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Vitamin D deficiency is common and is associated with overweight in Mexican children aged 1–11 years

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Abstract
Objective: To assess vitamin D dietary sources, intake and 25-hydroxyvitamin D status and their association with individual and sociodemographic characteristics in Mexican children.
Design: Data obtained from 2695 children aged 1–11 years from the Mexican National Health and Nutrition Survey (2012) were analysed. Diet was assessed by a 141-item FFQ. 25-Hydroxyvitamin D was measured by a chemiluminescent assay.
Results: Mean vitamin D intake was 3·38 (SE 0·09) μg/d (135·2 (SE 3·6) IU/d) among pre-school children and 2·85 (SE 0·06) μg/d (114·0 (SE 2·4) IU/d) in school-age children. Milk accounted for 64·4 % of vitamin D intake in pre-school children and 54·7 % in school-age children. Vitamin D deficiency (serum 25-hydroxyvitamin D < 50 nmol/l) was 25·9 % in pre-schoolers and 36·6 % in school-age children. Overweight/obese school-age children had a higher risk of vitamin D deficiency compared with normal-weight children (OR = 2·23; 95 % CI 1·36, 3·66; $P < 0·05$).
Conclusions: Vitamin D intakes are low in Mexican children, and milk is the main source of the vitamin. Vitamin D deficiency is common and associated with overweight in school-age children.

Keywords
Vitamin D
Nutritional deficiencies
Dairy
Children
Mexico

Vitamin D is a prohormone that is essential for Ca absorption and vital for bone development during infancy and childhood. Low serum concentrations of the intermediary metabolite of vitamin D and the main indicator of vitamin D nutritional status, 25-hydroxyvitamin D, lead to the release of parathyroid hormone, causing Ca mobilization from bone[1,2]. Vitamin D deficiency can cause rickets in children. This is especially negative during the stage in which growth is accelerated[1,2]. In addition to its functions in bone metabolism, it has recently been reported that vitamin D may help to reduce the risk of autoimmune diseases, respiratory tract infections, type 1 diabetes and wheezing in childhood[3–5].

The main source of vitamin D is the cutaneous synthesis from 7-dehydrocholesterol in response to sunlight UVB radiation[6]. Diet represents a relatively minor source of this prohormone because it is found naturally in only a few foods. Its main dietary sources are milk and dairy, oily fish, and other foods fortified with this vitamin[2,3].

Studies worldwide have shown inadequate vitamin D status for populations of both developed and developing countries[7–11]. It is estimated that 1 billion people worldwide have vitamin D deficiency[7]. According to data from the National Health and Nutrition Examination Survey (NHANES) 2003–2006, 10·3 % of children aged 6–18 years in the USA had serum 25-hydroxyvitamin D levels <40 nmol/l (<16 ng/ml)[9]. In the same population, another study showed a prevalence of vitamin D deficiency (serum 25-hydroxyvitamin D < 50 nmol/l (<20 ng/ml)) of 21, 29, 34 and 49 % among healthy weight, overweight, obese and severely obese children, respectively[10].

A study based on data from the Mexican National Health and Nutrition Survey (2006) reported that 24 % of pre-school children were vitamin D-deficient (25-hydroxyvitamin D < 50 nmol/l) and 30 % of these children showed insufficiency (25-hydroxyvitamin D between 50 and 74·9 nmol/l)[11].

The aim of the present study was to assess dietary sources and intake of vitamin D and 25-hydroxyvitamin D status and their association with individual and sociodemographic characteristics in a representative sample of Mexican children aged 1–11 years.

Methods

Study population and source of information

The current cross-sectional study corresponds to a secondary analysis of the Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012). Information from

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1- to 11-year-old Mexican children was used. This specific age group is of particular interest according to national health priorities and therefore funds were obtained for determination of serum 25-hydroxyvitamin D in this population.

ENSANUT-2012 used a stratified, multistage probability sampling design and constructed sample weights to obtain nationally representative data. Each individual was assigned a sample weight inversely proportional to his/her probability of selection, representing a number of many individuals from the same age/gender/sociodemographic group.

ENSANUT-2012 collected information from 50 528 Mexican households through the implementation of 96 031 individual questionnaires according to different age groups[12].

Procedures

Food consumption

Dietary data were collected using a semi-quantitative FFQ in a sub-sample of the total population of the ENSANUT-2012 (approximately one-sixth of the participants according to the population group). The questionnaire for children aged 1–11 years was applied to their parent or caregiver[13]. The FFQ obtained information about foods and beverages classified into fourteen groups. The questions allowed obtaining information about portions, sizes and number of daily servings for each food during the 7 d preceding the interview[13].

A total of 8195 pre-school and school-age children were evaluated by ENSANUT-2012; this sample is representative of 8 327 400 children. From this sample, 6827 children had blood samples to evaluate 25-hydroxyvitamin D status. Additionally, a random sample of 1325 pre-school and 1370 school-age children had complete information on dietary intake, anthropometric measures and 25-hydroxyvitamin D determinations. After excluding implausible data, we analysed diet, anthropometry and serum 25-hydroxyvitamin D concentrations from a total sample of 698 pre-school and 956 school-age children.

Anthropometry

Weight, height and length measurements were done by trained personnel using Lohman and Martorell techniques[14] and standardized according to the methodology proposed by Habicht[15]. In children <2 years of age, supine position length was measured using a Seca® infantometer with an accuracy of 1 mm. For weight measurement, a Tanita® scale with an accuracy of 100 g was used, which was calibrated daily. Height was measured using a Dynatop® stadiometer with an accuracy of 1 mm.

Overweight and obesity

BMI was calculated by dividing weight in kilograms by the square of height in metres. BMI *Z*-score was used according to standards set by the WHO[16]. Children <5 years of age were classified as underweight when their *Z*-score was below −2, scores from −2 to +2 were classified as normal, and scores of more than +2 as overweight. Children aged 5–11 years were classified as low weight when their *Z*-score was below −2, normal when their *Z*-score was −2 to +1, and overweight when their *Z*-score was more than +1 to +2. Those children with *Z*-scores above +2 were classified as obese[16]. Underweight children (pre-schoolers, *n* 13; school age, *n* 22) were excluded due to the very low numbers in this category.

Socio-economic and demographic data

A household questionnaire was applied. Among the aspects collected were demographic (gender, age, ethnicity), economic (characteristics of households, property and household appliances) and social data (area of residence and region).

Blood samples

After an 8 h fast, a 15 ml blood sample was obtained from the antecubital vein. The sample was centrifuged and separated into individual aliquots, which were transported in nitrogen tanks to the laboratory of the National Institute of Public Health (Instituto Nacional de Salud Pública (INSP); Cuernavaca, Mexico). Samples were stored at −70°C until thawed for analysis.

Laboratory methods

Serum 25-hydroxyvitamin D was measured with an Abbott Architect® chemiluminescent microparticle immunoassay. Intra- and inter-assay CV were <10 %. This method has shown a high reactivity (~100 %) with 25-hydroxycholecalciferol (25-hydroxyvitamin D_3) and an acceptable performance compared with LC/MS/MS ($r = 0{\cdot}73$)[17]. Quality control of measurements in ENSANUT-2012 was performed using the Reference Standard Serum NIST 968E of the National Institute of Standards and Technology, for which it has been established that concentrations of 25-hydroxycholecalciferol are valid using the NIST reference method LCID MS/MS, which is approved by the Joint Committee for Traceability in Laboratory Medicine as a higher-order reference measurement procedure. The accuracy results for this control material were as follows. NIST 968E L1: mean 7·1 (SD 0·2) ng/ml, CV = 2·2 % (reference value: 7·1 (SD 0·1) ng/ml); NIST 968E L3: mean 19·9 (SD 1·4) ng/ml, CV % = 6·9 % (reference value: 19·9 (SD 0·4) ng/ml). Also, during the analysis of samples, three quality controls available from Abbott (Batch 03912A000) were used with the following results. LOW LEVEL: mean 19·5 (SD 1·5) ng/ml, CV = 7·6 % (reference value: 20 (SD 7) ng/ml); INTERMEDIATE LEVEL: mean 39·5 (SD 2·3) ng/ml, CV = 5·9 % (reference value: 40 (SD 14) ng/ml); HIGH LEVEL: mean 75·6 (SD 3·3) ng/ml, CV = 4·4 % (reference value: 75 (SD 26) ng/ml).

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Variables

Dietary sources

Dietary sources of vitamin D were identified according to the food composition table compiled and updated by the INSP[18]. Vitamin D content is presented per 100 g or 100 ml of food. Procedures for calculating daily energy and nutrient intakes have been previously described[13]. We identified the foods with the highest contribution to vitamin D intake in Mexican children. In accordance with Institute of Medicine recommendations, a vitamin D intake of ≥10 μg/d (≥400 IU/d) was considered adequate[2].

Vitamin D status

Serum 25-hydroxyvitamin D concentrations were used to evaluate vitamin D status. Vitamin D deficiency was defined as serum 25-hydroxyvitamin D < 50 nmol/l (<20 ng/ml)[1,19,20].

Socio-economic region

For sampling and analytical purposes of ENSANUT-2012, the regions in the country were divided as follows: North (Baja California, Baja California Sur, Coahuila, Chihuahua, Durango, Nuevo Leon, Sonora, Tamaulipas), Mexico City (Federal District), Central (Aguascalientes, Colima, Mexico, Guanajuato, Jalisco, Michoacán, Morelos, Nayarit, Querétaro, San Luis Potosí, Sinaloa, Zacatecas) and South (Campeche, Chiapas, Guerrero, Hidalgo, Oaxaca, Puebla, Quintana Roo, Tabasco, Tlaxcala, Veracruz, Yucatán)[21].

Urban and rural areas

Urban localities were defined as those with a population of ≥2500 inhabitants; rural localities were defined as those areas with <2500 inhabitants[21].

Socio-economic status

A socio-economic status index was constructed using principal component analysis on housing characteristics and availability of household goods. The first component explained 40·5 % of the total variability with a λ value of 3·24 and was selected as the index, which was later divided in tertiles (low, medium and high socio-economic status).

Ethnicity

The mother or caregiver was asked if the child spoke an indigenous language. If the answer was 'yes', the child was considered as 'indigenous'[21] (only for children aged 3 years or above).

Statistical analysis

We carried out a descriptive analysis presented as means and their standard errors for continuous variables and simple tabulations for categorical variables. Multivariate logistic regression models were used to evaluate the association between vitamin D deficiency and individual and sociodemographic characteristics. An expansion factor was applied to all statistical calculations to maintain representativeness, according to the survey's complex design. The SVY module in the Stata statistical software package version 12.0 was used to adjust for the complex survey design. A significance level of 0·05 was used in all analyses.

Ethical considerations

The ENSANUT-2012 was approved by the INSP Committees on Ethics and Biosafety and by the Research Committee of INSP. Children's assent was obtained for children aged 6 years or older. Informed consent of parents or guardians was also obtained for participation in the study[12].

Results

All results are presented stratified for pre-school (1–4 years) and school-age (5–11 years) children. Data from 1325 children aged 1–4 years and 1370 children aged 5–11 years who participated in ENSANUT-2012 and had complete information on dietary intake and anthropometric measures were analysed, representing 8·7 million pre-school children and 15·8 million school-age children, respectively, in accordance with the sample weights used. The proportions of pre-schoolers and school-age children that formed the study sample and gender distribution in both groups are shown in Table 1. In relation to nutritional status, we observed that 91 % of pre-school children had a normal BMI, whereas the remaining 9 % were overweight. Among school-age children, 65 % had a normal BMI, whereas the prevalence of overweight and obesity was 20 and 15 %, respectively.

Percentage contribution to vitamin D intake by food group is shown in Table 2. Dairy, milk, and milk-based beverages and desserts accounted for 90 % of vitamin D intake among pre-school children and 85 % among school-age children. Fish, meat, eggs and other animal-origin products contributed ≈20 % to total vitamin D intake in school-age children.

Children aged 1–4 years had a vitamin D intake of 3·38 μg/d (135·2 IU/d), while mean vitamin D intake was 2·85 μg/d (114·0 IU/d) in school-age children (Table 3). For both age groups, intakes were higher among overweight/obese children compared with normal-weight children. Vitamin D intakes were higher among urban compared with rural children and for children who lived in Mexico City compared with children from other regions. Vitamin D intake was positively associated with socio-economic status and the lowest intakes were observed among indigenous children. Only 1·5 % of pre-schoolers and 2·3 % of school-age children consumed a supplement containing vitamin D.

Vitamin D status is presented for 698 pre-school children who had dietary information, representing 2·7 million pre-school children nationwide, and 956 school-age

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Table 1 General characteristics of Mexican children aged 1–11 years, Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012)

	Pre-school children (1–4 years)				School-age children (5–11 years)			
Variable	Sub-category or value	*n*	*n* expanded (thousands)	% expanded	Sub-category or value	*n*	*n* expanded (thousands)	% expanded
Age (years)	1–4	1325	8744§	100·0	5–11	1370	15 838§	100·0
Mean	3·0				8·7			
SE	0·0				0·1			
95 % CI	2·9, 3·1				8·5, 8·8			
	1–2	656	4286	49·0	5–8	608	8746	55·0
	3–4	669	4458	51·0	9–11	762	7091	45·0
Sex								
Male		620	4432	51·0		716	8060	51·0
Female		705	4311	49·0		654	7777	49·0
BMI†	*n* 1241		8089		*n* 1300		14 952	
	Normal	1123	7387	91·3	Normal	827	9648	64·5
	Overweight	118	701	8·7	Overweight	259	3069	20·5
					Obesity	214	2234	14·9
Area								
Rural		525	2619	30·0		500	4658	29·4
Urban		800	6124	70·0		870	11 179	70·6
Region								
North		260	1721	19·7		290	3019	19·1
Central		468	2766	31·6		478	4923	31·1
Mexico City		74	1370	15·7		112	2555	16·1
South		523	2885	33·0		490	5339	33·7
Ethnicity‡	*n* 633		4252		*n* 966		10 844	
Indigenous		42	199	4·7		63	693	6·4
Non-indigenous		591	4052	95·3		903	10 151	93·6
Socio-economic status								
Low		568	3333	38·1		517	5287	33·4
Medium		420	2694	30·8		468	5185	32·7
High		337	2716	31·1		385	5365	33·9

†Cut-off points of BMI *Z*-score according to WHO.
‡Information on ethnicity is available for families with children >3 years old.
§According to Census data (2010) and population projections, the total Mexican population aged 1–4 years was 8·9 million and aged 5–11 years was 15·8 million, in 2012[27].

Table 2 Dietary sources, mean intake and percentage contribution to vitamin D intake in Mexican children aged 1–11 years, Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012)

	Pre-school children (1–4 years)†			School-age children (5–11 years)‡		
	Intake (IU/d)§			Intake (IU/d)§		
Food group	Mean	SE	% contribution‖	Mean	SE	% contribution‖
Milk	110·9	3·1	64·4	80·9	2·5	54·7
Dairy, cheese, yoghurt	19·4	1·0	13·4	15·9	1·1	10·4
Milk-based beverages (*atoles*)	8·0	0·7	6·6	17·3	1·7	14·0
Milk-based desserts: flan, Jell-O, pie, ice cream, cake	7·1	0·4	6·0	6·6	0·4	6·0
Chicken, meat and eggs	17·5	0·6	19·4	20·1	0·6	22·0
Fish, tuna and sardine	9·7	0·8	8·8	14·7	1·1	14·3
Ready-to eat cereals, corn, rice, doughnuts, cookies, sweets, cupcakes	12·8	1·0	8·1	17·3	0·9	12·3
Mexican *antojitos*, sandwiches, hamburgers, hot dogs	2·5	0·1	2·1	4·8	0·2	5·1
Cream, mayonnaise, margarine, butter, lard	2·3	0·2	2·0	2·7	0·1	2·6
Other (fried beans, vegetables)	0·8	0·2	1·0	0·8	0·9	1·2

†*n* 1235; *n* expanded 8 744 340.
‡*n* 1370; *n* expanded 15 838 145.
§To convert to μg/d, divide IU/d value by 40.
‖Percentage contributions not necessarily add to 100 %, given that they refer to groups' averages.

children, representing 4·6 million nationwide (Table 4). Mean serum 25-hydroxyvitamin D among pre-schoolers was 60·3 (95 % CI 57·8, 62·7) nmol/l and 56·6 (95 % CI 55·2, 58·0) nmol/l in school-age children. Vitamin D deficiency was observed in 25·9 % of pre-schoolers and 36·6 % of school-age children. Higher prevalence of vitamin D deficiency was observed among older children (9–11 years), school-age girls and overweight/obese school-age children. Among

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Table 3 Vitamin D intake according to general characteristics of Mexican children aged 1–11 years, Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012)

	Pre-school children (1–4 years)†				School-age children (5–11 years)‡		
	Intake (IU/d)§				Intake (IU/d)§		
Variable	Mean	SE	95 % CI		Mean	SE	95 % CI
Total	135·2	3·6	128·5, 141·8		114·0	2·4	108·9, 118·9
Age (years)							
1–2	130·8	4·8	121·3, 140·2	5–8	120·2[b]	3·8	112·6, 127·7
3–4	139·4	4·7	130·2, 148·7	9–11	106·1[a]	3·1	100·0, 112·2
Sex							
Male	136·3	5·0	126·4, 146·2		112·9	3·5	106·0, 119·8
Female	134·0	4·2	126·0, 142·2		114·9	3·9	107·3, 122·5
BMI							
n 1241				*n* 1300			
Normal	133·1[b]	3·8	125·5, 140·6	Normal	110·4[b]	3·3	104·0, 116·8
Overweight	159·9[a]	7·3	145·6, 174·2	Overweight/obesity	119·1[a]	4·1	111·1, 127·1
Area							
Urban	145·6[b]	4·3	137·2, 154·0		125·0[b]	3·2	118·8, 131·2
Rural	110·9[a]	4·9	101·2, 120·5		87·2[a]	3·9	79·4, 95·0
Region							
North	154·4[d]	6·0	142·7, 166·2		129·1[c,d]	5·8	117·7, 140·4
Central	138·4[d]	5·6	127·4, 149·5		117·5[c,d]	4·3	109·1, 126·0
Mexico City	156·6[d]	13·2	130·7, 182·5		148·0[a,b,d]	6·4	135·1, 160·3
South	110·4[a,b]	4·8	101·0, 119·8		85·7[a,b,c]	4·2	77·6, 93·9
Ethnicity							
n 633							
Indigenous	40·9[b]	5·8	29·4, 52·4		45·0[b]	4·6	36·0, 54·0
Non-indigenous	145·1[a]	5·0	135·3, 155·0		117·8[a]	2·6	112·7, 123·0
Socio-economic status							
Low	110·9[b,c]	4·7	101·6, 120·2		82·2[b,c]	4·0	74·4, 90·0
Medium	138·5[a,c]	5·9	127·0, 150·0		116·1[a,c]	4·1	108·0, 124·2
High	161·7[a,b]	6·9	148·2, 175·2		143·0[a]	4·3	134·4, 151·5

[a,b,c,d]Mean values within a column with unlike superscript letters were significantly different ($P < 0·05$).
†*n* 1325; *n* expanded 8 744 340
‡*n* 1370; *n* expanded 15 838 145.
§To convert to μg/d, divide IU/d value by 40.

school-age children, a higher prevalence of vitamin D deficiency was observed in urban children, those from the Central region, indigenous children and those with higher socio-economic status. Vitamin D status for the whole sample of 6827 children – with or without dietary data – is presented in the online supplementary material, Supplemental Table 1. This number is representative of 24·1 million Mexican children. In multivariate, logistic regression analysis, vitamin D deficiency was positively associated with age, female gender, overweight/obesity and living in the Central region. The analysis showed no statistically significant associations among pre-schoolers (Table 5).

Discussion

The present nationally representative study showed that vitamin D intakes are low in Mexican children aged 1 – 11 years, and milk and dairy are the main sources of the vitamin. Moreover, vitamin D deficiency is common, affecting 26 % of pre-schoolers and ~37 % of school-age children in Mexico.

A recent review on vitamin D status in Latin America and the Caribbean found that vitamin D intakes in children and adolescents were between 1·80 and 4·63 μg/d (72 and 185·2 IU/d)[8]. This was associated with a prevalence of dietary inadequacy of 100 %. The same review showed that vitamin D deficiency (25-hydroxyvitamin D < 50 nmol/l) affected 8 to 27 % of children and adolescents[8]. Our data are in accordance with the aforementioned study, confirming that vitamin D intake is insufficient and that vitamin D deficiency is a public health problem in Latin America.

A previous study, from the 2006 Mexican National Health and Nutrition Survey[11], reported a prevalence of vitamin D deficiency of 16 % among children aged 2–12 years. This is half of the prevalence currently observed. While this difference could be explained in part by lifestyle changes (i.e. decreased outdoor activities due social distress in some areas, increased use of sunscreen), aspects related to the laboratory analytical technique and handling of the serum samples in the previous survey should be also considered. The higher accuracy of the actual estimations, as reflected by smaller SD, the larger sample size and the use of NIST materials warrant a better estimation in the current survey.

In our study, overweight and obese children had a higher prevalence of vitamin D deficiency compared with

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Table 4 Serum 25-hydroxyvitamin D status according to general characteristics of Mexican children aged 1–11 years, Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012)

	Pre-school children (1–4 years)†							School-age children (5–11 years)‡					
	25-Hydroxyvitamin D (nmol/l)							25-Hydroxyvitamin D (nmol/l)					
Variable	Mean	95 % CI	<50 nmol/l (%)	95 % CI	≥ 50 nmol/l (%)	95 % CI		Mean	95 % CI	<50 nmol/l (%)	95 % CI	≥ 50 nmol/l (%)	95 % CI
Total	60·3	57·8, 62·7	25·9	20·7, 31·8	74·1	68·2, 79·2		56·6	55·2, 58·0	36·6	31·6, 41·9	63·4	58·1, 68·4
Age (years)													
1–2	61·0	57·4, 64·5	24·6	17·5, 33·3	75·4	66·7, 82·5	5–8	58·3	56·3, 60·2	32·8	25·7, 40·8	67·2	59·2, 74·3
3–4	59·6	56·8, 62·4	27·3	20·2, 35·8	72·7	64·2, 79·8	9–11	54·3	52·5, 56·2	41·7	34·9, 48·9	58·2	51·1, 65·0
Sex													
Male	61·4	57·5, 65·4	24·6	17·6, 33·3	75·4	66·7, 82·4		58·4	56·4, 60·4	29·1*	22·9, 36·2	70·9	63·8, 77·1
Female	59·3	56·6, 62·0	27·0	20·1, 35·2	73·0	64·8, 79·9		54·5	52·6, 56·4	45·7	37·9, 53·8	54·3	46·2, 62·1
BMI													
Normal	60·5	57·8, 63·1	25·7	20·2, 31·9	74·3	68·1, 79·7		58·1	56·3, 59·8	29·5*	24·1, 35·7	70·5	64·3, 75·9
Overweight	59·0	52·6, 65·5	28·7	13·7, 50·5	71·3	49·5, 86·3		55·1	52·4, 57·8	47·7	38·5, 57·0	52·3	43·0, 61·5
Obesity								53·1	49·7, 56·5				
Area													
Rural	60·5	58·3, 63·0	25·1	19·6, 31·5	74·9	68·4, 80·4		58·0	55·1, 60·6	33·5	26·1, 41·9	66·5	58·1, 73·9
Urban	60·2	57·0, 63·4	26·2	19·6, 34·2	73·8	65·8, 80·4		56·2	55·1, 60·6	37·6	31·5, 44·2	62·4	55·8, 68·5
Region													
North	55·5	52·0, 59·1	29·4	18·9, 42·8	70·6	57·2, 81·1		59·0	56·0, 62·0	31·4	22·5, 41·8	68·6	58·2, 77·5
Central	61·4	57·4, 65·5	25·8	17·9, 35·7	74·2	64·3, 82·1		54·0	61·3, 57·0	45·2*	36·8, 53·8	54·8	46·2, 63·2
Mexico City	59·0	49·5, 68·0	31·8	15·3, 54·6	68·2	45·4, 84·7		56·0	53·0, 59·0	37·8	25·5, 52·0	62·2	48·0, 74·5
South	62·0	59·7, 64·2	21·2	16·2, 27·2	78·8	72·8, 83·3		59·0	56·4, 61·2	29·0	22·9, 35·9	71·0	64·0, 77·1
Ethnicity§													
n 359													
Indigenous	52·0	45·5, 58·1	44·1	25·5, 64·5	55·9	35·5, 74·5		56·0	48·6, 63·1	41·3	27·0, 57·3	58·7	42·7, 73·0
Non-indigenous	59·0	45·5, 58·1	27·0	19·2, 36·6	72·3	63·4, 80·8		56·7	55·2, 58·1	36·4	31·2, 41·9	63·6	58·1, 68·8
Socio-economic status													
Low	61·1	59·2, 63·0	22·3	17·2, 28·3	77·7	71·7, 82·7		60·1	57·2, 63·0	30·6	23·7, 38·5	69·4	61·5, 76·3
Medium	57·3	54·6, 60·0	30·9	21·3, 42·5	69·1	57·5, 78·7		55·5	53·2, 58·0	35·4	27·1, 44·8	64·5	55·2, 72·9
High	62·4	55·0, 70·0	26·1	14·6, 42·1	73·9	57·9, 85·4		54·7	52·7, 57·0	42·6	32·9, 53·0	57·4	47·0, 67·1

*Among school-age children, prevalence of vitamin D deficiency (serum 25-hydroxyvitamin D <50 nmol/l (<20 ng/ml)) was significantly different among males *v.* females, normal weight *v.* overweight and Cental *v.* South (P<0·05).
†*n* 698; *n* expanded 2 692 583.
‡*n* 956; *n* expanded 4 654 316.
§Ethnicity information is available for children >3 years of age.

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Table 5 Risk of vitamin D deficiency† in Mexican children aged 1–11 years, Mexican National Health and Nutrition Survey 2012 (ENSANUT-2012)

	Pre-school children (1–4 years)			School-age children (5–11 years)	
Variable	OR	95 % CI		OR	95 % CI
Age (years)					
1–2	1·00	Ref.	5–8	1·00	Ref.
3–4	1·24	0·40, 3·87	9–11	1·76*	1·20, 2·57
Sex					
Male	1·00	Ref.		1·00	Ref.
Female	1·09	0·61, 1·93		1·63*	1·12, 2·39
BMI					
Normal	1·00	Ref.	Normal	1·00	Ref.
Overweight	1·08	0·40, 2·96	Overweight/obesity	2·23*	1·36, 3·66
Area					
Urban	1·00	Ref.		1·00	Ref.
Rural	1·35	0·76, 2·38		0·83	0·53, 1·29
Region					
North	1·00	Ref.		1·00	Ref.
Central	0·81	0·37, 1·79		2·18*	1·31, 3·63
Mexico City	1·21	0·37, 3·42		1·57	0·81, 3·06
South	0·65	0·32, 1·34		1·09	0·65, 1·80
Ethnicity					
Indigenous	1·00	Ref.		1·00	Ref.
Non-indigenous	0·93	0·54, 1·62		0·45*	0·22, 0·92
Socio-economic status					
Low	1·00	Ref.		1·00	Ref.
Medium	1·45	0·73, 2·66		1·08	0·67, 1·74
High	1·18	0·49, 2·81		1·62*	0·98, 2·67
Energy (kcal/d)	1·00	0·99, 1·00		0·99	0·99, 1·00
Vitamin D intake (IU/d)	1·00	0·99, 1·00		0·99	0·99, 1·00

Logistic regression model adjusted by BMI *Z*-score, age, gender, area, region, ethnicity, socio-economic status, energy and vitamin D intake (Ref., reference category)
$^{*}P < 0·05$.
†Vitamin D deficiency: serum 25-hydroxyvitamin D < 50 nmol/l (<20 ng/ml).

normal-weight children. The positive association of BMI with higher odds of vitamin D deficiency has been previously reported in the USA[10] and Mexico[11]. Sequestration of 25-hydroxyvitamin D in adipose tissue and abnormalities in vitamin D metabolism are plausible mechanisms behind this association[22,23].

Using data from NHANES 2003–2006, Karalius *et al.* found that the prevalence of vitamin D (25-hydroxyvitamin D) concentrations below 50 nmol/l was between 10·8 and 24·8 % in children aged 6–18 years[9]. It is noticeable that vitamin D deficiency is higher in Mexican children than in American children. One would expect, since occasional sun exposure is the main source of circulating 25-hydroxyvitamin D, that serum concentrations should be higher in Mexico than in the USA. Despite our belief that Mexican children are not having enough sun exposure and that dietary vitamin D intakes could be lower in Mexican compared with US children, the increased use of vitamin D-containing supplements in the US population could be an explanation for this somehow counter-intuitive finding. In a nationally representative sample of children aged 1–11 years from the USA, Mansbach *et al.*[24] found that ~34 % of the children consumed a vitamin D supplement and that this had a positive effect on 25-hydroxyvitamin D concentrations and the prevalence of vitamin D deficiency. In the present study, we found that only ~2 % of children consumed a vitamin D-containing supplement. Moreover, we did not find a difference in serum 25-hydroxyvitamin D concentrations between children who consumed a vitamin D-containing supplement and those who did not, indicating either that consumption occurred on a non-regular basis or that the dose was not sufficient to cause a noticeable rise in serum 25-hydroxyvitamin D concentrations.

The higher prevalence of vitamin D deficiency among urban children, compared with their rural counterparts, can probably be attributed to higher outdoor physical activity in rural children, but also to environmental air pollution in urban settings, which can minimize the amount of UV light available to reach the skin. This latter can be especially true for Mexico City, which showed the highest prevalence of vitamin D deficiency among regions.

While in Mexico we do not have traditional clothing that could lead to reduced exposure to sunlight, we think that there could be some reasons for avoiding sun exposure in these children: (i) there is an increasing awareness of the risk of skin cancer, as well as increased marketing of sunscreen products aimed at children; (ii) it is likely children's use of indoor entertainment (videogames, computers, etc.) is reducing outdoor recreational activities;

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(iii) at least in some regions, social distress and insecurity could be a factor that minimizes outdoor activities as well.

In our study, milk was the main source of vitamin D in the diet. The current level of milk fortification with vitamin D in Mexico has been established at 5 μg/l (200 IU/l)[25]. We suggest that this level could be improved to warrant that most children fulfil the current recommendations. Other dairy products such as butter, margarine and cheese could also be subject to fortification as part of a government strategy to improve the vitamin D status in the population.

In summary, avoiding sun exposure, an indoor lifestyle, overweight, air pollution, scarce food sources of vitamin D and low supplement use are among the possible causal factors of the high prevalence of vitamin D deficiency and low 25-hydroxyvitamin D serum concentrations observed in Mexican children.

The strengths of the present study are the inclusion of a representative sample of Mexican pre-school and school-age children, and training/standardization of the field personnel. Some of the constraints of the study are related to the limitations inherent to FFQ and misreporting of food intake by the caregiver, which could be related primarily to the child's age, gender and/or nutritional status. These may affect the estimate of the proportion of the population with suboptimal intakes[26].

Conclusion

In conclusion, in this nationwide study in Mexican children, we found low vitamin D intakes and that milk is the main source of the vitamin. There is a high prevalence of vitamin D deficiency and it is associated with overweight in school-age children. Urgent actions are needed to fight this public health problem in Mexico.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.1017/S1368980017000040

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