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REVIEWS

# Systematic Review on 25-Hydroxyvitamin *D* Levels in Various Populations of the Russian North

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**Abstract**—We analyzed published data on the levels of serum 25(*OH*)*D* in apparently healthy individuals from the Russian Far North. The total sample included 2061 subjects of various age and ethnic groups. The serum levels of 25(*OH*)*D* and its age dynamics in the northerners living in towns are similar to those of the inhabitants of the temperate climate zone of Russia. Data on the age-related changes in the vitamin *D* status of the indigenous Arctic people with the traditional lifestyle are scanty. Serum 25(*OH*)*D* concentrations in the indigenous and alien population of the high-latitude regions reflect the seasonal changes in the daylight duration. The level of vitamin *D* decreases in winter and reaches minimum in February, i.e., after the end of the polar night. We compared data on rural Russian and indigenous people and found ethnic differences in the 25(*OH*)*D* concentrations; however, the vitamin *D* status of various indigenous groups of the Russian North is poorly studied. We could not find publications that analyze the 25(*OH*)*D* concentrations along with the direct assessment of food consumption. The available data do not contradict the opinion that the traditional food products are beneficial. However, there are no studies to support this opinion. There are little data on the effect of foods from marine mammal catch, marine and freshwater fishery, and venison on the vitamin *D* status of the indigenous people of the Russian North.

*Keywords:* vitamin *D*, 25-hydroxyvitamin *D*, 25(*OH*)*D*, vitamin *D* status, Arctic, indigenous population, nutrition, natural light, latitude

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The term "vitamin D" denotes two steroid prohormones. Ergocalciferol $D_2$ is the "true" vitamin: similarly to other substances of this class, it cannot be synthesized in humans and is produced from an external source—dietary plant sterol. Cholecalciferol ($D_3$), unlike $D_2$, can be obtained by autosynthesis: 7-dehydrocholesterol present in human skin is converted under exposure to ultraviolet radiation first into a provitamin and then into the actual vitamin. Thus, from the standpoint of the formal classification of nutrients, cholecalciferol does not belong to the class of vitamins, and its attribution to these substances is largely a tribute to tradition.

$D_2$ and $D_3$ in chylomicrons enter the bloodstream, where they form a complex with the vitamin *D*-binding protein. In the liver, the vitamin is released from the complex and is converted into 25-hydroxyvitamin *D*, 25(*OH*)*D*. 25(*OH*)*D* circulating in the bloodstream is the transport form of the vitamin and, at the same time, remains its main source in the body. As a result of hydroxylation in the kidneys, 25(*OH*)*D* is converted into the active hormone form, calcitriol, whose function is the regulation of calcium and phosphorus homeostasis. Vitamin *D* deficiency leads to a decrease both in the absorption of calcium and phosphorus in the intestine and in their reabsorption in the kidneys [1, 2]. Hypovitaminosis *D* causes disturbances in the bone tissue state, which is clinically manifested as rickets in children and as osteomalacia and osteoporosis in adults.

High-latitude regions are reasonably classified with the areas of endemic risk of hypovitaminosis *D* [3]. Indeed, the Arctic conditions are unfavorable for the synthesis of cholecalciferol in the human body. UV radiation levels here remain low for several months. The body of northerners is always covered by clothing and only the facial skin is exposed to insolation. The relatively high melanin content in the epidermis of Arctic aboriginal mongoloids hampers $D_3$ autosynthesis, reflecting more than 80% of the physiologically active ultraviolet radiation.

The ideas of the increased (due to insufficient UV exposure) risk of vitamin *D* deficiency and resulting rickets and osteomalacia developed by mid-1970s. Since that time, the opinion prevails that the concentration of the vitamin in the body depends primarily on the insolation level and is maintained by autosynthesis of cholecalciferol. These standpoints are critically discussed in [2, 4].

The appearance of standardized laboratory methods for evaluating the vitamin *D* status on the basis of the serum concentration of 25(*OH*)*D* and the becoming of these methods an available (if not routine) procedure [5, 6] made it possible to expand the geography of studies and cover the previously "exotic" groups such as indigenous, old-timer, and migrant population of the North.

With the accumulation of data, it became clear that the problem of the vitamin *D* status of northerners is more difficult than originally anticipated. Not all studies revealed low levels of this vitamin in the high-latitude populations. For example, in the late winter and early spring, after the natural seasonal decline in the level of UV-irradiation, the content of vitamin *D* in French children in rural areas is significantly lower than that in the peers from the polar regions of Europe (in summer, the interpopulation differences are less pronounced) [7]. In Arctic reindeer herders Izhma Komi and Nenetses [8–10], as well as in the Norwegians, Swedes, and urban Finns [11–16], the content of 25(*OH*)*D* is often higher than that typical for the population of the southern regions of Europe.

It would seem that these data undermine the usual postulates of the decisive contribution of the factors of latitude and insolation level to the vitamin *D* status formation. However, on the other hand, a number of observations indicate a low content of 25(*OH*)*D* in the modern Inuit and Indians of the northern regions of the United States and Canada [17–20].

What is the cause for this inconsistency? Does the "northerness" (i.e., latitude) play such an important role in the formation of the vitamin *D* balance in the body as it is usually stated? If the concentration of 25(*OH*)*D* in modern indigenous northerners, indeed, is low, what are the causes for this decline?

Despite the large number of foreign publications devoted to the differences in the vitamin *D* status in individuals of the European, Asian, and African origin due to their anthropological peculiarities, the factor of skin pigmentation in the publications of Russian authors has been considered only in recent years [21–23]. Given that most of the indigenous (aboriginal) people of high latitudes belong to the Mongoloid groups with an increased content of melanin in the skin and less effective autosynthesis of cholecalciferol, attention should be paid to the specificity of vitamin *D* status in representatives of different racial groups of the population of the Russian North.

These fundamental issues are also important for solving applied medical problems. If the reduced content of 25(*OH*)*D* in comparison with Europeans and European Americans is a specific variant of the ethno-anthropological norm, then there is no particular reason for alarm: peculiar adaptive complexes might form for many generations in the high-latitude regions. However, if the relatively low vitamin *D* levels in modern northerners is a consequence of "modernization" changes, then it is necessary to develop and take additional measures for the prevention of rickets, osteoporosis, and other abnormalities.

The studies of the vitamin *D* status of the Russian North population on a large scale began, in fact, only in the last decade. At this stage, it is important for Russian scientist to systematize the available data in order to determine as early as possible the most relevant directions of further work. Of course, in this regard the data of American and Western European colleagues are important. However, when using these data, a number of significant anthropoecological differences between the Russian and foreign high-latitude populations should be taken into account.

The majority of the foreign studies of the vitamin *D* status of indigenous northerners were performed on materials obtained in groups of Greenland and North American Inuit (Eskimos), whose diet is enriched in the fat of marine animals, which is rich in vitamin *D*. However, in the high-latitude regions of Russia, the livelihoods based on fishing marine fishes and catching marine animals was characteristic for only few numerically small populations—the Siberian Eskimos, coastal Chukchi, and several groups of Nenetses. On the other hand, reindeer herding, a basic element of the economic structure of the majority of indigenous people of the Russian Arctic (and partly Fennoscandian Saami), is not practiced by the indigenous people of North America and Greenland [24]. Different traditions of nature management and, accordingly, the composition of local products as a source of ergocalciferol $D_2$, may determine the differences in the vitamin *D* status of populations.

It is also necessary to take into account the possible influence of social factors. In the Russian Arctic, the inhabitants of small villages, large villages, and towns differ more significantly that the inhabitants of similar settlements in the United States, Canada, Greenland, and Fennoscandia in terms of income, access to purchased ("grocery") products, and, accordingly, the contribution of the purchased and local food to their diet. The same applies to the representatives of the groups involved to varying degrees in the traditional activities—reindeer herding, fishing, and animal hunting. The diets of northern children in "organized groups" (kindergartens and boarding schools) and young northerners staying in families significantly differ [24].

All above factors may affect the serum level of 25(*OH*)*D* in different periods and the vitamin *D* status of the population in general.

The purpose of this review was to analyze the variability of the serum content of 25-hydroxyvitamin *D* in different ethnic, age, and social groups depending on the latitude, the natural level of light, life activity, and diet using the published array of data obtained in the studies of samples of apparently healthy population of northern and Arctic regions of the Russian Federation.

## MEHTODS

The publications for this review were selected by the following keywords (in Russian and English variants): vitamin *D*, 25-hydroxyvitamin *D*, 25(*OH*)*D*, and vitamin *D* status.

The criteria for inclusion of publications in the review were described in detail in our previous paper [25]. Therefore, here we can focus only on the main points.

Currently, a number of known technologies evaluating the content of 25(*OH*)*D* in serum are known [6]. To exclude possible methodological discrepancies, only the data obtained by the standardized enzyme immunoassay (IDS EIA) [5] in the samples containing at least ten healthy individuals were included in the review. A necessary condition was the presence in the publication of required statistics: the mean value (or median) and the variability indices.

This article discusses the content of serum 25(*OH*)*D* and the vitamin *D* status of representatives of various groups of the Russian North population: minor indigenous peoples and major ethnic groups of the Far North areas and/or similar regions [24]. Localization of the examined samples was determined with an accuracy of one degree of latitude.

When analyzing the situation of the groups of indigenous northerners, we took into account the type of economic management. The lifestyles of seminomadic reindeer herders and residents of small (less than 750 individuals according to the list of representatives) settlements were regarded as close to the traditional one. Permanent residents of large (over 1000 individuals) northern villages were assigned to the "modernized" indigenous population.

The daylight length during the sampling was set for the middle of the range of the examination dates for the nearest geographical point using the resource http://www.timezone.ru/suncalc.php. This method for estimating the contribution of the factor of natural illumination is acceptable, because the serum concentration of 25(*OH*)*D* is a physiologically relatively stable index (the half-life of elimination from the human body is 2–3 weeks) [5, 25].

The distribution of 25(*OH*)*D* values differs from the normal law and must be described by the median values of a trait and the percentile boundaries. However, a number of publications provide the arithmetic mean values and the standard deviations instead. Given this fact, our cumulative tables include both the mean and median values with respective variation indices. The concentration of 25(*OH*)*D* in all cases is given in nmol/L.

As in the previous review [25], the diagnostic criteria for the vitamin *D* status were set according to the recommendations of the Institute of Medicine (US) Committee [26]. The concentration of 25(*OH*)*D* less than 30 nmol/L was regarded as the vitamin deficiency; 30–50 nmol/L, an insufficient content; and 50 nmol/L and above, a satisfactory vitamin *D* status. In this review, we included the papers in which the specified diagnostic criteria of the vitamin status were used or which contained the data that could be recalculated.

For discussion, we used the materials presented in the publications that do not meet the specified set of criteria and cannot be included in the overall data array. In particular, this is the study by Blazheevich et al. [8], which was performed in the early 1980s. In that time, there were no standard reagent kits for carrying out mass-scale analyses, and the precise information on the laboratory techniques used in the study is missing. Because of the possible methodological inconsistencies, data of that article were not included in the general analysis. However, the exclusion of the materials published in that paper from consideration will lead to the loss of important information. First, they reflect the situation 35 years ago, when the lifestyle and diet of Russian Arctic indigenous people markedly differed from that at the beginning of the 21st century [24]. However, the main value of this study is that it included the group of Nenetses from the coastal settlements Varnek and Varandei, which do not exist today. At the beginning of the 1980s, the indigenous inhabitants of these settlements hunted marine mammals, and their diet, which included seal meat, was relatively close to that characteristic of the modern Greenland Eskimos. Other studies of Russian Arctic aborigines were performed in the groups of residents of tundra and forest tundra. Their traditional diets are based on the products of reindeer herding and lake and river fishing and differ significantly in composition from the diets of Greenland and American Inuit [24]. Thus, the data by Blazheevich et al. [8] are currently the only source that allows comparing the serum content of 25(*OH*)*D* in the indigenous population of the Russian and foreign Arctic with similar types of traditional diet.

## RESULTS

The information about the content of 25(*OH*)*D* in the blood serum of representatives of different age and ethno-territorial groups of northern and arctic regions of Russia, which was obtained in the methodical review is summarized in Tables 1 and 2. Table 3 shows the results of the survey of Nenetses of the Nenets Autonomous okrug at the beginning of the 1980s [8]; the specificity of these data was mentioned earlier. Tables 1–3 cover the results of survey of 2061 individuals.

Table 4 summarizes the data from the publications containing information about the vitamin *D* status in different population groups, which was estimated by the same criteria (see Methods).

## DISCUSSION

*Relationship of the vitamin D status with latitude.* Within the frame of this review, it is impossible to perform a quantitative estimation of the relationship between the concentration of 25(*OH*)*D* and/or vitamin *D* status with the latitudinal localization of a group: due to restrictions imposed on the selection of publications (only the populations of the Far North and equated territories), the range of latitudinal variability is too small. In addition, a number of studies contained either the aggregated data that were obtained in different seasons or do not specify the time or season of survey.

Given this fact, we had to limit ourselves to a qualitative analysis. It showed that the mean concentration of 25(*OH*)*D* in the children of Yakuts [30], Evens, and Chukchi living in towns [32] (Table 1), similarly to the adult Nenetses living in settlements [10, 35] (Table 2), are within the limits of variation of the trait characteristic of the urbanized Karelians and Russians of other northern regions of the country [38–40].

Both children and adult Komi by the 25(*OH*)*D* content (Tables 1, 2) do not differ from representatives of other groups of population of the European part of the Russian Federation—Komi-Permyaks, Udmurts, and Russians [31, 34].

The indices of the vitamin *D* status of adult Nenetses (without taking into account of the residence and occupation, Table 2) do not differ from the indices of adult inhabitants of towns located to the south in the range 57–61° N, who were examined in the same season [10].

It can be concluded that the northerners of the Russian Federation living in towns and villages, in general, do not differ in the 25(*OH*)*D* content from the residents of the temperate zone of Russia or, in any case, these differences are small.

Thus, dwelling in high-latitude regions per se does not have an adverse effect on the vitamin *D* status of population.

*Age dynamics.* Information on the age variability of the vitamin *D* status in groups of the population of northern regions of Russia is fairly scarce.

The authors of [27] reported the concentration of 25(*OH*)*D* in Russian and Nenets children 0–3 years old living in Naryan-Mar, who were surveyed in the spring and autumn of 2013–2014. However, the statistical characteristics are incomplete, and the samples of the Nenets children are very small (3–5 individuals in each age group), which did not allow us to include these data in the review. The comparison of the characteristics of adolescents 13–15 years old and adults of Izhma Komi [10, 31] can also be considered incorrect, because these groups significantly differ in the lifestyle: the schoolchildren are the residents of large Arctic villages Izhma and Sizyabsk, whereas the sample of adults was represented by the reindeer herders leading semi-nomadic lifestyle, with its inherent features of physical activity, nutrition, and staying outdoors.

Thus, the data of the content of 25(*OH*)*D* in the groups of Komi are reduced only to the groups of adolescents living in village Kortkeros and adults living in Syktyvkar. The serum content of the vitamin (Tables 1, 2) and the vitamin *D* status (Table 4) in adults was significantly higher than in 13–15-year-old adolescences ($p < 0.05$ according to the Mann–Whitney *U* test).

The age-related changes in the serum concentration of 25(*OH*)*D* in the children and adults of ethnically undifferentiated population of Arkhangelsk were traced in more detail [27, 28, 33]. In the samples examined in spring and autumn, the highest values of 25(*OH*)*D* were in the children of the first 12 months of life; then, the content of 25(*OH*)*D* decreased to the representatives of the age group of 6–7 years (the cohort-wide negative trend was statistically significant, $p < 0.01$). Further, in the samples of 13–15-year-old adolescences (Table 1) and adults with a mean age of 20 and 45 years (Table 2), the concentration of 25(*OH*)*D* sequentially increased. This dynamics is generally consistent with the results of the meta-analysis performed for the populations of the temperate zone of Russia [25].

*Role of natural light and seasonality.* According to the data obtained during the examination of children (Table 1), in February–March (daylight period, 10 h) the content of 25(*OH*)*D* in 11–15 year-old children of Yakutsk is twice lower ($p < 0.001$) than in August, at a daylength close to 16 h [30]. The fact that the serum concentration of 25-$OHD_3$ in Komi children of the same age in February (daylight 8.5 h) is significantly ($p < 0.001$) lower than in November, when the daylight period was 1 h shorter (7.5 h) [31], we do not consider as contrary to the previous observation. In our opinion, in this case the factor of seasonality manifests itself: in November, the body still retains the vitamin reserves accumulated during the light time of the year due to autosynthesis of cholecalciferol, whereas in February the northern "vitamin-D-deficient winter" only comes to the end. This is consistent with the results obtained in the non-arctic populations, in which the increased levels of vitamin *D* are formed by the end of the period of high insolation (August–October), whereas at the end of winter/early spring (February–March), the concentration of 25(*OH*)*D* is minimum [25].

Data for the groups of adults (Table 2) confirm the effect of the factors of natural light and seasonality. In adult Nenetsreindeer herders, who were surveyed in winter at the minimum day length (0 to 3 h), the level of 25(*OH*)*D* was significantly lower ($p < 0.05$) than in

**Table 1.** Content of 25(*OH*)*D* (nmol/L) in different age, sex, and territorial groups of the population of the Russian North (children 0–18 years old)

| Ethnic group[1] | Locality surveyed | ° N[2] | Age, years[3] | Sex | Season/month | Daylight duration[4] | *n* | *M* | *SD* | *Me* | *Q*1–*Q*3 | *m* | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Russian (conditionally) | Arkhangelsk | 64 | 0–1 | M + F | Spring–Autumn | – | 76 | – | – | 86.3 | 54.3–124.8 | – | [27, 28] |
| Russian (conditionally) | Arkhangelsk | 64 | 1–2 | M + F | Spring–Autumn | – | 34 | – | – | 66.5 | 48.8–90.5 | – | [27, 28] |
| Russian (conditionally) | Arkhangelsk | 64 | 2–3 | M + F | Spring–Autumn | – | 45 | – | – | 53.5 | 41.5–76.25 | – | [27, 28] |
| Russian (conditionally) | Arkhangelsk | 64 | 6–7 | M + F | Spring–Autumn | – | 80 | – | – | 32.8 | 25.25–52.0 | – | [28] |
| Russian (conditionally) | Arkhangelsk | 64 | 13–15 | M + F | Spring–Autumn | – | 184 | – | – | 43.5 | 38.0–51.5 | – | [28] |
| Russian (conditionally) | Arkhangelsk | 64 | 11–15 (13.0) | M + F | Excluding | – | 41 | – | – | 59.8 | 54.0–62.7 | – | [29] |
| Yakuts + Russian (1.8 : 1) | Yakutsk | 62 | 9–15 | M + F | II–III | 10:10 | 80 | 35.1 | – | – | – | 2.20 | [30] |
| Yakuts + Russian (1.8 : 1) | Yakutsk | 62 | 9–15 | M + F | VIII | 16:05 | 67 | 62.8 | – | – | – | 5.61 | [30] |
| Komi | Kortkeros, Komi Republic | 61 | 13–16 | M + F | XI | 7:35 | 43 | 37.9 | 12.2 | 38 | – | 1.70 | [31] |
| Izhma Komi | Izhma, Komi Republic | 65 | 13–15 (13.6) | M + F | II | 8:30 | 51 | 31.06 | 8.76 | 30 | – | 1.57 | [31] |
| Evens | Anyuisk, Keperveem | 68 | 2–18 (9.5) | M | No data | – | 44 | 47.17 | – | – | – | 3.77 | [32] |
| | | | | F | | – | 44 | 38.94 | – | – | – | 5.74 | |
| Chukchi | Ostrovnoe, Keperveem | 68 | | M | | – | 76 | 40.44 | – | – | – | 4.49 | |
| | | | | F | | – | 60 | 39.19 | – | – | – | 3.99 | |
| Russians | Bilibino (ChAO) | 68 | | M | | – | 94 | 33.20 | – | – | – | 4.49 | |
| | | | | F | | – | 82 | 34.20 | – | – | – | 3.24 | |

[1] In the absence of accurate data, the ethnicity of urban population is specified conditionally (by that prevailing in the region); [2] °N is the latitude of the locality surveyed (degrees); [3] age range of the surveyed subjected or the mean value for the sample (unless otherwise stated); [4] the daylight duration in the period of survey (in hours).

**Table 2.** Content of 25(*OH*)*D* (nmol/L) in different age, sex, and territorial groups of the population of the Russian North (adults)

| Ethnic group[1] | Locality surveyed | ° N[2] | Age, years[3] | Sex | Season/month | Daylight duration[4] | *n* | *M* | *SD* | *Me* | *Q*1–*Q*3 | *m* | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Russian (conditionally) | Arkhangelsk | 64.5 | 18–22 | M + F | Spring–Autumn | | 260 | – | – | 51.0 | 37.1–75.0 | – | [33] |
| Russian (conditionally) | Arkhangelsk | 64.5 | 24–60 | M + F | Spring–Autumn | | 85 | – | – | 60.8 | 40.5–76.75 | – | [33] |
| Komi Permyak | Kudimkar KPO | 59 | 19–59 | M + F | III | 13:00 | 46 | 44.7 | 9.01 | 43.5 | – | 1.33 | [34] |
| Komi | Syktyvkar, Komi Republic | 61.67 | 17–23 | M + F | XI | 7:35 | 52 | 47.7 | 12.0 | 47.0 | – | 1.74 | [34] |
| Komi Izhma | Nomads' camps, Komi Republic | 65.00 | 18–52 | M + F | II | 8:30 | 13 | 68.7 | 25.20 | – | – | 6.99 | [10] |
| Nenets | Taz, NAO | 67.23 | 45.4 | M + F | III–IV | 13:50 | 69 | 69.5 | – | – | 47.0–64.5 | 3.0 | [35] |
| Nenets | Gyda, NAO | 70.53 | 45.4 | M + F | III–IV | 14:13 | 65 | 84.5 | – | – | 61.8–97.5 | 3.75 | [35] |
| Russian | Taz, NAO | 67.23 | 45.4 | M + F | III–IV | 13:50 | 40 | 56.8 | – | – | 38.3–48.8 | 4.4 | [35] |
| Nenets | Nes, NAO | 66.36 | 18–59 | M + F | XII | 2:42 | 42 | 31.3 | 12.72 | 27.8 | – | 2.28 | [10] |
| | Nomads' camps | 67.00 | 21–60 | M + F | XII | 2:38 | 40 | 35.3 | 11.33 | 34.5 | – | 1.85 | |
| | Khorei-Ver, NAO | 67.24 | 20–58 | M + F | XII | 1:20 | 46 | 47.1 | 10.64 | 48.3 | – | 1.64 | |
| | Nomads' camps | 68.00 | 18–56 | M + F | XII | 0:00 | 37 | 50.2 | 11.12 | 50.5 | – | 1.75 | |

[1] In the absence of accurate data, the ethnicity of urban population is specified conditionally (by that prevailing in the region); [2] °N is the latitude of the locality surveyed (degrees); [3] age range of the surveyed subjected or the mean value for the sample (unless otherwise stated); [4] the daylight duration in the period of survey (in hours).

**Table 3.** Content of 25(*OH*)*D* (nmol/L) in different groups of Nenetses of the Nenets AO

| Locality surveyed | Latitude, °N | Age, years | Sex | Season/month | Daylinght duration, h | *n* | *M* | *SD* | *m* |
|---|---|---|---|---|---|---|---|---|---|
| Naryan-Mar (boarding school) | 68 | 9–17 | M + F | V | 20:16 | 95 | 43.75 | 21.93 | 2.25 |
| Naryan-Mar (orphanage) | 68 | 3–7 | M + F | VI | 24:00 | 14 | 40.0 | 20.84 | 5.57 |
| Naryan-Mar | 68 | 20–35 | F mothers | Winter | 0:54 | 18 | 65.75 | 59.40 | 14.0 |
| Varandei, Varnek | 69 | Adults. | M + F | III | 9:43 | 38 | 110.0 | 78.66 | 7.5 |

Source: [8], with modifications.

**Table 4.** Ratio of examined subjects with vitamin *D* deficiency and insufficiency (25(*OH*)*D* concentration less than 50 nmol/L) in different populations of the North of Russia

| Nationality | Region | Age, years | Season | *n* | 25(*OH*)*D* < 50 nmol/L, percentage in sample | Source |
|---|---|---|---|---|---|---|
| Russians (conditionally) | Arkhangelsk | 0–1 | Spring–Autumn | 76 | 20.65 | [27] |
| Russians (conditionally) | Arkhangelsk | 1–2 | Spring–Autumn | 34 | 26.56 | [27] |
| Russians (conditionally) | Arkhangelsk | 2–3 | Spring–Autumn | 45 | 43.11 | [27] |
| Russians (conditionally) | Arkhangelsk | 6–7 | Spring–Autumn | 80 | 71 | [36] |
| Russians (conditionally) | Arkhangelsk | 13–15 | Spring–Autumn | 184 | 70 | [36] |
| Russians (conditionally) | Arkhangelsk | 11–15 | Excluding | 41 | 14.6 | [29] |
| Russians (conditionally) | Arkhangelsk | 18–22 | Spring–Autumn | 88 | 48 | [33] |
| Russians (conditionally) | Arkhangelsk | 24–60 | Spring–Autumn | 85 | 33 | [36] |
| Komi | Kortkeros (village) | 13–16 | XI | 43 | 86 | [31] |
| Izhma Komi | Izhma (village) | 13–15 | II | 51 | 98 | [31] |
| Yakuts + Russian (1.8 : 1) | Yakutsk | 9–15 | II–III | | 60 | [30] |
| Yakuts + Russian (1.8 : 1) | Yakutsk | 9–15 | VIII | | 10.4 | [30] |
| Komi | Syktyvkar | 17–23 | XI | 52 | 62 | [34] |
| Komi-Permyak | Kudymkar | 19–59 | III | 46 | 30 | [34] |
| Nenetses | Yamal-Nenets AO | 20–75 | III–IV | | 34.7 | [37] |
| Russians, Yamal-Nenets AO | Yamal-Nenets AO | 20–75 | III–IV | | 50 | [37] |

In percentage of the number of surveyed subjects, regardless of the sex.

the Komi herders, whose blood for research was taken in spring, when the light period increased to 8.5 h [10]. The interseasonal differences between the groups of Nenetses living in villages was also significant ($p < 0.001$) [10, 35]. The comparison was performed with allowance for the size of the locality, separately for the inhabitants of small settlements (Gyda and Khorei-Ver) and large urban villages Tazovskii and Nes. In both cases, the subjects who were examined in March–April, at a daylight duration of approximately 14 h, were characterized by almost twice higher levels of 25(*OH*)*D* in blood serum compared with those who were examined in December (daylight duration from 1 h 20 min to 2 h 40 min).

These data are consistent with the data reported by Blazheevich et al. [8] (Table 3): the content of 25(*OH*)*D* in Nenetses living in Naryan-Mar in winter (daylight duration in December less than 1 h) was also lower compared with the villagers surveyed in March (daylight duration approximately 10 h).

It should be concluded that the level of natural light has a significant influence on the serum level of vitamin *D* in northerners.

*Effect of ethnicity and race.* In the groups of the population of the North of the Russian Federation included in the survey, the Caucasian race was represented by the Russian, Komi (including Izhma Komi), and Komi-Permyaks, and the Mongoloid race was represented by Yakuts, Evens, Chukchi, and Nenetses.

In the urban children of different racial and ethnic groups (Nenetses and Russians 0–3 years old [27], Yakuts and Russians 9–15 years old [30]), no statistically significant differences in the concentration of 25(*OH*)*D* were detected. The rural children of the

Mongoloid groups (Evens and Chukchi) also do not differ by the considered trait [32].

In all cases of significant interethnic differences, the content of 25(*OH*)*D* was higher in the representatives of the Mongoloid groups (in the below pairwise comparisons, $p < 0.05$). Children of Evens and Chukchi living in villages of the Chukotka Autonomous Okrug by the level of 25(*OH*)*D* were superior to the simultaneously surveyed age-matched Russian children living in the same villages [32] (Table 1). In the samples of adults (Table 2), the Nenetses living in villages by this trait were superior to the Russians living in the same localities [35], and the Nenetses living in the large village Tazovskii [35] were superior to the Komi-Permyak people living in towns, who were examined at the same day length [34]. In addition, the concentration of 25(*OH*)*D* in the Nenetses engaged in reindeer herding and living in the small village Gyda was higher than in the Izhma Komi reindeer herders [10, 35].

In performing this analysis, we took into account such characteristics of the samples as the season and the daylight length during the survey period, the type of residence (city, large or small village), and the lifestyle (in particular, involvement in reindeer herding). However, the contribution of a number of factors (such as the type of nutrition and the diet, the duration of staying outdoors, etc.) cannot be estimated on the basis of the available data. With this in mind, we can summarize that, in the medical and anthropological terms, the relationship between the race and ethnicity of northerners and the content of 25(*OH*)*D* in their blood serum cannot be ruled out; however, this issue requires a special study.

*Nutrition specifics contribution.* The role of nutrition in the formation of vitamin *D* status of northerners is indicated by almost all researchers. The deterioration in the vitamin *D* status, associated with a reduced consumption of the traditional food [7, 41], was detected in the Nenetses living in the Russian Federation as well as in the Inuit (Eskimos) of Greenland [18] and Canada [19, 42] and in Amerindians of the Canadian Arctic [43].

Data by Blazheevich et al. [8] (Table 3) confirm the low levels of vitamin *D* in Nenets children living in boarding schools and orphanages, whose nutrition was organized according to the requirements that are same for the entire country and dramatically differed from the traditional variants [24].

An important nutritiological cause for the formation of the vitamin *D* status of northerners is the high contribution of fish to their diet. Indeed, it was confirmed that the traditional fish dishes with a large amount of fish oil help to maintain the optimal levels of vitamin *D* [44]. Since a significant proportion of the needs of Arctic aborigines for food is covered by the fishery products (for example, in Nenetses of the Nenets Autonomous Okrug, this value varies in the range 30–40% [45]), the intergroup differences in the vitamin *D* status are often a priori explained by the contribution of fish dishes to their diet. For example, Beketova et al. [35] assumed that the significant ($p < 0.05$) differences in the content of 25(*OH*)*D* in the examined samples of Nenetses (Table 2) is the consequence of a higher consumption of fish by the inhabitants of village Gyda as compared with the population of the village Tazovskii. Although this assumption is plausible, it, similarly to other studies of Russian authors included in this analysis, is not supported by a direct assessment of the diets of the examined individuals.

The lack of detailed nutritiological data can be considered a significant drawback of sample surveys of the vitamin *D* status of northerners of the Russian Federation.

The analysis of the possible contribution of the diet, which was performed at the population level, confirms the necessity of this type of research. In particular, it was found that the concentration of 25(*OH*)*D* in the residents of settlements and semi-nomadic reindeer herders of Khorei-Ver was higher ($p < 0.01$) than in the Nenetses of Nes village (Table 2, [10]). In this case, fish in the diet of the inhabitants of Khorei-Ver covers 15–20% of the demands for products, and approximately 50% is covered by venison, whereas in the large district center Nes village, as well as in the entire Nenets Autonomous Okrug, the contribution of the local products (i.e., fish and venison in total) to the diet is 30–40% [45]. Since the survey was performed during the polar night at the minimum day length, the contribution of cholecalciferol to the formation of the vitamin *D* status can be excluded. Thus, at least in this case, the key source of vitamin *D* in the tundra reindeer herders is not fish. It should also be emphasized that the fish consumed by the Nenetses of Nes and Khorei-Ver villages and the Izhma Komi reindeer herders ([10], Table 2) is represented primarily by the freshwater species, the content of vitamin *D* in the fat of which is lower than that in the marine fish. Currently, the indigenous people of the Russian European Arctic do not catch marine fish and mammals.

Marine mammal hunting was practiced earlier by small group of coastal Nenetses, in particular, the inhabitants of settlements Varnek on Vaigach Island and Varandei on the Barents Sea coast. In 2000, the Varandey settlement was officially closed, and only 100 people left in Varnek. Thus, the data of the study performed by Blazheevich et al. [8] in the early 1980s in these villages is the only evidence of the vitamin *D* status of the Russian Arctic sea hunters, whose diet still included the marine fishery and hunting products (data on the 25(*OH*)*D* content in the marine mammal hunters of Chukotka were not found in the available literature). With a high probability it can be assumed that the marine hunting products (fish and seal meat) determined the very high levels of 25(*OH*)*D* in the sample of coastal Nenetses (Table 3). Data reported in [8] are the only materials that can be correctly used when comparing with the results of studies of Greenland sea hunters.

When considering the contribution of the traditional food to the formation of the vitamin *D* status of northerners, one should pay attention to the possible role of venison. It was found relatively recently that reindeer (*Rangifer tarandus*) tissues, unlike other animals, contain significant amounts of vitamin *D* [44, 46]. The concentration of the vitamin in the liver and kidney of the reindeer (1.1–1.4 μg per 100 g of product) is close to its content in the blubber of seals [47]. Ergocalciferol is produced in significant amounts in lichens (*Cladina* spp.), which are components of the diet of the reindeer, and then accumulates in animal tissues. It is believed that the man, as a consumer of a higher order, is able to obtain sufficient amounts of vitamin *D* with venison. The theoretical aspects of the ways of provision with the vitamin were considered by Goering [48]. Unfortunately, direct studies of the content of $D_2$ and $D_3$ in different types of lichens are rare [49–51], and a comprehensive analysis of northern phyto- and biocenoses from the standpoint of vitamin *D* metabolism has not been performed.

The importance of meat and fat of the reindeer as a source of ergocalciferol is indirectly confirmed by the differences in the content of 25(*OH*)*D* in the representatives of northerners with different access to reindeer herding products. The maximum levels of vitamin *D* in the blood serum of herders, who have to use the products of their herds as a basis of their diet while staying in the tundra. The concentration of 25(*OH*)*D* in the inhabitants of small settlements is lower: the access to the grocery products in them is limited, and up to 50% of the needs is met by venison supplied by community members. Finally, the level of the vitamin is further reduced in the inhabitants of the district center, who are involved in the "post-traditional" lifestyle and are oriented at purchased food. Among the women living in the large village, the content of 25(*OH*)*D* in the young Nenets women, who are relatively "westernized" in terms of nutrition, is lower ($p < 0.05$) compared to the representatives of the older age group (42–59 years old), who use the traditional food products [10, 41].

Thus, in the indigenous northerners, the consumption of the traditional food is associated with the higher levels of 25(*OH*)*D* in the serum.

However, the contribution of the specific components (sea hunting products, marine and freshwater fish, and venison) remains insufficiently studied.

## CONCLUSIONS

The paper discusses the results of the survey of 2061 representatives of the indigenous peoples and the major ethnic groups inhabiting the territory of the Far North and equivalent areas of the Russian Federation.

The main results of the systematic review show:

(1) Dwelling in high-latitude regions (i.e., the latitude of the localization of a group) per se does not have an adverse effect on the vitamin *D* status of the population. In the 25(*OH*)*D* content, the rural and urban northerners of the Russian Federation, in general, do not differ from the inhabitants of the temperate zone of Russia.

(2) The available data on the age-related dynamics of the 25(*OH*)*D* content in the blood serum of residents of the northern regions sufficiently well characterize only the ethnically mixed (conditionally Russian) population of the city of Arkhangelsk. The levels of 25(*OH*)*D* are maximum in infants of the first year of life and decline by an age of 6–7 years ($p < 0.01$). In the group of adolescents 13–15 years old and adults younger than 59 years, the concentration of 25(*OH*)*D* sequentially increases. The described age-related dynamic corresponds to that characteristic of the populations of the temperate zone of Russia.

(3) The age-related changes in the vitamin *D* status in the groups of indigenous people of the Arctic are studied insufficiently and require special studies.

(4) The level of natural light has a significant effect on the serum content of vitamin *D* of northerners. When comparing the representatives of different groups, samples should be ranked according to the daylight length or season of the year in the period of survey.

(5) The relationship between the race and ethnicity of northerners and the serum content of 25(*OH*)*D* cannot be ruled out; however, this issue requires a special study. The interethnic differences in the concentration of 25(*OH*)*D* are manifested only when comparing the rural Russian and indigenous population. Information about the features of the vitamin *D* status of representatives of different racial groups of indigenous peoples of the Russian North is insufficient.

We found no studies in which the analysis of the 25(*OH*)*D* content in northerners of the Russian Federation would be accompanied by a study of the diet, i.e., direct assessment of food consumption. The available data do not contradict the opinion about the favorable role of traditional products; however, all confirmations are indirect. The contribution of specific components of the "northern cuisine" (sea hunting products, marine and freshwater fish, and venison) remains insufficiently studied.

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## COMPLIANCE WITH ETHICAL STANDARDS

The authors report no conflicts of interest related to the implementation of the research and publication of its results. This article does not contain any studies involving animals or human participants performed by any of the authors.

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