultraviolet light deficit resulting from the changes in the sun's altitude height above the horizon. Even in summer the conditions for absorption of natural UV radiation are minimal due to low sun's altitude height and considerable losses on foggy and cloudy days (the number of such days reaches 75–90%) [1].

It is well known that the body's vitamin D levels depend on a number of factors, which include the season. For example, in St. Petersburg the vitamin D concentrations measured in summer were 1.75 times higher than that measured in winter. The seasonal improvement in the body's vitamin sufficiency was observed in 61.4% of the surveyed individuals in Samara versus sufficient vitamin levels found only in 23.4% in winter. In autumn, winter, and spring the body does not synthesize enough vitamin D [3–6, 31].

Despite the fact that our study was conducted in summer, the majority of the organized group members had vitamin D insufficiency or deficiency. The optimal levels were found only in one sixth of the surveyed individuals, however, the average levels were close to the lower limit of optimal range. The lowest value of interquartile range (Q_{25}) was close to the upper limit of the range estimated as deficiency (31.75 ng/mL).

Our findings are consistent with the data provided by other researchers. Thus, 29% of the adult population of Arkhangelsk (subarctic region) have vitamin D deficiency in spring and summer, and 41% have vitamin D insufficiency, while students show vitamin D deficiency and insufficiency in 40 and 32% of cases, respectively (another 8% have severe deficiency) [5].

Vitamin D and its metabolites are an important component of the endocrine system that regulates the body's calcium homeostasis [32, 33]. The vitamin D active form is an key regulator of the calcium and phosphate homeostasis: it is involved in maintaining the calcium and phosphate homeostasis, bone tissue mineralization and remodeling [23–26].

Calcium contained in bones provides structure and strength to the skeleton, while calcium present in extracellular fluid and cytosol is essential for maintaining numerous biochemical processes [26].

During the study the reduced blood levels of ionized calcium were found in almost 30.0% of the surveyed individuals, while in the others the ionized calcium levels were close to the lower limit of reference range. This means that it's physiological function, i.e. involvement in blood coagulation as a cofactor, maintaining the optimal levels of ions for bone mineralization, involvement in stabilization of plasma membranes via binding of phospholipids in the lipid bilayer, and involvement in regulation of the membrane permeability to sodium, was impaired. The increase in membrane permeability to sodium reduces activity of all excitable tissues [26].

The bound calcium and inorganic phosphorus were within normal ranges; the values of these parameters were close to the lower limits of normal ranges in all the surveyed individuals.

The findings suggest that more considerable changes in the body's vitamin D and phosphorus and calcium sufficiency would take place during the polar night.

Thus, the negative shifts in the balance of the vitamin and minerals pose health risks to the military deployed in Arctic for a long time. The year-round preventive measures should be applied fill the deficit in the body's levels of vitamin D and minerals.

CONCLUSIONS

In summer, 29.4% of the military, who had been deployed in Arctic for 5.9 ± 0.4 years, had vitamin D deficiency, 52.9% had vitamin D insufficiency, and 17.7% had optimal vitamin levels. Low ionized calcium levels were found in 29.4% of cases. The assessment results of 70.59% of samples that were within normal ranges were at the lower limit of normal range based on Q_{25}. The total calcium and inorganic phosphorus levels appeared to be close to the lower limits of normal ranges.

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