Clinical Nutrition Open Science 43 (2022) 56–66

Contents lists available at ScienceDirect

Clinical Nutrition Open Science

journal homepage: www.clinicalnutritionopenscience.com

Original Article

Vitamin D dietary intake and status in a sample of adolescents

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ARTICLE INFO

Article history:
Received 31 December 2021
Accepted 4 May 2022
Available online 10 May 2022

Keywords:
Vitamin D
Dietary intake
Vitamin D status
Dietary sources
Adolescents
Switzerland

SUMMARY

Background & Aims: Vitamin D is an essential micronutrient in multiple cellular and physiological regulatory processes including related bone health. Several European surveys including children and adolescents have reported a low vitamin D intake and high prevalence of insufficient or even deficient vitamin D status. In Switzerland, no recent data are available. This study aimed to assess dietary intakes, status, and major dietary sources of vitamin D in a convenience sample of Swiss healthy adolescents.
Methods: Adolescents aged between 11 and 18 years were recruited in the Lausanne region, Switzerland, between April and November 2017. Their diet was assessed using two 24-hour recalls. Vitamin D content of consumed foods was calculated using the Swiss Food Composition Database. Vitamin D levels were analyzed using high-performance liquid chromatography coupled with ultraviolet–visible spectroscopy.
Results: In 29 adolescents, median [P25–P75] vitamin D intake was 0.9 [0.6–1.5] μg/day. This value reached less than 10% of recommended intake (15 μg/day). Median plasma 25(OH)D level was 56.9 [48.3–69.8] nmol/L. One-third of participants had therefore insufficient vitamin D status (≤50 nmol/L). Among adolescents

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https://doi.org/10.1016/j.nutos.2022.05.002

tested in summer, 90% had a sufficient status. The main dietary sources of vitamin D were fish (35.2%) and dairy products (32.3%). *Conclusion:* In this small group of Swiss adolescents, vitamin D intake was below the recommendations. A sufficient vitamin D level seems attainable for the majority of adolescents in summer unlike for the fall to spring period. Further studies are necessary to validate these findings on a representative sample of children and adolescent at the national level.

Introduction

Sufficient vitamin D status in adolescents is important during growth and until the post-pubertal stage to build and reach peak bone mass [1]. Not reaching this peak is an issue as bone reserves are predictive of the osteoporosis risk later in adulthood [2,3]. Vitamin D does not only act on bone tissue, it has multiple functions including immunomodulation roles of innate and adaptive responses [4]. Numerous studies have also reported a negative association between vitamin D status as measured by circulating levels of 25(OH)D and cardiovascular, infectious and some autoimmune diseases [5].

Optimal sun exposure, the main source of vitamin D, is difficult to reach, especially in European winter. In addition, vitamin D dietary intake in children and adolescents is low, rarely exceeding 3 μg/day, except in Nordic countries [6]. Therefore, insufficient or deficient vitamin D status is common in European countries, including in the pediatric population [7]. In 2012, the European study HELENA reported suboptimal serum 25(OH)D levels in 80% of adolescents aged 12–17 years [8], based on samples collected between October 2006 and June 2007 and in October 2007. In Switzerland, population-based data in children and adolescents are limited. Despite numerous publications on vitamin D in Switzerland [9–12], the only comparable dataset on vitamin D status and intakes among children and adolescents date back to 2004. Ginty *et al.* reported vitamin D intakes between 1.8 and 3.2 μg/day depending on sex and age, which corresponded to 36–64% of the 5 μg/day recommended at that time. In addition, 16% of the participants had a 25(OH)D level below 25 nmol/l [13]. Furthermore, the main dietary sources of vitamin D have never been investigated in this age group in Switzerland. Currently, the only data available about vitamin D intake in the Swiss population are based on agricultural statistics [14], which cannot be considered as accurate vitamin D intake for population subgroups, such as children.

Based on epidemiological data, several European countries are advocating for vitamin D supplementation beyond the second year of life [15–17]. In Switzerland, a supplementation is only recommended in children and adolescents at risk of deficiency (e.g., dark skin or overweight) [18]. However, a recent Swiss study showed that up to 6.5 hours of sun exposure might be needed in winter and autumn for skin phototype II and III individuals to produce enough vitamin D [19]. Overall, these data suggest that low or deficient vitamin D status may be common in Swiss youth, as suggested by the latest adult study [9], which showed 75% insufficiency prevalence. The objective of this pilot study was to assess intakes, including major dietary sources, and status of vitamin D in a group of healthy adolescents in the French-speaking part of Switzerland.

Materials and methods

Study design and dataset

We used data from a cross-sectional feasibility study that aimed to prepare the next national Swiss nutrition survey in children and adolescents [20,21]. The feasibility study was conducted in a convenience sample of healthy children and adolescents aged 3–18 years living in the region of Lausanne, Switzerland. Individuals who were hospitalized, pregnant, had severe chronic diseases were not eligible for the study. Sufficient French language skills were also required to complete the study. A first face-to-face appointment was organized with participants (and their caregivers (parents), depending on age) to assess their dietary intakes and collect several bio-samples. A phone appointment took place 2–6 weeks later to assess dietary intakes a second time. All appointments were conducted between April and November 2017. Among the 53 study participants, 29 were aged between 11 and 18 years and included in our study. The feasibility study was described in detail in a previous work [20,21].

Demographic and anthropometric variables

Sex, date of birth, country of birth as well as education of both caregivers were assessed by questionnaire. The participants were weighted in light clothing to the nearest 0.1 kg with a calibrated scale (Seca 701 scale) and measured with a Seca 213 gauge to the nearest 0.1 cm, following the guidelines of the World Health Organization (WHO) [22]. Body mass index (BMI) was calculated and classified according to WHO standards [23]: ≤-2 Standard Deviation (SD) (thinness), >-2SD to <+1SD (normal weight), +1SD to <+2SD (overweight), ≥+2SD (obesity).

Dietary intake assessment

Two non-consecutive 24-hour recalls, one face-to-face and one by phone, were carried out by two registered dietitians to assess food consumption using the computer-directed interview program Globodiet® [24,25]. To support participants and/or caregivers in quantifying consumed amounts, dietitians used a set of actual household measures and a book with >100 series of graduated portion-size pictures [26]. As the GloboDiet software does not report the micronutrient content of consumed foods, nutritional values were added manually using the Swiss Food Composition Database [27]. Vitamin D, calcium, and phosphorus were reported for the major dietary contributors of these three nutrients: i.e., a) for vitamin D: fish and shellfish, fats and oils, milk and dairy products, eggs and egg products, and meat and meat products, b) for calcium: milk and dairy products, vegetables, sugar-free and alcohol-free drinks, grains, legumes, seeds and nuts, c) for phosphorus: milk and dairy products, meat and meat products, grains, vegetables, fish and shellfish, legumes, seeds and nuts, eggs and egg products and sugar-free and alcohol-free drinks. These food groups were selected according to the sixth Swiss nutrition report [14], which determined that these major contributors account for 95% of the total estimated intake of each nutrient in the Swiss population.

The 24-hour recalls were complemented by a food propensity questionnaire (FPQ), following the recommendations of the European Food Safety Authority (EFSA) [28]. It included notably questions on the usual consumption frequency of fish, shellfish and dairy products. The consumption of dietary supplements was also assessed in a questionnaire. Participants and caregivers were asked the name (brand) and consumption frequency of the taken supplement(s). Both questionnaires were completed before the first appointment at home with caregivers.

Recommended micronutrient intake

Vitamin D, calcium and phosphorus intakes were compared to the Dietary Recommended Intake (DRI) of the EFSA for age- and sex-specific groups. The DRI for vitamin D is 15 ug/day for adolescents aged 11–18 years [29]. For 11-17-year-olds, the DRI is 1150 mg/day for calcium and 640 mg/day for phosphorus [30,31]. From the age of 18, the DRI are 1000 mg/day for calcium and 550 mg/day for phosphorous [30,31].

Assessment of vitamin D status

Plasma venous blood samples were collected at the first appointment by a registered nurse while participants were fasting. Blood samples were stored at -80°C in a registered biobank prior to analysis. The 25(OH)D level of participants was analyzed by high-performance liquid chromatography coupled with ultraviolet-visible spectroscopy [32]. It was classified according to the cut-offs proposed by the

European Society for Paediatric Gastroenterology Hepatology and Nutrition: >50 nmol/L (sufficient status), 50-25 nmol/L (insufficient status), and <25 nmol/L (deficiency) [33].

Data analyses

Descriptive statistics, including proportions, were used to show the characteristics of the population, the main dietary sources of each nutrient and the responses to the FPQ. Nutrient intakes were described using medians and interquartile ranges (IQR) due to their non-normal distribution. As expected, energy intake differed between boys and girls, and age groups (11–14 and 15–18 years old), therefore nutritional intake was stratified for these variables. Nutrient intakes in vitamin D, calcium and phosphorus were compared to the DRI to estimate adherence to recommendations. The Wilcoxon-Mann-Whitney test was used to test the differences in 25(OH)D level according to sex, parental education level and age group. It was also used to test the difference in Vitamin D intake according to vitamin D status. Association between vitamin D level and vitamin D intake was tested by Spearman's rank correlation. Fisher's Exact Test was used to test the associations between characteristics of participants and their vitamin D status (insufficient/sufficient), and between characteristics of participants and their adherence to DRI (10% of the DRI or < 10%). All statistical analyses were performed using Stata 16.0 software (StataCorp, College Station, TX, USA).

Ethical considerations

The study was approved by the Human Research Ethics Commission of the Canton of Vaud, Switzerland, in February 2017 (Project ID: Nutrition Survey 2016–02170). Written informed consent was obtained from all participants and one of their caregivers before data collection.

Results

Characteristics of participants

A total of 29 adolescents, i.e., 15 boys and 14 girls, aged 11–18 years were included in the study. The characteristics of adolescents are presented in Table 1. The majority of participants (79%) had a BMI within the normal range,17% were overweight and one adolescent was thin. None of them were obese. All participants were born in Switzerland.

Nutritional intakes and adherence to DRI

Table 2 shows the nutrient intake of the participants. Median [P25–P75] intake of vitamin D was 1.2 μg/day in adolescents aged 11–14 years and 0.8 μg/day in the group 15–18 years old, respectively (Table 2). None of the participants met the DRI of 15 μg/day from the EFSA [29]. In adolescents aged 11–14 years, the median intake of calcium and phosphorus was 677 mg/day and 1020 mg/day, respectively. In the group aged 15–18 years, the intakes were 592 mg/day of calcium and 943 mg/day of phosphorus. Only 2 participants (6.9%) met the DRI for calcium but 26 (89.7%) met the DRI for phosphorus. Median intake of vitamin D was 1.1 μg/day in boys and 0.8 μg/day in girls. DRI for calcium was achieved by 13.3% of boys but not by any girl. For phosphorus, 93.3% of boys and 85.7% of girls achieved the DRI. Figs. 1 and 2 shows the percentage of DRI achieved by sex. In addition, three (10.3%) participants took supplements containing between 5 and 6.3 μg of vitamin D. Supplementary file 1 (Table S1) shows the adherence to DRI (intake ≥ 10% of the DRI or < 10%) according to the characteristics of participants. Age groups and consumption of milk were statistically associated with adherence to DRI.

Main dietary sources of nutrients

The main dietary sources of vitamin D, calcium and phosphorus are presented in Fig. 3. Fish and shellfish (35.2%) as well as dairy products and their substitutes (32.3%) provided two-thirds of vitamin D intake. Calcium and phosphorus came mainly from dairy products and their substitutes (76.9% for

Table 1
Characteristics of the participants (N=29)

Participants' characteristics	All (n=29)
Sex (%)	
Boys	51.7
Girls	48.3
Age group (%)	
11–14 years	48.3
15–18 years	51.7
BMI category (23) (%)	
Thinness	3.4
Normal body weight	79.3
Overweight	17.3
Obesity	0.0
Parental education level[a] (%)	
Compulsory school	0.0
Upper secondary[b]	27.6
Tertiary[c]	72.4

[a] Highest level of education obtained by one of the two parents.
[b] Include baccalaureate schools, upper secondary specialized schools and apprenticeships.
[c] Include universities, federal institutes of technology and colleges of higher education (teacher education and of applied sciences).

calcium and 39.1% for phosphorus). Starchy foods (25.5%) as well as meats and their substitutes (25.4%) also provided half of the phosphorus intake. In addition, the FPQ showed that only 25% of adolescents consumed some fish or shellfish 1 to 3 times per week.

Vitamin D levels and status

Vitamin D status data were available for 24 adolescents because 5 (17.2%) participants refused blood sampling. Most samples were collected in summer (n=10) and fall (n=9). Median 25(OH)D level was 56.9 nmol/L [48.3–69.8]. Two-thirds of participants (n=16) had sufficient vitamin D status (>50 nmol/L) and one-third (n=8) had insufficient one (25–50 nmol/L). None had a deficiency. Fig. 4 shows vitamin D status and intakes according to the date of the blood sampling. Median level of 25(OH)D did not differ significantly according to sex (P=0.98), age group (P=0.90), or parental education (P=0.77). Furthermore, level of 25(OH)D was not associated with median vitamin D intake (-0.38, P=0.07).

Comparison of participants by vitamin D status

Differences between participants with sufficient and insufficient vitamin D status were explored and are presented in Table 3 (P-values > 0.05 for all tests). More than half (n=9) of the participants with sufficient vitamin D status were tested in summer. Only one participant tested in summer had insufficient vitamin D status. Median vitamin D dietary intake was similar in the group with sufficient vitamin D status than in the insufficient group (P=0.22). There were fewer participants taking a supplement containing vitamin D in the sufficient group. All adolescents reported consumption of cheese and other dairy products, except one participant in the sufficient group. More participants reported consuming fish or shellfish 1–3 times per month in the sufficient group (n=9) than in the insufficient group (n=3).

Discussion

This study aimed to assess intakes, status, and major dietary sources of vitamin D in a convenience sample of adolescents in the French-speaking part of Switzerland. The median [P25–P75] vitamin D intake was 0.9 [0.6–1.5] μg/day, which was less than 10% of the intake recommended by the EFSA (15 μg/day). Fish/shellfish, dairy products and their substitutes provided nearly 70% of the vitamin D

Table 2
Nutritional intake and adherence to recommendations[a]

	All (n=29)	11–14 years (n=14)	15–18 years (n=15)	Boys (n=15)	Girls (n=14)
Nutritional intake					
Energy intake (kcal/d)	1908 [1739–2230]	1940 [1892–2108]	1851 [1478–3244]	1982 [1877–2777]	1826 [1478–2009]
Vitamin D intake (ug/d)	0.9 [0.6–1.5]	1.2 [0.7–1.9]	0.8 [0.6–1.1]	1.1 [0.6–2.6]	0.8 [0.7–1.1]
Calcium intake (mg/d)	645 [507–769]	677 [518–845]	592 [345–758]	708 [547–859]	574 [360–758]
Phosphorus intake (mg/d)	946 [710–1362]	1020 [780–1379]	943 [652–1362]	1269 [788–1669]	818 [652–946]
Participants reaching the recommended intake (%)					
Vitamin D (15 μg/d)	0	0	0	0	0
Calcium (1000/1150 mg/d)	6.9	7.1	6.7	13.3	
Phosphorus (550/640 mg/d)	89.7	92.9	86.7	93.3	85.7

[a] Energy and micronutrient intakes are presented with median and IQR.

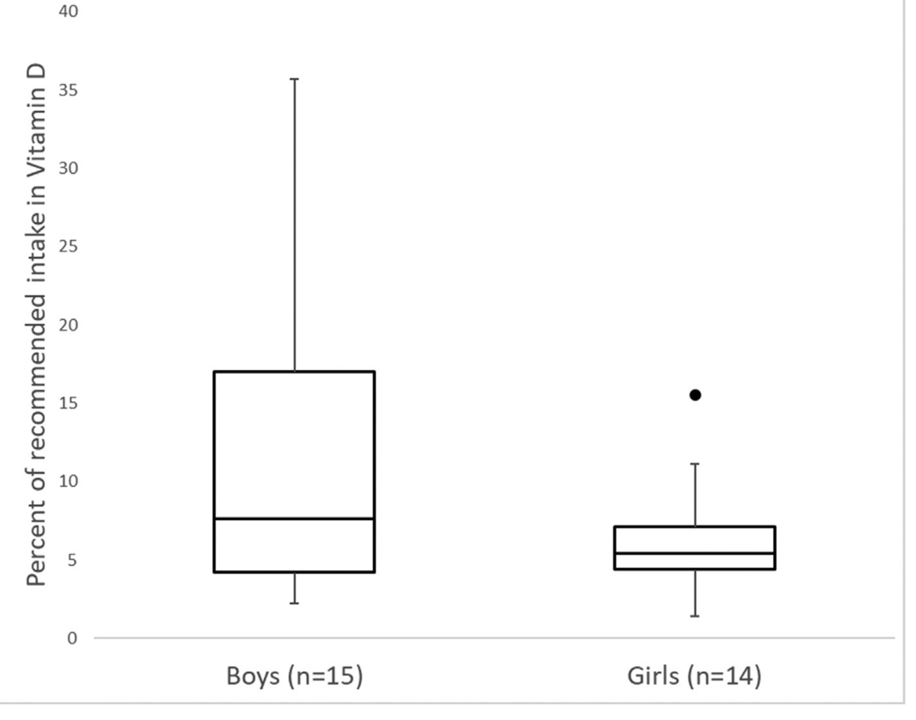

Fig. 1. Percentage of recommended vitamin D intake achieved by sex. Legend: Median, IQR and outliers.

consumed. No participants had a vitamin D deficiency and one third were considered as insufficient. In summer, 90% of the participants tested had sufficient status.

The low vitamin D intakes observed in this study are consistent with a previous study conducted in Switzerland [13] and with international food surveys [6]. In 2004, Ginty *et al.* reported intakes of 1.5–3 μg/d among Swiss adolescents [13]. The intakes were 3–3.1 μg/d in the 10-17-year-olds from the 2015 Belgian national survey [34] and 2.6 μg/d in the French INCA3 study (11–17years old) [35]. These data show that the intake of 15 μg/d recommended by EFSA is difficult to achieve. Indeed, this recommended amount of vitamin D would be provided by 180 grams of salmon, 260 grams of tuna or 10 eggs

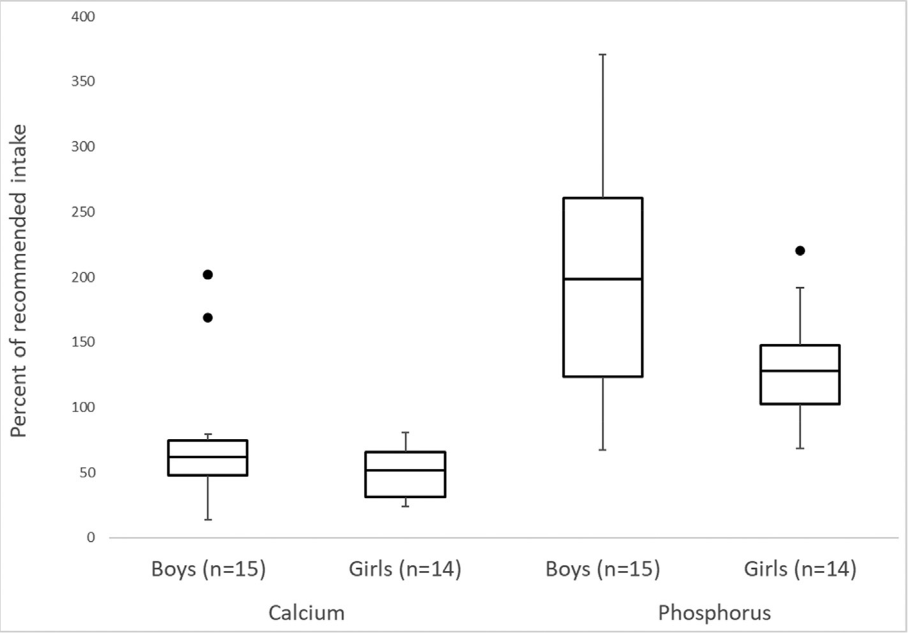

Fig. 2. Percentage of recommended calcium and phosphorus intake achieved by sex. Legend: Median, IQR and outliers.

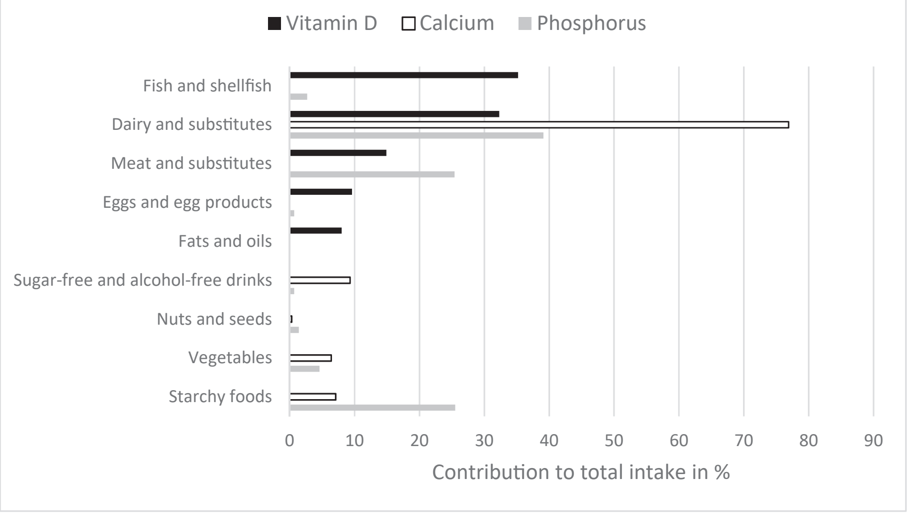

Fig. 3. Main dietary sources of vitamin D, calcium and phosphorus.

per day. However, actual vitamin D intake in the present study was slightly underestimated because only the main dietary sources were considered. For instance, in the Belgian study, pastries, confectionery and condiments, which were not considered here, represented 13.7% of the total intake [34].

Regarding the main dietary sources of vitamin D, dairy products followed by the meat-fish-egg group were the main contributors, similar to the INCA3 French study [35]. In the Belgian survey,

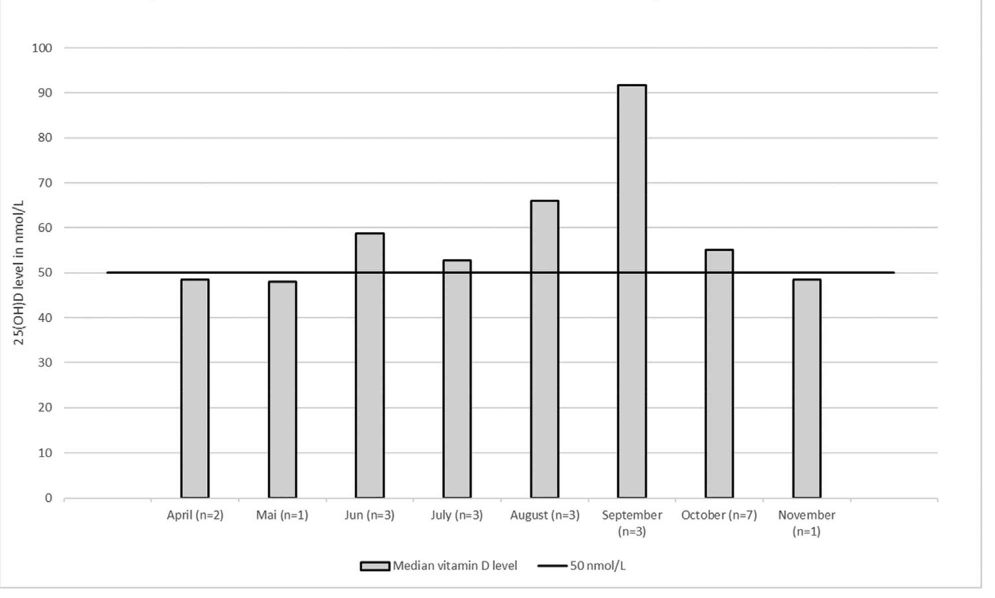

Fig. 4. Vitamin D status according to the month of the vitamin D testing. Footnote: One of the participants tested in July had an abnormally high level of 25(OH)D (518 nmol/L) and was excluded from Fig. 4 for better visibility.

Table 3
Characteristics of participants by vitamin D status

Characteristics (%)	All (n=24)	Sufficient status (n=16)	Insufficient status (n=8)
Sex			
Boys	58.3	62.5	50
Girls	41.7	37.5	50
Age-group			
11-14	50	50	50
15-18	50	50	50
Season of the blood sample			
Spring	20.8	12.4	37.5
Summer	41.7	56.4	12.5
Fall	37.5	31.3	50.0
Winter	0	0	0
Vitamin D intake (μg/d) (excluding supplements)	0.9 [0.6–1.5]	0.8 [0.6–1.2]	1.2 [0.8–2.1]
Participant taking a supplement containing vitamin D	12.5	6.3	25.0
Usual consumption of milk			
≥1 glasses a day	62.5	73.3	50.0
<1 glass a day	37.5	26.7	50.0
Usual consumption of cheese			
Yes	95.8	93.8	100.0
No	4.2	6.2	0.0
Usual consumption of other dairy products			
Yes	95.8	93.8	100.0
No	4.2	6.2	0.0
Usual consumption of portion[a] of fish or shellfish			
≥1 time a week	25.0	25.0	25.0
<1 time a week	75.0	75	75

[a] One portion size correspond to ¼ of the plate.

meat and meat substitutes were the main dietary sources of vitamin D while fish and shellfish only contributed to 4.9–7% of the intake [34]. By comparison, in our study fish and shellfish contributed to 35.2% of the intake. This could be due to a difference in the type of fish and meat (fat content) consumed in these two countries.

In this study, we observed that one third of adolescents had an insufficient vitamin D status, especially in those tested in spring and fall, and none suffered from deficiency. The previous Swiss study, where participants were tested during winter, reported a deficiency (25(OH)D < 30nmol/L) in 15–17% of the participants [13]. Another study conducted among Swiss males late adolescent also reported seasonality as the most significant factor associated with vitamin D level and 40% of them had insufficient status [12]. In 2014, a study conducted in Pisa (Italy) reported insufficient status in 57% (April–June) and 34% (July–September) of adolescents and young adults aged 10–21 years [36]. For the same periods of the year (April–June and July–September), a UK study reported deficiency status in 12–13% of adolescents aged 11–18 years [37]. Of note, the Italian and British studies used the same definition for deficiency and insufficiency as ours (25(OH)D < 25nmol/L and 25(OH)D < 50nmol/L). This is why many scientific societies recommend systematic vitamin D supplementation and/or the use of vitamin D food fortification [11,15,16]. On the other hand, some societies consider that vitamin D supplementation should only be considered in case of insufficient status [17], or is not justified in the general pediatric population [38]. In the absence of a consensus, regarding vitamin D supplementation (with the exception of newborns), pediatricians and dieticians should consider its usefulness for each patient on an individual basis.

This study has some limitations. Due to the small sample size from a specific geographical region of Switzerland, these results cannot be generalized at the national or even cantonal levels. The absence of participants suffering from obesity and the overrepresentation of adolescents with highly educated parents informs about the lack of representativeness of our sample. Moreover, no adolescent was recruited during the winter period. In terms of vitamin D intake, some food groups, such as pastries, were not considered in this study. Although these food groups provide little vitamin D [34], the vitamin D intake may have been slightly underestimated. Despite these limitations, this is the first study to report the main dietary sources of vitamin D, calcium and phosphorus in the Swiss pediatric population, and to provide recent data on vitamin D intake and status in adolescents. The dietary history included two 24-hour recalls using the GloboDiet® software in addition to a dietary propensity questionnaire, as recommended by EFSA. In the future, longitudinal studies are needed and should include children of all ages, take into account vitamin D supplementation and cover the three linguistics regions of Switzerland, different geographic areas, and take place over at least one full year.

Conclusion

Vitamin D intake in a small convenience sample of Swiss adolescents, aged 11–18 years, was low in comparison with the recommendation and was mainly provided by fish/shellfish and dairy products. A sufficient vitamin D level during the summer period seems attainable for almost all adolescents, but becomes more difficult to achieve from fall to spring. These results raise the question of the necessity of large-scale vitamin D supplementation in this age group. Further studies are needed and should include children of all ages at national level during a full year to cover all seasons.

Author contributions

N. Parel participated in study design, define micronutrient values in consumed foods, analyzed and interpreted the data, and wrote the first draft of the manuscript. M. Bochud designed the feasibility study, participated in data interpretation and revised the manuscript. S. Rezzi's laboratory analyzed blood samples and he revised the manuscript. A. Chatelan designed the feasibility study, recruited the participants, collected field data. She also participated in this study design, data interpretation, and revised the first draft of the manuscript. C. Jotterand Chaparro participated in study design, data interpretation, and revised the first draft of the manuscript.

Data availablity

Raw data were generated at Unisanté, University of Lausanne, in the context of the pilot study. Derived data supporting the findings of this study are available from the corresponding author [C.J.C] upon reasonable request.

Funding sources

The feasibility study was fully funded by Federal Food Safety and Veterinary Office of Switzerland.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Acknowledgements

We would like to thank the Federal Food Safety and Veterinary Office and Unisanté for sharing data of the feasibility study. This article is based on the results of a Master thesis conducted within the joint Master of Science (MSc) in Health Sciences of HES-SO (University of Applied Sciences and Arts Western Switzerland) and University of Lausanne (UNIL), major in Nutrition and dietetics, at HES-SO Master.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.nutos.2022.05.002.

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