Vitamin D deficiency in Korean children: prevalence and risk factors

Abstract

Background

Vitamin D is an essential vitamin, supplied by exposure to sunlight, used in the growth and health of bones. Vitamin D deficiency not only results in skeletal diseases such as rickets, but also is reported to increase metabolic syndromes, cardiovascular diseases, and allergic diseases. The prevalence of vitamin D deficiency is different across countries. This study aimed to investigate the prevalence and risk factors of vitamin D deficiency among Korean children and adolescents.

Methods

From September of 2013 to May of 2014, we analyzed the medical records of 330 patients from the age of six to twelve who visited endocrinology clinic of the pediatrics department at Pusan National University. The patients were grouped into either the deficiency group (25(OH)D < 20 ng/mL) or the sufficiency group (25(OH) ≥ 20 ng/mL) depending on their serum 25(OH)D levels. The difference between the two groups was compared.

Results

There were 195 patients (59.1%) who had vitamin D deficiency. The mean serum level of 25(OH)D of all the patients was 19.83 ± 7.39 ng/mL. The differences in sex, age, and pubertal status between the two groups were not statistically significant. Compared to autumn, spring (OR, 9.7; 95% CI, 4.3-22.0) and winter (OR, 5.9; 95% CI, 3.5-10.0) were found to have effects on vitamin deficiency.

Conclusion

Vitamin D deficiency among Korean children and adolescents is very common. Seasonal differences have been confirmed to have an effect on vitamin D deficiency. To improve the vitamin D status, there needs to be efforts to increase outdoor activities for sunlight exposure and to take vitamin D supplements.

Introduction

Vitamin D is an essential vitamin for the health and growth of bones. It is also important for calcium and phosphorus metabolism. 1)

Humans receive vitamin D from sunlight exposure, food, and dietary supplements. 2) In dietary supplements and food such as fish and liver oil, vitamin D exists in the forms of cholecalciferol (vitamin D3) and ergocalciferol (vitamin D2). There are not many natural food items that contain vitamin D, so sun exposure is a major source of vitamin D. The ultraviolet B radiation from sunlight transforms the 7-dehydrocholestrerol of the skin into cholecalciferol (Vitamin D3). 3)

Vitamin D from skin and diet is transformed into 25-hydroxyvitamin D(25[OH]D) in the liver. Afterwards, it is further processed to become the active form, 1,25-dihydroxyvitamin D(calcitriol), by 1 α–hydroxylase in the kidneys and bind to a vitamin D receptor. This promotes bone remodeling by increasing the absorption of calcium and phosphorus in the intestines and inhibiting the activity of parathyroid hormones. 4)

Therefore, vitamin D deficiency could result in skeletal diseases such as rickets and osteomalacia.5) In addition, Vitamin D receptors exist in endocrine glands (pituitary, pancreas, parathyroid, gonads, and placenta), and cardiovascular tissues (endothelial cell, vascular smooth muscle cells, and cardiomyocytes), taking part in cell differentiation and the production of interleukins and cytokines, having relevance in metabolic syndromes, diabetes, autoimmune diseases, and cardiovascular diseases. 6-8) Moreover, respiratory infections, food allergy, and asthma are known to increase with vitamin D deficiency, and there are also reports that menarche comes sooner in girls. 9-11)

Recently, vitamin D deficiency has become very common in both adults and children due to lack of exposure to sunlight. 12) The prevalence of vitamin D deficiency varies widely from country to country ranging from 15 to 60 percent. 13, 14) Therefore, this study aimed to investigate the prevalence and risk factors of vitamin D deficiency among Korean children and adolescents.

Methods

Study population

We targeted patients who are of six to twelve years in age and visited endocrinology clinic of the pediatrics department at Pusan National University from September of 2013 to May of 2014. The total of 330 patients were included. The patients with chronic diseases such as epilepsy and hypothyroidism were excluded. Normal weight was defined as being in the third to 84th percentile in terms of BMI. Being overweight was defined as being in the 85th to 94th percentile. Obesity was defined as being in the 95th or higher percentile. This was based on the 2007 standard growth chart of Korean children and adolescents.

Central precocious puberty means the early activation of hypothalamic-pituitary-gonadal axis before eight years of age in girls and before nine years of age in boys.15) This study defined idiopathic central precocious puberty as the following: breast budding in girls before the age of eight, testicular volume of equal to or more than 4 cc or 4 cm² before the age of nine, advanced bone age (one year or more compared to the chronological age), and the peak stimulated luteinizing hormone (LH) level being equal to or higher than 5.0 IU/L on immunoradiometric assay (IMRA) after stimulation by gonadotropin-releasing hormone (GnRH).16)

Study design

We reviewed the participants’ medical records to collect data on their height, weight, pubertal status, bone age, calcium level, phosphorus level, and alkaline phosphatase level. Breast development was classified according to the Tanner stages. Testicular volume was measured using the Prader orchidometer by comparing beads of certain volume with the target testis. Bone age was measured using the method described by Greulich and Pyle.

Laboratory measurements

Serum 25-hydroxyvitamin D (25OHD) level was measured using the electrochemiluminescence binding assay (Roche Diagnostics, Indianapolis, IN, USA). Serum calcium, phosphorus, and alkaline phosphatase levels were measured. According to vitamin D status, the patients were divided into two groups, deficiency (25OHD, < 20ng/mL) and sufficiency (25OHD, ≥ 20 ng/mL) groups.

Statistical analysis

SAS ver. 9.3 (SAS Institute, Cary, NC, USA) was used for statistical analysis. Continuous variables were expressed using the mean value and the standard deviation (SD). The differences between the vitamin D deficiency group and the sufficiency group were compared using two sample t-test and Wilcoxon rank sum test. In terms of the categorical values, Chi-squared test was used to compare the differences between the two groups. Multiple logistic regression analysis was used to analyze the factors that affect vitamin D deficiency. In all the statistical analyses, p-values of below 0.05 were considered to be statistically significant.

Results

A total of 330 patients were included, and their characteristics are presented in Table 1. There were 264 (80%) girls and 66 (20%) boys. Among the patients, 232 (70.3%) had normal weight, 58 (17.6%) were overweight, and 40 (12.1%) were obese. The season when the measurements were taken were spring with 50 (15.1%) patients, autumn with 129 (39.1%) patients, and winter with 151 (45.8%) patients. There were 195 (59.1%) patients in the vitamin D deficiency group and 135 (40.9%) patients in the sufficiency group. Of the 330 patients, 42 (12.7%) were diagnosed with idiopathic central precocious puberty.

Table 2 shows the comparison of characteristics of vitamin D deficiency and sufficiency groups. Mean serum level of 25[OH]D was 14.86 ± 3.20 ng/mL and 27.01 ± 5.59 ng/mL, respectively. The differences between the two groups in terms of sex, age, and pubertal status were not statistically significant. When the patients’ weights were separated into normal, obese, and overweight, and the distribution was compared between the two groups, the differences were not statistically significant. However, the frequency of overweight and obese patients in the deficiency group was higher. Weight SDS and BMI SDS were significantly higher in the vitamin D deficiency group (p = 0.002 for each). For each season, there were 41 (21%) from the deficiency group and 9 (6.7%) from the sufficiency group in spring. In autumn, there were 42 (21.5%) and 87 (64.4%) from each group, and there were 112 (57.4%) and 39 (6.7%) from each group in winter. Compared to autumn, the patients who were measured in spring and winter had higher percentage of vitamin D deficiency.

The mean serum levels of Calcium, phosphorus, and ALP were 9.71±0.35 mg/dL, 4.83±0.52 mg/dL, and 253.06±61.54 IU/L, respectively. The mean serum calcium levels for vitamin D deficiency group and sufficiency group were 9.67±0.36 mg/dL and 9.76±0.32 mg/dL, respectively, being significantly higher in the sufficiency group (p = 0.018). For phosphorus, the levels were 4.79±0.52 mg/dL and 4.89±0.51 mg/dL respectively for each group, and for ALP, 257.96±65.89 IU/L and 245.93±54.06 IU/L, not statistically significant (p = 0.107, 0.073). When multiple logistic regression was performed to investigate the factors related to vitamin D deficiency, spring (OR, 9.7; 95% CI, 4.3-22.0) and winter (OR, 5.9; 95% CI, 3.5-10.0) were found to be factors affecting vitamin D deficiency compared to autumn (Table 3).

Discussions

In this study, vitamin D deficiency was found to be very common among Korean children and adolescents. There were 195 (59.1%) patients with the serum vitamin D level of lower than 20 ng/mL, and the mean serum level of 25(OH)D was 19.83±7.39 ng/mL. The prevalence was found to increase in spring and winter compared to autumn.

In a previous study on the vitamin D status of Korean children and adolescents, Lee et al. reported the mean serum level of 25(OH)D in 2880 children and adolescents to be 17.42±8.95 ng/mL.17) Another study reported that mean serum level of 25(OH)D in 1660 children and adolescents was 18.8±5.0 ng/mL. 18) As with this study, the levels of 25(OH)D in the two studies were lower than the standard for vitamin D deficiency of 20 ng/mL.

It is reported that as one is farther away from the equator, the yearly duration of ultraviolet B irradiation enough for vitamin D synthesis becomes shorter.2) In Korea (Latitude 33-38°N), sunlight is known to be effective in synthesizing vitamin D from April to October, from ten in the morning to three in the afternoon. 19) There are reports on the effect of seasonal variations on 25(OH)D according to the differences in latitudes. In the northern hemisphere, the serum 25(OH)D level is reported to gradually decrease from summer to winter. 20-23) In this study, serum 25(OH)D level measured in spring and winter was lower, and summer was not included. According to Foo et al., the serum 25(OH)D level of adolescent girls in Beijing, China (Latitude 40°N) was 36 nmol/L (14.4 ng/mL) when participating in sports and 30 nmol/L (12 ng/mL) when not participating in sports.24) Another study reported that during winter time, 40% of the adolescent girls in Beijing show vitamin D deficiency. In Mongolia (Latitude 42-50°N), which is adjacent to China, ultraviolet light exposure is reported to be sufficient only in summer, and the risk of vitamin D deficiency increases in winter.25)

The changes in lifestyle in the modern society caused an increase in indoor activities, decreasing exposure to sunlight among children. In this study also, the decrease in outdoor activities could be a cause of high prevalence of vitamin D deficiency.

Obese people are known to have a lower level of vitamin D compared to people with normal weight. In vitamin D deficiency, key enzymes that act on adipose tissue difference such as lipoprotein lipase and fatty acid synthase are thought to be inhibited, thereby affecting fat accumulation. Vitamin D3 is stored in subcutaneous fat, and the vitamin D3 synthesized in the skin of obese people become more sequestered. Due to a decrease in the bioavailability of vitamin D3, vitamin deficiency appears in obese people.27) This study showed a significant difference between the vitamin D deficiency and sufficiency groups in terms of weight SDS. However, when multiple logistic regression analysis was used to analyze the factors affecting vitamin D deficiency, weight was not a statistically significant factor.

There have been several studies on the relationship between vitamin D status and sexual maturation. According to Grivas et al., menarche started at a younger age in the northern latitudes where the level of vitamin D synthesis is lower. 28) Villamor et al. followed a cohort of 242 healthy girls who were of five to twelve years in age for 30 months and observed that menarche occurs earlier in those with vitamin D deficiency. They explained that vitamin D deficiency is related to obesity, so vitamin D status would have indirectly affected menarche age.29) In this study, there was no significant difference in pubertal status between the vitamin D deficiency and sufficiency groups.

There is a number of limitations to this study. This is a hospital based study and most of the patients live in Busan, so this data might not be representative of the whole population in Korea. The levels of parathyroid hormone, which is one of the important factors affecting vitamin D status, were not measured. Of the four seasons, summer was not included. Therefore, there needs to be a further study on the vitamin D status of children and adolescents, involving a larger region and including all four seasons.

In conclusion, vitamin D deficiency among Korean children and adolescents is very common, and seasonal variations affect vitamin D status. There needs to be efforts to improve vitamin D status, such as increasing outdoor activities for more exposure to sunlight and taking vitamin D supplements during a season when vitamin D deficiency is widely prevalent.

Table 1. Characteristics of the study participants (n=330)

|  |  |
| --- | --- |
| Characteristic | No. (%) |
| Sex |  |
| Male | 66 (20.0) |
| Female | 264 (80.0) |
| Body weight |  |
| Normal (<85th percetntile) | 232 (70.3) |
| Overweight (85-95th percentile) | 58 (17.6) |
| Obese (≥95th percentile) | 40 (12.1) |
| Season |  |
| Spring (March-May) | 50 (15.1) |
| Fall (September-November) | 129 (39.1) |
| Winter (December-February) | 151 (45.8) |
| Vitamin D (25[OH]D) |  |
| Deficiency (<20ng/mL) | 195 (59.1) |
| Sufficiency (≥20ng/mL) | 135 (40.9) |
| Puberty |  |
| Normal | 288 (87.2) |
| Precocious puberty | 42 (12.7) |

Table 2. Characteristics of participants according to vitamin D status

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Total(n=330, 100.0%) | Vitamin Ddeficiency(n=195, 59.1%) | Vitamin Dsufficiency(n=135, 40.9%) | p-value1) |
| Serum 25(OH)D (ng/mL) | 19.83±7.39 | 14.86±3.20 | 27.01±5.59 |  |
| Sex (%) |  |  |  | 0.576 |
| Male | 66 (20.0) | 41 (21.0) | 25 (18.5) |  |
| Female | 264 (80.0) | 154 (79.0) | 110 (81.5) |  |
| Age | 8.70±1.24 | 8.80±1.22 | 8.55±1.26 | 0.078 |
| Season |  |  |  | <0.001 |
| Spring (March-May) | 50 (15.2) | 41 (21.0) | 9 (6.7) |  |
| Fall (September-November) | 129 (39.1) | 42 (21.5) | 87 (64.4) |  |
| Winter (December-February) | 151 (45.8) | 112 (57.4) | 39 (28.9) |  |
| Body weight |  |  |  | 0.071 |
| Normal(<85th percentile) | 232 (70.3) | 128 (65.6) | 104 (77.0) |  |
| Overweight(85-95th percentile) | 58 (17.6) | 41 (21.0) | 17 (12.6) |  |
| Obese(≥95th percentile) | 40 (12.1) | 26 (13.3) | 16 (10.4) |  |
| Puberty |  |  |  | 0.951 |
| Normal | 288 (87.3) | 170 (87.2) | 118 (87.4) |  |
| Precocious puberty | 42 (12.7) | 25 (12.8) | 17 (12.6) |  |
| Calcium (mg/dL) | 9.71±0.35 | 9.67±0.36 | 9.76±0.32 | 0.018 |
| Phosphorus (mg/dL) | 4.83±0.52 | 4.79±0.52 | 4.89±0.51 | 0.107 |
| ALP (IU/L) | 253.06±61.54 | 257.96±65.89 | 245.93±54.06 | 0.073 |
|  |  | 247.0 (212.5-292.0) | 253.0 (203.0-282.0) | 0.3612) |
| Weight SDS | 0.51±1.01 | 0.65±0.98 | 0.30±1.03 | 0.002 |
| Height SDS | 0.46±1.00 | 0.55±1.02 | 0.34±0.97 | 0.061 |
| BMI SDS | 0.41±1.02 | 0.55±0.98 | 0.19±1.05 | 0.002 |

1) Chi-square test, Two sample t-test
2) Wilcoxon rank sum test

Valuables are presented as mean±standard deviation or number (%).

25(OH)D, 25-hydroxyvitamin D; SDS, standard deviation score; BMI, body mass index

Table 3. The factors associated with vitamin D deficiency in logistic regression analysis

|  |  |  |
| --- | --- | --- |
|  | OR(95% CI) | Adjustedp-value1) |
| Sex (%) |  | 0.978 |
| Male | 1(ref.) |  |
| Female | 1.0(0.5-1.9) |  |
| Age\_year | 1.1(0.9-1.3) | 0.373 |
| Season |  | <0.001 |
| Spring (March-May) | 9.7(4.3-22.0) |  |
| Fall (September-November) | 1(ref.) |  |
| Winter (December-February) | 5.9(3.5-10.0) |  |
| Body weight |  | 0.101 |
| Normal(<85th percentile) | 1(ref.) |  |
| Overweight(85-95th percentile) | 2.1(1.1-4.3) |  |
| Obese(≥95th percentile) | 1.1(0.5-2.3) |  |
| Puberty |  | 0.886 |
| Normal | 1(ref.) |  |
| Precocious puberty | 0.9(0.4-2.1) |  |

1) Adjusted: sex age season puberty

CI, confidence interval

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