Vitamin D status in Mexican children 1 to 11 years of age: an update from the Ensanut 2018-19

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Abstract

Objective. To evaluate vitamin D status and deficiency in Mexican children and related factors, with updated data from a representative national survey**. Materials and methods.** Data and serum samples of child participants were collected in the Ensanut 2018-19. The measurement 25-(OH)-D was obtained through chemiluminescence. Height and weight, as well as dietary information, were measured using a semi-quantitative food frequency questionnaire and sociodemographic information. **Results.** Data of 4 691 children aged 1-11 years were analyzed. Vitamin D deficiency (25-OH-D<50 nmol/L) was found in 27.3% of pre-school-age children and 17.2% of school-age children, and was positively associated with the body mass index (BMI). Main dietary sources were milk, eggs and dairy products, which in combination provided >70% of vitamin D intake. **Conclusions.** Vitamin D deficiency is important in Mexican children. Actions and programs to fight this deficiency are required.

Keywords: vitamin D; nutritional deficiencies; children; national surveys; Mexico

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Resumen

Objetivo. Evaluar el estado y la deficiencia de vitamina D en niños mexicanos, así como los factores relacionados, con datos actualizados de una encuesta nacional representativa. **Material y métodos.** Los datos y muestras de suero de niños participantes se recolectaron en la Ensanut 2018-19. La medición de 25- (OH)- D se realizó mediante quimioluminiscencia. Se obtuvo estatura, peso e información dietética a través de un cuestionario semicuantitativo de frecuencia alimentaria e información sociodemográfica. **Resultados.** Se analizaron datos de 4 691 niños entre 1 y 11 años. Se observó deficiencia de vitamina D (25-OH-D <50 nmol/L) en 27.3% de preescolares y en 17.2% de los escolares, en ambos grupos se asoció positivamente con el índice de masa corporal (IMC). Las principales fuentes dietéticas de vitamina D fueron leche, huevo y productos lácteos, que aportaron >70% de la ingesta. **Conclusiones.** La deficiencia de vitamina D es considerable en los niños mexicanos. Se requieren acciones y programas para combatirla.

Palabras clave: vitamina D; desnutrición; niños; encuestas nacionales; México

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Vitamin D and its metabolites are a number of cholesterol-like compounds related to mineral metabolism. The best-known effect of vitamin D is to promote intestinal absorption of calcium, although it also stimulates absorption of phosphate and magnesium. These minerals also play important roles in the muscle; therefore vitamin D is essential for the maintenance and function of the musculoskeletal system, bone health, and child growth.[1]

Humans obtain vitamin D3 from exposure to sunlight, which provides more than 90% of the body´s vitamin D requirements.[2] Ultraviolet rays trigger the synthesis of vitamin D through the skin, converting 7-dehydrocholesterol into vitamin D3, which then enters into the blood circulation.[3] Vitamin D is sequentially metabolized in the liver and kidneys into 25-hydroxyvitamin-D (25-OH-D), and 1,25-dihydroxyvitamin D, respectively, the latter being its biologically active steroid hormone form, also known as calcitriol.[3]

The widespread distribution of the vitamin D receptor (VDR) and vitamin D metabolizing enzymes CYP24A1 and CYP27B1, as well as the impressive number of genes (almost 3% of human genome) subject to 1,25-dihydroxyvitamin D regulation, explain the pleiotropic actions of vitamin D in many organs and systems in the body. These actions range from bone formation, calcium and phosphorus homeostasis, regulation of cell proliferation, and insulin production, to the modulation of the immune system, among others.[4]

Globally, studies have demonstrated that vitamin D deficiency is a public health issue across all age groups, even in countries near the equator, where, in theory, enough sunlight is consistently available to prevent deficiency.[5] An estimated one billion children and adults around the world are affected by vitamin D deficiency.[6] In Mexico alone, this deficiency has been documented in 25.9% of pre-school-age children and 36.6% of school-age children.[7]

Furthermore, some studies have shown that vitamin D deficiency is associated with excess body weight and obesity,[8] and that it is more frequent in children who spend greater amounts of time indoors, whether at home, school or a childcare center, as well as in cases in which dietary vitamin D intake is insufficient for their metabolic needs.[3] In Mexico, the average vitamin D dietary consumption is 3.38 (SD 0.09) μg/d (135.2 [SD 3.6] IU/d) in pre-school-age children, and 2.85 (SD 0.06) μg/d (114.0 [SD 2.4] IU/d) in school-age children; the daily intake recommended for the latter is 400 IU/d according to the Institute of Medicine (IOM).[9] Milk contributes 64.4% of dietary vitamin D in pre-school-age children, and 54.7% in school-age children.[7]

The prevalence of vitamin D deficiency is a nutritional problem among Mexican children; therefore, the objective of the present study is to evaluate vitamin D status and deficiency, as well as related factors, in these children, with updated data obtained from a representative national survey.

Materials and methods

Study population

The information gathered from 1 209 pre-school-age children (1-4 years of age) and 3 482 school-age children (5-11 years of age) who participated in the National Health and Nutrition Survey 2018-19 in Mexico (Ensanut 2018-19, for its Spanish acronym) was analyzed. This subsample of pre-school- and school-age children is representative both on a national level and by geographical region and area. Trained personnel collected all the information using standardized methods. Detailed information regarding the sampling procedures and methodology has been described in previous publications.[10]

Procedures for blood sample collection and biochemical assessment

Blood samples were obtained from an antecubital vein directly to a vacuum tube and were centrifuged *in situ* to 3 000 g. Serum samples were stored in cryovials which were immediately frozen in liquid nitrogen (-130 °C) in Dewar tanks until their reception at the Laboratory of Biochemical Nutrition of the National Institute of Public Health (INSP, for its acronym in Spanish) in Cuernavaca, Morelos, Mexico, where they were stored in -75 °C freezers. Serum concentrations of 25-hydroxyvitamin-D (25-OH-D) were measured with an Abbott Architect automated analyzer (Abbott Lab, Michigan, IL, USA) by chemiluminescent microparticle immunoassay (CMIA). The C-reactive protein (CRP) was measured with ultrasensitive monoclonal antibodies, using the same instrument. Quality control of measurements was performed using the Standard Reference Serum NIST 968E of the National Institute of Standards and Technology. The coefficients of variation (CV) of 25-OH-D intra- and intertrial were 1.34 and 3.69%, respectively. This method has previously been shown to perform adequately when compared to the LC/MS/MS (r=0.73).

Diagnostic criteria for determining vitamin D deficiency

The vitamin D status was determined based on the serum concentration of 25-OH-D, according to the classification specified in "The clinical practice guidelines of the Endocrine Society Task force on Vitamin D".[11,12] Deficiency was considered as a serum level below 50 nmol/L (<20 ng/mL); insufficiency, as serum levels between 50 and 75 nmol/L (20<30 ng/mL), and sufficient levels, as greater than or equal to 75 nmol/L (>30 ng/mL).

Anthropometry

Body weight and height/length was measured by trained and standardized personnel, in accordance with internationally accepted protocols.[13,14] Afterwards, numerical values were converted to *Z*-scores according to the standards of the World Health Organization (WHO).[15] The nutritional status was classified into the categories underweight (low weight-for-age), stunting (low lenght-for-age), and wasting (low weight-for-height) as defined by a *Z*-score of <-2 standard deviations (SD), and excess body weight or obesity was defined by a *Z*-score of body mass index (BMI) of >+2 SD in pre-school-age children; for school-age children: excess body weight was defined as *Z*-score of >+1 SD, and obesity, as *Z*-score of >+2 SD.[15]

Dietary information

Dietary information was obtained through a semi-quantitative food frequency questionnaire (FFQ) with a reference period of seven days prior to the interview, which included 140 previously validated food and drink items.[16] Food items that contained vitamin D were classified into 15 groups: 1) Milk, 2) Eggs, 3) Other dairy products (cheese and yogurt), 4) Ready-to eat cereal, 5) Fast food and Mexican food, 6) Fish and seafood, 7) Powdered chocolate, 8) Processed meats, 9) Dairy-based desserts, 10) Pork, 11) *Atole* (corn-based drink) with milk, 12) Beef, 13) Chicken, 14) Animal fats, 15) Others (certain crackers, noodle soup, French fries, beans, etc.). The percentage of consumers of each food group was calculated. Consumption was defined as ingesting any food item in the food group of interest at least one day during the week, in any quantity. The total quantity of vitamin D consumed was estimated, and the percentage which each of the food groups contributed to total consumption was subsequently calculated.

Sociodemographic variables

Demographic and socioeconomic information was obtained through an ad hoc questionnaire. Data of the children's sex and age was obtained, age being categorized by range (1-2, 3-4, 5-8 y 9-11 years), and sex, as male or female.

Region: The country of Mexico was divided in three geographical regions: 1) North, 2) Center-Mexico City and 3) South. Given the size of the Mexico City sample, the city was classified as part of the Central region.

Area: Localities with populations of 2 500 or more inhabitants were classified as urban areas, while rural areas were defined as having less than 2 500 inhabitants.

Household wellbeing index (HWI): An index was generated through principal component analysis, based on housing characteristics (floor, wall and ceiling materials, number of rooms, water availability and supply, etc.) and possession of domestic and electrical appliances (refrigerator, gas stove, washing machine, television, etc.). This index was categorized by tertile (low, medium, high), had been used in previous surveys.[17]

Information about the mother

Information was obtained from the mother of each child participant, including age (categorized by range: <20, ≥20-<40, ≥40 years) and BMI, classified according to the cut-off points of the WHO: low weight (<18.5), normal weight (18.5-24.9), overweight (25-29.9) and obese (≥30).[18] Education level was categorized as: basic or absent when the mother had completed elementary to middle school; middle-high, when she had completed high school or studies in a technical/education institute, and superior, when she had completed university or post-graduate studies.

Statistical analysis

The descriptive characteristics of the sample were presented as proportions with a confidence interval of 95% (CI95%) for categorical variables, and as averages with CI95% for continuous variables. Logistical regression models were used to evaluate the association between vitamin D deficiency and sociodemographic characteristics of the child participants. The models were adjusted for the analyzed sociodemographic variables. All analyses accounted for the design of the survey, using the SVY module of STATA, edition 14.0.* In all analyses, statistically significant differences were defined by a *p*-value of <0.05.

* StataCorp. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP, 2015.

Ethical considerations

The present study was conducted according to the Declaration of Helsinki. The Ethics, Research and Biosecurity Committees of the National Institute of Public Health of Mexico approved the study protocol. Written informed consent from the parents of all child participants and assent from all school-age participants were obtained. Copies of the consent and assent forms were provided to all participants.

Results

Information from 4 691 children (1 209 of pre-school age and 3 482 of school age), representing 22.3 million Mexican children, was analyzed.

Table I describes the characteristics of the studied sample. The distribution by sex was divided evenly between male and female (approximately 50% each). The mean age was 2.8 years for the pre-school-age group, and 8.2 years for the school-age group. According to nutritional status, based on anthropometric measures, 14.7% of pre-school-age children were stunted, and 5.4% were overweight. Among school-age children, 37.5% were overweight or obese. Over 70% of the children resided in an urban area, and more than 46%, within the Central-Mexico City region. Over 40% of the children had a low HWI, and around 60% of their mothers lacked formal education or had completed only up to elementary education; 71-78% of these mothers were overweight or obese.

The average concentration of 25-OH-D was 60.93 nmol/L (CI95% 58.85-63.0) in pre-school-age children, and 65.36 nmol/L (CI95% 64.26-66.46) in school-age children (data not shown).

Regarding the vitamin D status (table II), deficiency (25-OH-D<50 nmol/L) was observed in 27.3% of pre-school-age children and 17.2% of school-age children. Sufficient levels (25-OH-D≥75 nmol/L or ≥30 ng/mL) were recorded in 26.8% of the pre-school-age children and in 25.0% of the school-age children.

Vitamin D deficiency affected female children to a greater extent (36.8%), and reached 29.2% among the children aged 3-4 years. A positive trend was observed between vitamin D deficiency and high BMI in school-age children: 14.9, 18.2 and 24.7% in children with normal body weight, excess body weight and obesity, respectively.

Vitamin D deficiency was more prevalent in children residing in urban areas, whether of pre-school- or school-age. Prevalence was highest in pre-school age children in the Central-Mexico City region. Among school-age children, the highest prevalence was observed in the North.

In relation to the HWI, both age groups displayed greater levels of vitamin D deficiency at the medium level. Prevalence of this deficiency was highest in pre-school-age children whose mothers had a low BMI, as well as among school-age children whose mothers were overweight or obese.

As for dietary sources of vitamin D (table III), these were mainly milk, eggs and other dairy products, which, combined, provided 78.3% of the vitamin D consumption in pre-school-age children, and 71.1% in school-age children.

The average intake of vitamin D was 168.5 IU/d in pre-school-age children and 123.8 IU/d in school-age children, both far below the international recommendation of 400 IU/d (table IV). Among school-age children, vitamin D consumption was higher in residents of urban areas, those with a higher HWI, and those residing in the Northern region. School-age children with mothers who had a higher HWI exhibited higher intakes of vitamin D.

The logistic regression model, adjusted for potential confounding factors (table V), showed that, in pre-school-age children, being female was associated with a greater risk of having vitamin D deficiency (OR=2.7, CI95% 1.6-4.4), while, among school-age children, the factors associated with the same risk for deficiency (25-OH-D <50nmol/L) were the age range of 9-11 years (OR=1.4, CI95% 1.0-1.9) and obesity (OR=1.7, CI95% 1.1-2.7).

The results were not modified by adding information to the model regarding the consumption of supplements, which was noted to be of 6.13% in pre-school-age children (CI95% 4.3-8.6) and 0.44% (CI95% 0.2-0.8) in school-age children (data not shown).

Discussion

In this analysis of recent (2018) data of a nationally representative sample of pre-school-age and school-age Mexican children, it was observed that vitamin D deficiency affects 27% of children aged 1-4 years and 17% of children aged 5-11 years, which evidences a critical nutritional problem in the country.

Vitamin D deficiency was positively associated with being female, the age group of 9 to 11 years, and with the presence of obesity, in school-age children. Furthermore, it was higher in children residing in urban areas than in those within rural areas, as well as in those with a medium HWI.

The main dietary sources of vitamin D were milk, eggs and other dairy products, which together contribute 70-79% of daily vitamin D intake for all child participants. Average vitamin D consumption was less than 170 IU/d in both age groups, with more than 90%

Table I

CHARACTERISTICS OF MEXICAN CHILDREN AGED 1–11 Y. MEXICO, ENSANUT 2018-19

	Preschoolers (n=1 209)				*Schoolchildren (n=3 482)*			
	Sample	*Expansion factor (thousands)*	*%*	*CI95%*	*Sample*	*Expansion factor (thousands)*	*%*	*CI95%*
Children's characteristics								
Sex								
Male	576	3 382.9	47.8	(43.1-52.6)	1 741	7 754.7	50.9	(48.1-53.7)
Female	633	3 692.0	52.2	(47.4-56.9)	1 741	7 483.5	49.1	(46.3-51.9)
Mean age, y	-	-	2.8	(2.7-2.9)	-	-	8.2	(8.1-8.3)
1-2	496	2 794.1	39.5	(35.2-43.9)	-	-	-	-
3-4	713	4 280.8	60.5	(56.1-64.8)	-	-	-	-
5-8	-	-	-	-	2 039	8 260.3	54.2	(51.5-56.9)
9-11	-	-	-	-	1 443	6 977.8	45.8	(43.1-48.6)
Nutritional status*								
Underweight	48	360.6	5.4	(3.1-9.0)	-	-	-	-
Wasting	16	87.2	1.3	(0.7-2.5)	-	-	-	-
Stunting	171	986.7	14.7	(11.4-18.7)	-	-	-	-
BMI (WHO)*								
Normal	1 080	6 358.2	94.6	(92.3-96.2)	2 210	9 344.7	62.5	(59.4-65.5)
Overweight	70	366.0	5.4	(3.8-7.7)	685	2 935.4	19.6	(17.5-22.0)
Obesity	-	-	-	-	530	2 673.8	17.9	(15.6-20.4)
Home characteristics								
Area								
Urban	710	5 051.1	71.4	(68.5-74.1)	2 068	11 129.003	73.0	(70.7-75.3
Rural	499	2 023.7	28.6	(25.9-31.5)	1 414	4 109.155	27.0	(24.8-29.3)
Region								
North	178	1 395.9	19.7	(17.2-22.5)	583	2 967.4	19.5	(17.8-21.3)
Central-Mexico City	430	3 319.2	46.9	(43.5-50.3)	1 241	7 284.5	47.8	(45.3-50.4)
South	601	2 359.8	33.4	(30.2-36.7)	1 658	4 986.2	32.7	(30.4-35.2)
Household well-being index								
Low	630	3 015.9	42.63	(38.8-46.6)	1 671	6 220.1	40.8	(38.0-43.7)
Medium	381	2 513.7	35.56	(31.7-39.6)	1 139	5 035.2	33.0	(30.4-35.8)
High	198	1 545.2	21.84	(18.5-25.6)	672	3 982.9	26.1	(23.3-29.2)
Mother's characteristics								
Mean age, y*	-	-	28.8	(28.2-29.3)	-	-	34.3	(33.9-34.8)
<20	65	428.5	6.3	(4.2-9.3)	6	11.6	0.1	(0.03-0.2)
20-<40	1 009	5 956.7	87.2	(83.6-90.1)	2 526	10 888.0	76.7	(73.8-79.2)
≥40	86	447.8	6.6	(5.9-8.9)	712	3 305.4	23.3	(20.7-26.1)
Mean BMI*								
Underweight	6	76.2	2.5	(0.8-7.9)	12	35.2	0.5	(0.3-1.0)
Normal	141	779.8	26.0	(20.9-31.8)	343	1 396.5	20.8	(17.6-24.4)
Overweight	183	989.9	33.0	(27.3-39.3)	599	2 562.3	38.2	(33.9-42.6)
Obesity	191	1 152.0	38.4	(32.0-45.3)	617	2 718.2	40.5	(35.8-45.3)
Schooling*								
Elementary school or less	730	3 967.093	57.9	(53.4.62.2)	2 260	9 394.8	65.8	(62.3-68.8)
High school	335	2 247.779	32.8	(28.8-37.1)	749	3 472.1	24.3	(21.6-27.3)
University or more	100	637.161	9.3	(6.8-12.6)	251	1 420.0	9.9	(7.9-12.4)

* Subsample
BMI: body mass index ;WHO: World Health Organization
Source: National Health and Nutrition Survey 2018-19 in Mexico (Ensanut 2018-19)

Table II

Serum 25-hydroxyvitamin D status according to characteristics of Mexican children aged 1–11 y. Mexico, Ensanut 2018-19

Vitamin D status (nmol/l)	Preschoolers						Schoolchildren					
	% Deficiency <50*	CI95%	% Insufficiency (50<75)[‡]	CI95%	% Sufficiency (>75)[§]	CI95%	% Deficiency <50*	CI95%	% Insufficiency (50<75)[‡]	CI95%	% Sufficiency (>75)[§]	CI95%
National	27.3	(23.4-31.6)	45.9	(41.3-50.6)	26.8	(23.0-31.2)	17.2	(15.0-19.6)	57.8	(54.9-60.6)	25.0	(22.6-27.6)
Children's characteristics												
Sex												
Male	16.9[‡,§]	(12.4-22.6)	50.4[*,§]	(44.0-56.8)	32.7[*,‡]	(26.5-39.5)	15.1[‡,§]	(12.2-18.69)	57.2[*,§]	(52.9-61.4)	27.7[*,‡]	(23.9-31.7)
Female	36.8[§]	(30.8-43.3)	41.7[§]	(35.5-48.2)	21.5[*,‡]	(17.1-26.6)	19.3[‡]	(16.2-22.8)	58.4[*,§]	(54.7-62.0)	22.3[‡]	(19.6-25.3)
Age, y												
1-2	24.4	(18.9-30.7)	49.1	(42.6-55.65)	26.5	(21.3-32.5)	-	-	-	-	-	-
3-4	29.2	(24.1-35.0)	43.7	(37.9-49.8)	27.0	(21.9-32.8)	-	-	-	-	-	-
5-8	-	-	-	-	-	-	13.9[‡,§]	(11.5-16.7)	55.0[*,§]	(51.6-58.3)	31.1[*,‡]	(28.2-34.2)
9-11	-	-	-	-	-	-	21.0[‡]	(17.6-25.0)	61.1[*,§]	(56.7-65.4)	17.8[‡]	(14.79-21.3)
Nutritional status[#]												
Underweight	30.3	(11.7-59.0)	50.2	(25.1-75.2)	19.5	(8.7-37.9)	-	-	-	-	-	-
Wasting	35.2	(9.7-73.3)	28.3	(9.6-59.5)	36.6	(13.5-68.0)	-	-	-	-	-	-
Stunting	28.0	(17.2-42.1)	52.6	(39.5-65.3)	19.5	(13.1-28.0)	-	-	-	-	-	-
BMI (WHO)[#]												
Normal	27.2	(23.0-31.8)	47.0	(42.1-52.0	25.8	(21.8-30.3)	14.9[‡,§]	(12.4-17.8)	56.9[*,§]	(53.1-60.5)	28.3[*,‡]	(24.9-31.9)
Overweight	31.5	(16.9-51.0)	43.4	(27.4-60.9)	25.1	(14.2-40.4)	18.2[‡]	(13.9-23.5)	62.1[*,§]	(55.9-67.9)	19.7[‡]	(15.4-24.9)
Obesity	-	-	-	-	-	-	24.7[‡]	(18.5-32.2)	57.2[*,§]	(49.7-64.4)	18.1[‡]	(13.5-23.8)
Home characteristics												
Area												
Urban	29.0	(24.1-34.5)	46.3	(40.9-51.8)	24.7	(20.0-30.1)	18.9[‡]	(16.0-22.1)	59.0[*,§]	(55.3-62.6)	22.2[‡]	(19.3-25.3)

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Rural	23.1	(17.6-29.6)	44.8	(36.1-53.9)	32.1	(25.0-40.2)	$12.6^{\ddagger,\S}$	(10.2-15.5)	$54.5^{*,\S}$	(50.7-58.3)	$32.9^{*,\ddagger}$	(28.6-37.5)
Region												
North	22.4	(15.9-30.5)	48.4	(38.9-58.0)	29.3	(21.4-38.6)	$24.2^{\ddagger}$	(19.0-30.3)	$55.5^{*,\S}$	(49.5-61.4)	$20.3^{\ddagger}$	(16.1-25.2)
Central-Mexico City	30.1	(23.6-37.5)	47.3	(39.6-55.2)	22.6	(17.0-29.4)	$16.3^{\ddagger}$	(13.0-20.2)	$62.5^{*,\S}$	(58.3-66.5)	$21.2^{\ddagger}$	(18.4-24.4)
South	26.3	(20.7-32.8)	42.3	(36.2-48.7)	31.4	(24.8-38.8)	$14.3^{\ddagger,\S}$	(11.2-18.0)	$52.3^{*,\S}$	(47.6-57.0)	$33.4^{*,\ddagger}$	(28.5-38.8)
Household well-being index												
Low	26.2	(20.8-32.4)	44.4	(37.7-51.2)	29.5	(23.7-36.1)	$13.5^{\ddagger,\S}$	(10.6-16.9)	$56.7^{*,\S}$	(52.6-60.7)	$29.9^{*,\ddagger}$	(26.3-33.8)
Medium	28.7	(22.3-36.0)	45.3	(37.8-52.9)	26.0	(20.3-32.8)	$20.4^{\ddagger}$	(16.4-25.2)	$56.5^{*,\S}$	(51.8-61.1)	$23.1^{\ddagger}$	(19.9-26.6)
High	27.3	(18.7-38.1)	49.8	(40.1-59.4)	22.9	(15.3-32.9)	$18.9^{\ddagger}$	(14.3-24.6)	$61.2^{*,\S}$	(53.8-68.0)	$20.0^{\ddagger}$	(14.2-27.3)
Mother's characteristics												
Age, y[#]												
<20	35.7	(19.5-56.0)	37.4	(12.1-57.1)	27.0	(10.0-55.0)	9.1	(1.8-35.4)	57.8	(20.8-87.7)	33.1	(7.9-74.0)
20-<40	26.9	(22.7-31.5)	46.5	(41.4-51.6)	26.6	(22.4-31.3)	15.1	(12.8-17.8)	58.1	(54.7-61.3)	26.8	(23.7-30.0)
≥40	28.4	(16.8-43.7)	46.2	(31.8-61.22)	25.4	(14.5-40.6)	24.1	(18.9-30.22)	57.7	(51.5-63.6)	18.2	(14.9-22.1)
BMI*												
Underweight	57.8	(13.5-92.3)	32.4	(5.4-80.19)	9.8	(1.5-43.4)	3.0	(0.4-18.0)	83.0	(55.1-95.1)	14.0	(3.2-44.2)
Normal	22.3	(13.8-33.9)	48.7	(36.5-60.9)	29.1	(20.0-40.2)	15.6	(10.2-23.1)	59.8	(51.1-67.9)	24.6	(18.4-32.2)
Overweight	29.0	(20.0-40.1)	48.4	(38.6-58.3)	22.6	(15.6-31.6)	15.9	(11.9-21.0)	61.5	55.4-67.2)	22.7	(18.5-27.4)
Obesity	26.0	(17.0-37.6)	45.5	(33.3-58.1)	28.6	(19.8-39.3)	17.4	(13.0-23.0)	55.3	(47.1-63.2)	27.3	(20.9-29.5)
Schooling[#]												
Elementary school or less	27.6	(22.5-33.3)	46.5	(40.5-52.5)	25.9	(21.3-31.2)	17.0	(14.4-20.0)	57.5	(54.2-60.8)	25.5	(22.8-28.3)
High school	30.1	(22.9-38.4)	46.3	(38.0-54.8)	23.6	(17.8-30.6)	17.8	(13.8-22.7)	56.1	(49.3-62.7)	26.1	(19.8-33.6)
University or more	19.5	(11.4-31.3)	40.2	(26.5-55.7)	40.3	(25.8-56.8)	17.4	(10.0-28.5)	66.1	(54.1-76.2)	16.6	(10.5-25.3)

*,‡,§ Statistically significant differences between categories $p<0.05$
[#] Subsample
BMI: body mass index
Differences were made using Chi-square test
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Table III

Dietary sources and percent contribution to vitamin D intake in Mexican children aged 1–11 y. Mexico, Ensanut 2018-19

	Preschoolers (n=1 037)				Schoolchildren (n=3 172)			
	Frequency of consumption		Contribution to total intake of VD (%)		Frequency of consumption		Contribution to total intake of VD (%)	
	%	(CI95%)	Mean	(CI95%)	%	(CI95%)	Mean	(CI95%)
Food								
Milk	88.14	(84.9-90.7)	49.7	(47.1-52.3)	86.1	(83.9-88.0)	38.5	(37.1-40.0)
Eggs	83.46	(79.5-86.8)	16.3	(14.5-18.0)	83.31	(80.9-85.5)	19.9	(18.8-21.0)
Other dairy products	45.1	(40.2-50.0)	12.3	(10.9-17.8)	75.6	(72.9-78.1)	12.7	(11.9-13.6)
Ready to eat cereals	50.3	(45.4-55.1)	4.8	(3.9-5.7)	47.2	(44.1-50.4)	5.6	(5.1-6.2)
Fast food and Mexican food	77.5	(73.77-80.76)	2.5	(2.0-3.0)	85.93	(83.8-87.8)	5.6	(0.2-5.1)
Fish and seafood	31.0	(26.6-35.7)	3.3	(2.5-4.1)	30.6	(27.8-33.6)	4.3	(3.7-4.8)
Chocolate	24.5	(20.5-29.0)	4.3	(3.3-5.2)	25.9	(23.6-28.5)	4.2	(3.7-4.8)
Processed meats	58.8	53.9-63.5)	1.4	(1.0-1.8)	56.98	(53.7-60.2)	2.1	(1.7-2.4)
Milk-based desserts	45.1	(40.2-50.0)	1.3	(1.1-1.5)	38.1	(35.1-41.2)	1.0	(0.9-1.2)
Pork meat	31.1	(26.7-35.8)	0.3	(0.3-0.4)	38.9	(35.8-42.0)	0.9	(0.8-1.1)
Atole with milk	7.4	(5.4-10.1)	0.7	(0.4-1.0)	7.5	(6.0-9.3)	0.9	(0.7-1.1)
Beef	38.33	(33.9-43.0)	0.6	(0.4-0.8)	42.4	(39.3-45.5)	0.8	(0.7-0.9)
Chicken	76.4	(72.5-79.8)	0.5	(0.4-0.6)	73.9	(71.1-76.5)	0.7	(0.6-0.7)
Fat (animal origen)	3.1	(1.2-4.9)	0.1	(0.01-0.1)	4.9	(3.2-7.3)	0.1	(0.1-0.1)
Other	99.2	(98.1-99.7)	1.8	(1.4-2.3)	98.4	(97.0-99.2)	2.6	(2.3-2.9)

VD: Vitamin D
National Health and Nutrition Survey 2018-19 in Mexico (Ensanut 2018-19)

of the children failing to meet the international dietary recommendation of 400 IU/d.[9]

Vitamin D deficiency has previously been documented in this population through data from Ensanut 2012,[7] as has been the association of this deficiency with BMI and urban residency. Serum concentrations in pre-school-age children in the present study are very similar to those described in the 2012 study mentioned; nonetheless, the present study shows slightly higher values in school-age children. Vitamin D consumption reported in the present study is 8-20% higher than that described in 2012, which could partially explain the increase observed in serum concentrations and the lower prevalence of deficiency in children. Other related factors may include the consumption of vitamin D supplements, which in the 2012 study was less than 3% and in the present study was 6% in pre-school-age children, although in school-age children the percentage of children whose mothers reported consumption of supplements was less than 0.5%.

The findings of the present study partially reflect those reported in other countries. A meta-analysis of 72 studies on vitamin D in Brazil[19] reported serum levels of 25-OH-D of 67.65 nmol/L (CI95% 65.91-69.38) in the general population; the prevalence of vitamin D deficiency was 28.16% (CI95% 23.90-32.40); in children, the mean serum concentration of 25-OH-D was 66.68 nmol/L (CI95% 35.51-97.86), and the prevalence of vitamin D deficiency was 22.95% (CI95% 10.00-35.89). These data are similar to those evidenced in the present study, which is notable, given important differences in latitude, feeding habits, ethnicity and more, between the two studied populations.

In the National Health and Nutrition Examination Survey (NHANES) 2007-2010 study, which reports national estimates of vitamin D status in the general population of the United States of America,[20] vitamin D deficiency in children aged 1-11 years was 9.7% (CI95% 7.8-12.0). Specifically in Hispanic children, this prevalence rose to 13% (CI95% 10.0-16.0). Furthermore,

Table IV

Vitamin D intake according to characteristics of Mexican children aged 1–11 y. Mexico, Ensanut 2018-19

	Preschoolers			*Schoolchildren*		
	Vitamin D intake			*Vitamin D intake*		
	Sample	*Mean IU/d*	*CI95%*	*Sample*	*Mean IU/d*	*CI95%*
National	1 037	168.5	(154.7-182.3)	3 172	123.8	(118.7-129.0)
Children's characteristics						
Sex						
Male	498	167.9	(149.5-186.2)	1 582	127.9	(121.4-134.4)
Female	539	169.1	(148.4-189.7)	1 590	119.5	(111.6-137.4)
Age, y						
1-2	443	180.2	(158.8-201.5)	-	-	-
3-4	594	160.4	(142.7-178.1)	-	-	-
5-8	-	-	-	1 877	124.4	(117.3-131.5)
9-11	-	-	-	1 295	123.1	(115.8-130.5)
Nutritional status*						
Underweight	41	155.7	(40.8-270.6)	-	-	-
Wasting	14	122.5	(46.0-199.1)	-	-	-
Stunting	143	143.8	(158.9-186.3)	-	-	-
BMI (WHO)*						
Normal	946	168.2	(153.7-182.8)	2 021	120.9	(115.2-126.6)
Overweight	61	177.1	(130.2-224.0)	628	128.3	(112.4-144.3)
Obesity	-	-	-	481	131.0	(119.0-142.9)
Home characteristics						
Area						
Urban‡	613	175.6	(159.6-191.5)	1 877	131.9§	(125.4-138.5)
Rural§	424	151.1	(124.3-177.9)	1 295	102.0‡	(95.5-108.5)
Region						
North‡	157	173.2	(151.9-194.4)	518	136.6#	(125.9-147.2)
Central-Mexico City§	380	169.3	(147.6-191.1)	1 135	129.4#	(120.9-137.9)
South#	500	164.2	(139.3-189.2)	1 519	108.6‡,§	(101.1-116.1)
Household wellbeing index						
Low‡	539	160.3	(134.6-186.0)	1 504	100.9§,#	(94.4-107.3)
Medium§	323	177.3	(158.1-196.4)	1 048	129.9‡,#	(122.4-137.3)
High#	175	170.1	(147.2-193.1)	620	151.3‡,§	(138.1-164.4)
Mother's characteristics						
Age, y*						
<20‡	59	165.6	(113.4-217.8)	6	135.1	(30.2-240.0)
20-<40§	866	162.1#	(148.4-175.9)	2 308	124.5	(118.2-130.7)
>40#	72	217.8§	(172.2-263.3)	647	122.8	(112.6-133.1)
BMI*						
Underweight	6	137.4	(76.8-197.9)	12	96.0	(52.2-139.9)
Normal	124	168.8	(142.6-194.9)	308	120.6	(105.8-135.4)
Overweight	156	179.8	(138.1-221.4)	542	118.9	(109.2-128.6)
Obesity	167	189.6	(143.8-235.4)	563	121.5	(110.7-132.4)
Schooling*						
Elementary school or less‡	626	155.3	(139.2-171.4)	2 051	113.94§,#	(108.6-119.3)
High school§	285	177.8	(151.6-204.1)	691	139.7‡	(125.9-153.6)
University or more#	90	191.5	(159.0-223.9)	232	151.3‡	(129.7-172.9)

* Subsample
‡,§,# Statistically significant differences between categories p<0.05
BMI: body mass index; WHO: Wold Health Organization
Mean differences were made by simple linear regression
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Table V
Risk of vitamin D deficiency* in Mexican children aged 1–11 y. Mexico, Ensanut 2018-19

	Preschoolers (n= 965)			Schoolchildren (n= 3 118)		
	Expansion factor (thousands) 5 564.9			Expansion factor (thousands) 13 442.4		
	OR	CI95%	p	OR	CI95%	p
Vitamin D Deficiency						
Sex						
Male	ref	-	<0.001	ref	-	0.150
Female	2.7	(1.6-4.4)		1.3	(0.9-1.8)	
Age, y						
1-2	ref	-	0.323	-	-	-
3-4	1.3	(0.8-2.1)		-	-	-
5-8	-	-	-	ref	-	0.038
9-11	-	-	-	1.4	(1.0-1.9)	
Nutritional status						
Underweight	1.3	(0.3-5.6)	0.725	-	-	-
Wasting	2.3	(0.4-12.5)	0.320	-	-	-
Stunting	0.7	(0.3-1.6)	0.391	-	-	-
BMI						
Normal	ref	-		ref	-	
Overweight	0.8	(0.3-2.2)	0.661	1.4	(0.8-2.1)	0.148
Obesity	-	-	-	1.7	(1.1-2.7)	0.018
C-Reactive Protein, mg/L						
<5	ref	-	0.93	ref	-	0.51
≥5	1.0	(0.5-2.1)		1.3	(0.6-2.8)	
Vitamin D intake, µg/d	0.9	(0.8-1.0)	0.065	1.1	(1.0-1.2)	0.299
Area						
Urban	ref	-	0.168	ref	-	0.351
Rural	0.7	(0.4-1.2)		0.8	(0.6-1.2)	
Region						
Central-Mexico City	ref	-		ref	-	
North	0.5	(0.3-1.1)	0.119	1.5	(1.0-2.30)	0.071
South	0.9	(0.5-1.5)	0.587	0.9	(0.6-1.4)	0.770
Household wellbeing index						
Low	ref	-		ref	-	
Medium	1.3	(0.8-2.2)	0.344	1.3	(0.8-2.0)	0.263
High	0.9	(0.4-1.7)	0.703	1.1	(0.7-1.9)	0.661

*Vitamin D deficiency: serum 25-hydroxyvitamin D <50 nmol/l (<20 ng/ml)
The logistic regression model is adjusted for all the variables in the table
BMI: body mass index; ref: reference category
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serum levels of 25-OH-D were on average 76.5 nmol/L in children aged 1-5 years, and 72.2 nmol/L in children aged 6-11 years, all of whom exhibited higher concentrations of serum 25-OH-D than those reported in the present study, as well as significantly fewer measures below 50 nmol/L. Nonetheless, among the NHANES population, nearly 30% of individuals had a higher intake of vitamin D due to supplementation, which may explain the differences observed. In those who did not consume supplements, serum 25-OH-D average levels were 62.5 nmol/L (CI95% 60.4-64.5), which are more similar to those found in the present study.

As in Mexico, multiple countries in Europe report low vitamin D intake on a population level, usually below 200 IU/d; this is observed as well in Eastern Europe. On the other hand, Nordic countries report higher levels of intake of this vitamin.[21] In Europe, vitamin D deficiency (25-OH-D <50 nmol/L) has been shown to affect 27-61.4% of the population. In Germany, 54.5% of the children aged 1-17 years were shown to have this deficiency, and mean serum 25-OH-D levels were 54 nmol/L, while in Greece, the problem of vitamin D deficiency is more pronounced than in the area covered by the present study, and serum vitamin D levels are even lower.

Among the potential causes of the persistence of vitamin D deficiency in children as observed in two national-level surveys in Mexico (2012 and 2018), inadequate intake of vitamin D has been suggested, mainly due to the fact that the main food sources providing vitamin D are animal-based, and, although milk is a widely consumed food product among young children, its fortification with 200 IU/L is considered to be insufficient. Furthermore, consumption of vitamin D supplements is low, and Mexico does not have supplementation programs targeted towards vulnerable groups. Together, these factors, as well as indoor lifestyles, environmental contamination and excess body weight, may be contributing to vitamin D deficiency. In addition, genetic variations (SNPs) related to vitamin D metabolism have been documented to be widely present in the Mexican population and may be associated with up to 50% of the deficiencies.[22]

Two of the strengths of the present study are the inclusion of a representative sample of pre-school-age and school-age Mexican children, and the use of standardized methods and personnel to perform data collection. Furthermore, the laboratory method used for 25-OH-D measurements (CMIA) has been shown to have a high rate of reactivity towards 25-hydroxyvitamin-D3 (approximately 100%) and an adequate performance when compared to the gold standard (tandem mass spectrometry).[7]

The limitations of this study relate to inherent characteristics of the use of the FFQ method, which may underestimate nutrient intake, as well as the potential over- or under-reporting by the informant associated with age, sex and nutritional state of the child participant and which introduces potential biases in the estimation of the intake. Nonetheless, our findings are consistent with previous studies, not only in Mexico but in other populations as well.

Recently, a modification to the Official Mexican Standard (NOM, for its acronym in spanish) 051 was approved by the Senate of the Republic,[23] made official in October of 2020, in which the daily intake recommendation of vitamin D was increased from 200 IU/d to 400 IU/d (10 μg/d). This constitutes an important advancement in building legislation that supports improved vitamin D intake in Mexico.

In conclusion, vitamin D deficiency continues to be a population nutrition problem in Mexican children, being most important in pre-school-age children, female children and school-age children with a high BMI. The fight against vitamin D deficiency in vulnerable groups requires concrete actions and supplementation programs, as well as efforts towards improving the fortification of widely consumed food products (for example, increasing the fortification of milk, while also including other potential vehicles such as eggs).[24]

Declaration of conflict of interests. The authors declare that they have no conflict of interests.

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