Vitamin D status by sociodemographic factors and body mass index in Mexican women at reproductive age

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Abstract

Objective. To describe the prevalence of Vitamin D deficiency (VDD) and insufficiency (VDI), and the main dietary sources of vitamin D (VD) in a probabilistic sample of Mexican women at reproductive age participating in Ensanut 2012, stratified by sociodemographic factors and body mass index (BMI) categories. **Materials and methods.** Serum concentrations of 25-hydroxyvitamin-D(25-OH-D) were determined using an ELISA technique in 4 162 women participants of Ensanut 2012 and classified as VDD, VDI or optimal VD status. Sociodemographic, anthropometric and dietary data were also collected. The association between VDD/VDI and sociodemographic and anthropometry factors was assessed adjusting for potential confounders through an estimation of a multinomial logistic regression model. **Results.** The prevalence of VDD was 36.8%, and that of VDI was 49.8%. The mean dietary intake of VD was 2.56 µg/d. The relative risk ratio (RRR) of VDD or VDI was calculated by a multinomial logistic regression model in 4 162 women. The RRR of VDD or VDI were significantly higher in women with overweight (RRR: 1.85 and 1.44, $p<0.05$), obesity (RRR: 2.94 and 1.93, $p<0.001$), urban dwelling (RRR: 1.68 and 1.31, $p<0.06$), belonging to the 3rd tertile of income (RRR: 5.32 and 2.22, $p<0.001$), or of indigenous ethnicity (RRR: 2.86 and 1.70, $p<0.05$), respectively. **Conclusion.** The high prevalence of VDD/VDI in Mexican women calls for stronger actions from the health authorities, strengthtening the actual policy of food supplementation and recommending a reasonable amount of sun exposure.

Keywords: vitamin D deficiency; 25-OH-D; women; indigenous population; obesity

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Resumen

Objetivo. Describir la prevalencia de deficiencia (DVD) e insuficiencia (IVD) de vitamina D (VD), y las principales fuentes dietéticas de VD en una muestra probabilística de mujeres mexicanas en edad reproductiva participantes de la Ensanut 2012, estratificando por factores sociodemográficos y categorías de IMC. **Material y métodos.** Las concentraciones séricas de 25-hidroxivitamina-D (25-OH-D) se midieron utilizando la técnica ELISA en 4 162 mujeres participantes de la Ensanut 2012, que fueron clasificadas con DVD, IVD u óptimos niveles de VD. Se recolectaron datos sociodemográficos, antropometría y dieta, y se evaluó su asociación con DVD/IVD por medio de un modelo de regresión logística multinomial. **Resultados.** 36.8% de las mujeres presentaron DVD y 49.8% IVD. La media de ingesta de VD fue 2.56 µg/d. La probabilidad de presentar DVD o IVD fue mayor en las mujeres con sobrepeso (RRR: 1.85 y 1.44, $p<0.05$), obesidad (RRR: 2.94 y 1.93, $p<0.001$), residentes del área urbana (RRR: 1.68 y 1.31, $p<0.06$), del tercil 3 de nivel socioeconómico (RRR: 5.32 y 2.22, $p<0.001$) o indígenas (RRR: 2.86 y 1.70, $p<0.05$) respectivamente. **Conclusiones.** La alta prevalencia de DVD/IVD en mujeres mexicanas es un llamado a las autoridades de salud para implementar una política de suplementación de alimentos más fuerte y hacer recomendaciones para una razonable exposición al sol.

Palabras clave: deficiencia de vitamina D; 25-OH-D; mujeres; indígenas; obesidad

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Vitamin D deficiency (VDD<50 nmol/L) is considered globally as a public health issue.[1] Vitamin D insufficiency (VDI<75 nmol/L) is found in approximately 50% of the world population.[2,3] A high proportion of adults in the American continent have VDD: Brazil (77%), Chile (27-60%), Puerto Rico (28-32%), Argentina (52-87%), USA (34-37%), or Guatemala (46%).[4-6] The reported prevalence of VDD in Europe and Australia varies between 30 and 50%.[3] In México, despite the large availability of sunlight, the National Health and Nutrition Survey (Ensanut) documented that in 2012 33% of children aged 1-11years were VD-deficient.[7]

Several factors have been identified in women with VDD, as such as the lack of exposure to sunlight, the culture, (e.g. wearing long garments), the age, the skin pigmentation, along with a low VD dietary intake.[8-10] Long lactation periods, the use of skin sun blockers, the frequent use of umbrellas,[3,11,12] tobacco smoking, obesity and renal chronic disease have been also associated with VDD in women.[3,11-16] It is not clear whether the VDD is produced by obesity or obesity is a consequence of VDD,[17] because obese individuals specially women,[18] are susceptible to VDD due to diminished availability of VD stored in the adipose tissue, and on the other hand,[18] some studies in obese individuals suggest that the supplementation with VD reduces the body fat mass.[19-21]

Women at reproductive age are a group that can be intervened at earlier age for VDD and its long term complications.VDD during adulthood increases the risk of osteopenia, osteoporosis, muscle weakness, osteomalasia and pathological fractures and can worsen other chronic conditions, such as the polycystic ovary syndrome; it also is a risk factor for cardiovascular diseases, metabolic syndrome, some types of cancer and some autoimmune diseases.[16-24]

This study aims to describe the prevalence of VDD and VDI, and the dietary sources of VD, in a probabilistic sample of women at reproductive age participating in Ensanut-2012, stratified by sociodemographic factors and BMI categories.

Materials and methods

Study population: This cross-sectional analysis was carried out in women aged 20-49 years participating in the National Health and Nutrition Survey-2012 (Ensanut 2012), a probabilistic survey designed to represent the national population, and urban and rural dwelling.[25]A detailed description of the sampling was published previously.[26]

Blood and dietary sample. Blood samples were obtained from 30% of the whole sample, i.e. 4,162 women 20-49 yo. The collection of the samples occurred between the winter of 2011 and the spring of 2012. The sampling occurred between the latitudes 14°54′ and 32°31′ N. The dietary information was obtained through an iterative multiple steps 24-h recall questionnaire applied to 15% of the total Ensanut-2012 sample, consisting of 869 women with dietary and serum data. More detailed information on the multiple-pass method was published elsewhere.[27] The dietary information was gleaned in accordance with the methodology described by López and colleagues.[28-30]

Those foods that were the main source of dietary VD were identified according to their reported VD content in the food composition tables used by Ensanut 2012.[31] The first 10 foods that contributed more than 10% of VD intake in 24 h were listed in decreasing order. Based on the 24 h dietary recall in 869 women, we constructed an index to identify the main dietary sources of VD, the frequency of eating and the VD content in each food item.

Collection of blood samples and laboratory procedures. Blood samples were obtained from an antecubital vein and were spinned down "in situ" at 3000 g. The serum was separated and stored in codified cryovials and preserved in a liquid N tank until delivered to the Central Nutrition laboratory at Instituto Nacional de Salud Pública (INSP), Cuernavaca, Mor, Mexico. The serum concentrations of 25-hydroxyvitamin-D (25-OH-D) in nmol/L were measured by microparticles' chemoluminiscence technique, using commercial kits of Abbot in an "Architect CI8200" automatic analyzer (Abbott Lab, Michigan, III USA). The inter- and intra-assay coefficients of variability were 1.34 and 3.69%, respectively. The accuracy of the determinations was checked with the NIST SRM-968E reference material.[32,33]

Sociodemographic information

Sociodemographic variables were captured by the Ensanut 2012; including age in years, sex, region and urban and rural dwelling and socioeconomic status (SES). We defined three geographic regions in Mexico: North, Center (includes Mexico City), and South. Locations with <2 500 inhabitants were classified as rural, and those with ≥2 500 inhabitants were classified as urban.[34] A socioeconomic index was constructed using a factor analysis using a principal components approach, that included household characteristics and assets.[34] The

index was computed for each respondent and then classified into tertiles (low, medium, and high) as cutoff points for socioeconomic status.[35]

Anthropometry. The body weight was measured in an electronic balance with a precision of 100 g, Tanita (Tokio, Japan) and the height with a stadiometer with precision of 1 mm, Dynatop (Mexico City). Anthropometry was measured by standardized personnel using the methods proposed by Lohman[36] and were standardized using Habicht's method.[37] Based on the body weight and height, the body mass index (BMI) was calculated and classified according to the WHO: BMI>18.5 and ≤24.9 kg/m^2= normal; 25-29.9 kg/m^2= overweight and BMI≥30= obesity.[38]

Vitamin D status definitions. The definition of VD status was based in the classification of 25-OH-D concentrations by Heaney and Holick: Deficiency <50 nmol/L (8-20 ng/mL), insufficiency ≥50 and <75 nmol/L (21-30 ng/mL) and VD sufficiency ≥75 nmol/L (> 30 ng/mL).[39]

Statistical analysis

The descriptive bivariate information is presented as means and 95%CI of the serum concentrations of 25-OH-D. The dietary intake of VD is presented as means and 95%CI. The prevalence and 95%CI of VDD was calculated and stratified by sociodemographic characteristics and BMI. The statistical comparisons between the dependent variable (VDD or VDI) and the independent variables (dwelling, region, BMI categories, SES and indigenous ethnicity) were made by multiple logistic regression models. Each model (VDD or VDI) was adjusted by the survey design using the module SVY of STATA SE v14 (College Station, USA, 2013). The significance was established with an alpha value <0.05 and 95%CI. To assess the representativeness of the final sample (n= 4 126), we compared the distribution of the sociodemographic and anthropometric characteristics in the whole sample of Ensanut 2012 (n= 24 500) and found no differences.

Ethical aspects

The protocol was reviewed and approved by the Committees of Research, Biosafety and Ethics in Research of Instituto Nacional de Salud Pública, Cuernavaca, Mexico. Informed consent letters were signed by the participants after a careful explanation of the aims, advantages and discomforts of the project.

Results

Sociodemographic and anthropometric characteristics

4 162 women aged 20-49 years representing 25 million of women at reproductive age were studied. The overall prevalence was 36.8% for VDD, and 49.8% for VDI. The VDD and VDI indices for normal BMI were 30.1 and 51.5%; 36.2 and 50.3% for overweight, and 43.0% (p<0.05) and 47.9% for obesity, respectively. By dwelling, VDD was higher in urban (40.2%) than in rural dwellings (25.1%, p<0.05). The urban VDI (48.7%) was not different from the rural (53.7%) (table I). In the South, the VDD concentration was significantly lower (25.9%), and the VDI higher (53.5%) than in the Central region, with 46.3% (p<0.05) and 45% (p<0.05), and in the North region (31.7%, p<0.05). VDI was significantly higher in the North (55.6%) than in the Center (45.0%, p<0.05).

Women in tertile 1 of SES had the lowest prevalence of VDD (22.6%), compared with tertile 2 (32.5%, p<0.05), and tertile 3 (48.8%).VDI prevalence was not different between tertiles of SES. There were no differences for VDD and VDI between non-indigenous and indigenous women (table I).

Mean serum concentrations of 25-OH-D and dietary intake of VD

The overall mean serum concentration of 25-OH-D was 56.7 (55.7, 57.8) nmol/L. The mean concentration of 25-OH-D was higher in women with normal BMI, 60.2 (58.6, 62.4) nmol/L, than in women with overweight, 57.1 (55.5, 58.7) nmol/L, p<0.05, or obesity 53.6 (52.0, 55.2) nmol/L, p<0.05. It was higher in rural 62.2 (60.6, 63.7) than in urban dwellings 55.2 (53.9, 56.5) nmol/L, p<0.05. The concentrations were lower in the North 57.6 (56.0, 59.1) nmol/L, p<0.05 and the Center 53 (51.2, 54.7) nmol/L, p<0.05 than in the South 61.9 (60.3, 63.4) nmol/L. Tertile 1 of SES had greater concentrations 63.0 (61.4, 64.7) nmol/L than tertile 2, 58.3 (56.5, 60.2) nmol/L, p<0.05, and tertile 3, 51.7 (50.2, 53.3) nmol/L, p<0.05. Indigenous women had an average concentration of 56.6nmol/L and non-indigenous women, of 58.8 nmol/L of 25-OH-D, p<0.05 (table II).

The overall mean of dietary intake of VD was 2.56 (2.27, 2.86) μg/d. Women with a normal BMI 2.24 (1.74, 2.74), overweight 2.70 (2.15, 3.25), and obesity 2.68 (2.10, 3.25) μg/d did not show significant differences (NS). Indigenous women ate more VD (2.59, IC95 2.28, 2.91)

Table I
PREVALENCE OF VITAMIN D DEFICIENCY AND INSUFFICIENCY IN MEXICAN WOMAN AGED 20 TO 49 YEARS. MEXICO, ENSANUT 2012

		n sample (n expanded)	*4 162 24 210 060*			
			VDD		*VDI*	
			%	*(95%CI)*	*%*	*(95%CI)*
Total			36.8	(33.7, 40.1)	49.8	(46.9, 52.7)
BMI	Normal		30.1	(24.3, 36.6)	51.5	(45.5, 57.5)
	Overweight		36.2	(31.1, 41.7)	50.3	(45.3, 55.4)
	Obesity		43.0*	(37.8, 48.3)	47.9	(42.9, 52.9)
Dwelling	Urban		40.2	(36.4, 44.1)	48.7	(45.1, 52.3)
	Rural		25.1*	(21.0, 29.6)	53.7‡	(49.7, 57.7)
Region	North		31.7*	(27.6, 36.0)	55.6	(51.3, 60.0)
	Center		46.3*	(40.8, 51.8)	45.0*	(39.8, 50.2)
	South		25.9	(22.1, 30.0)	53.5	(49.8, 57.2)
SES	Tertile 1		22.6	(19.2, 26.5)	56.8	(52.8, 60.7)
	Tertile 2		32.5*	(27.3, 38.1)	50.4	(45.2, 55.5)
	Tertile 3		48.8*	(43.5, 54.0)	45.1	(40.1, 50.3)
Indigenous ethnicity	No		33.2	(26.1, 41.2)	52.3	(44.5, 59.9)
	Yes		37.1	(33.8, 40.4)	49.7	(46.6, 52.7)

VDD: Vitamin D deficiency
VDI: Vitamin D insufficiency
SES: Socioeconomic status
BMI: Body Mass Index

Significantly different * ($p<0.05$) ‡ ($p<0.10$) of reference category; normal BMI, Rural dwelling, South region, Tertile 1 of SES, indigenous ethicity

than non-indigenous women (1.98, 95%CI 1.56, 2.39 μg/d, $p<0.05$). There were no differences in VD intake between categories of dwelling, region, SES, or VD serum status (table II).

Main dietary sources of vitamin D

Milk was drunk by 50.0% of the sample (231 mL/d), representing 55.9% of the mean daily intake of VD. Eggs were consumed by 48% of the sample (74.5 g/d), representing 53.7% of the mean daily intake of VD. Fish and sea food were eaten by 14.2% of the sample (60.1 g/d), representing 39.5% of the daily intake of VD. Other sources were ready-to-eat cereals, dairy products as such cheese, yogurts, cream and milk desserts, and other products of animal origin as such beef, pork, chicken meats and animal fats (table III).

The relative risk ratio (RRR) of present VDD or VDI by SES characteristics and BMI

The RRR of VDD or VDI was calculated by a multinomial logistic regression model in 4 162 women (table IV). The risk ratios (RRR) of VDD or VDI were significantly higher in women with overweight (1.85 and 1.44, $p<0.05$), with obesity (2.94 and 1.93, $p<0.001$), living in an urban dwelling (1.68 and 1.31, $p<0.06$), belonging to tertile 3 of socioeconomic status (5.32 and 2.22, $p<0.001$) or with indigenous ethnicity (2.86 and 1.70, $p<0.05$) respectively (table IV).

Discussion

VDD and VDI in Mexico are very frequent in adult women (36.8 and 49.8%, respectively). Our results confirm that, despite the intense sunlight in Mexico, the serum concentrations of 25-OH-D are low. The strengths of this study are the randomization and the national representativeness of the sample; we were able to measure 25-OH-D and the 24 h VD intake with appropriate instruments.

The NHANES III proved that VDD and VDI in Hispanic women older than 18 years was 76.2% and that indigenous women had a 3.3-fold probability of suffering these conditions compared with white women.[40] One reason is that ethnicity plays an important role in

Table II
Mean serum concentrations of 25-OH-D, and dietary intake of vitamin D in Mexican women aged 20 to 49 years. Mexico, Ensanut 2012

		n sample *n expansion*	*4 162* *24 210 060* *25-OH-D nmol/L* *Mean (95%CI)*	*869* *6 751 792* *VD intake (µg)* *Mean (95%CI)*
Total			56.7 (55.7,57.8)	2.56 (2.27,2.86)
BMI	Normal		60.2 (58.6,62.4)	2.24 (1.74,2.74)
	Overweight		57.1 (55.5,58.7)*	2.70 (2.15,3.25)
	Obesity		53.6 (52.0,55.2)*	2.68 (2.10,3.25)
Dwelling	Urban		55.2 (53.9,56.5)	2.67 (2.31,3.04)
	Rural		62.2 (60.6,63.7)*	2.24 (1.78,2.69)
Region	North		57.6 (56.0,59.1)*	2.70 (2.27,3.12)
	Center		53.0 (51.2,54.7)*	2.59 (2.09,3.09)
	South		61.9 (60.3,63.4)	2.44 (2.04,2.83)
SES	Tertile 1		63.0 (61.4,64.7)	2.26 (1.88,2.64)
	Tertile 2		58.3 (56.5,60.2)*	2.41 (1.99,2.83)
	Tertile 3		51.7 (50.2,53.3)*	2.85 (2.26,3.43)
Indigenous ethnicity	No		56.6 (55.5,57.7)	2.59 (2.28,2.91)
	Yes		58.8 (56.1,61.5)	1.98 (1.56,2.39)*
VD serum status	VDD		39.5 (38.6,40.4)*	2.50 (1.83,3.10)
	VDI		61.4 (60.8,61.9)*	2.58 (2.18,2.99)
	Optimal		86.9 (85.2,88.6)	2.68 (1.86,3.50)

VDD: Vitamin D deficiency
VDI: Vitamin D insufficiency
VD: Vitamin D
SES: Socioeconomic status
BMI: Body Mass Index

Significantly different * ($p<0.05$) ‡($p<0.10$) of reference category; normal BMI, Rural dwelling, South region, Tertile 1 of SES, indigenous ethnicity

Table III
Main dietary sources of vitamin D in Mexican women aged 20-49 years participating in Ensanut 2012. Mexico

Food *n sample (869)* *n expanded (6751792)*	*Frequency of consumption*		*Intake of food (g/100 g)*		*Content of VD in food (µg/100 g)*		*Contribution to the total intake of VD (%)*	
	%	*(95%CI)*	*Mean*	*(95%CI)*	*Mean*	*(95%CI)*	*Mean*	*(95%CI)*
Milk	50.0	(45.4, 54.7)	231	(208.5, 53.5)	1.80	(1.58, 2.02)	55.9	(51.8, 60.0)
Eggs	48.1	(43.5, 52.7)	74.5	(67.0, 82.1)	1.34	(1.19, 1.49)	53.7	(48.6, 58.7)
Fish and sea food	14.2	(10.9, 18.2)	60.1	(37.5, 82.6)	3.24	(0.24, 6.24)	39.5	(19.8, 59.2)
Ready to eat cereals	6.6	(4.5, 9.6)	48.8	(32.6, 65.0)	2.76	(1.45, 4.07)	46.5	(35.9, 57.0)
Other dairy products	36.8	(32.0, 41.8)	60.0	(38.0, 82.0)	0.45	(0.31, 0.58)	22.4	(17.9, 26.9)
Beef meat	16.9	(13.8, 20.6)	62.2	(37.9, 86.5)	0.70	(0.41, 0.99)	27.3	(20.4, 34.3)
Milk based desserts	5.1	(3.3, 7.8)	51.3	(28.9, 73.7)	2.08	(0.96, 3.19)	28.2	(16.3, 40.1)
Chicken meat	23.5	(19.3, 28.3)	129.7	(101.4, 158.0)	0.18	(0.15, 0.22)	24.1	(19.1, 29.9)
Pork meat	21.6	(17.7, 26.0)	50.5	(38.2, 62.9)	0.44	(0.33, 0.55)	24.8	(18.6, 31.0)
Fat (animal origin)	33.0	(28.3, 38.1)	18.2	(15.2, 21.2)	0.12	(0.09, 0.14)	12.8	(9.2, 16.5)

VD: vitamin D
Other dairy products: cheeses: aged, cotija, grill, camembert, cheddar, chihuahua, cottage, cream, *fresco*, goat, gouda, manchego, parmesan, Swiss; yogurt, curdled milk, drinkable yogurt
Fat: lard or average animal fat, butter, mayonnaise
Data from an iterative 24h dietary recall questionnaire

Table IV
MULTINOMIAL LOGISTIC REGRESSION MODEL TO ASSESS THE RISK OF VITAMIN D DEFICIENCY OR INSUFFICIENCY IN MEXICAN WOMEN 20-49 YO, BY SOCIODEMOGRAPHIC CHARACTERISTICS AND BMI. MEXICO, ENSANUT 2012

n sample *n expanded*		*4 162* *24 210 060*		
		RRR	*(95%CI)*	*p*
VDD				
Age		1.01	(0.98, 1.03)	0.354
BMI	Normal	Ref.		
	Overweight	1.85	(1.20, 2.83)	0.005
	Obesity	2.94	(1.92, 4.52)	<0.001
Dwelling	Rural	Ref.		
	Urban	1.68	(1.14, 2.48)	0.009
Region	South	Ref.		
	North	1.38	(0.91, 2.10)	0.131
	Center	3.19	(2.12, 4.80)	<0.001
SES	Tertile 1	Ref.		
	Tertile 2	1.44	(0.96, 2.15)	0.074
	Tertile 3	5.32	(3.31, 8.53)	<0.001
Indigenous ethnicity	No	Ref.		
	Yes	2.86	(1.53, 5.32)	0.001
VDI				
Age		1.00	(0.98, 1.02)	0.918
BMI	Normal	Ref.		
	Overweight	1.44	(1.02, 2.02)	0.039
	Obesity	1.93	(1.37, 2.72)	<0.001
Dwelling	Rural	Ref.		
	Urban	1.31	(0.99, 1.74)	0.058
Region	South	Ref.		
	North	1.43	(1.03, 1.98)	0.035
	Center	1.76	(1.28, 2.43)	0.001
SES	Tertile 1	Ref.		
	Tertile 2	0.95	(0.69, 1.32)	0.012
	Tertile 3	2.22	(1.46, 3.39)	<0.001
Indigenous ethnicity	No	Ref.		
	Yes	1.70	(1.01, 2.87)	0.047

Optimal VD status was the reference. RRR=relative risk ratio

the cutaneous transformation of VD.[41-43] Previous studies suggest that the concentrations of 25-OH-D for the optimal bone and calcium and phosphorous metabolism differ among ethnic groups. In this study the probability of VDD was higher in indigenous women, a group with lower dietary intake of VD than non-indigenous women. One limitation of the present study is that, because of its cross sectional design, it does not allow to infer a causality, in the associations observed, of the higher probability of VDD in indigenous women. We hypothesized that the use of long-sleeve blouses and skirts worn by this population interferes with the UV radiation during work days; also, their low intake of VD and the more intense pigmentation of their skin make them vulnerable to VDD and VDI. Nevertheless the probability of VDD may be due to a genetic predisposition that is not linked to the frequently occurring bone fractures in Caucasian population. A cohort study found that 15% of Mexican-American women showed a polymorphism in the gen codifying for the cellular VD receptor; although the serum concentrations of 25-OH-D were comparable between phenotypes, women with polymorphism experienced bone demineralization earlier in life than women without it.[44]

Another point is that the majority of studies for defining the cut-off points for VDD and VDI and the associated alterations have been carried out in white persons. This has several implications: they may not be adequate for a population with darker skin. Thus, the available cut-off points are the best proxy available for our population.[3,13,39,45]

Women living in rural communities had a lower probability of VDD than those living in urban localities, probably because people in urban localities stay under a roof for large periods and are therefore less exposed to sunlight; also, they suffer higher levels of air pollution. A limitation of this study was that it includes no measurements of sun exposure or nutritional supplement consumption, which is not common among the Mexican population.[46]

Urbanization seems to be a factor preventing sunlight exposure, as is demonstrated by the fact that women living in the North and Center of the country had higher prevalence of VDD than those living in the South. The Center and North regions are more urbanized than the South; urbanization has been associated with less open air activities and a higher level of air pollution.[47,48] This is supported by the comparable VD intake in all regions. Thus the differences in 25-OH VD3 can only be accounted for by the intensity of sun-light exposure and differences in skin pigmentation.

Milk intake was the main dietary source of VD among the Mexican population, along with eggs, fish and seafood. The total intake in women was very low (2.5 μg/d) compared with the 10 μg/d recommended by the IOM.[49] The fortification of foods, especially milk, with VD and sessions of prudent exposure to sunlight, below the time of risk for skin cancer, are recommended. To our knowledge, there is no governmental initiative

to prevent VDD/VDI, as such food supplementation programs and recommendations for a reasonable sun exposure, among the Mexican population.

Another finding of our study was the greater prevalence of VDD in obese women compared with women with a normal BMI. Discrepancies between the etiology of this association were postulated by Foss and colleagues in 2008, who hypothesized that in primitive human beings VD was a consequence of the changes in sunlight intensity during the winter and a way to accumulate body fat.[50] A meta-analysis of 21 cohorts of adults, found that a higher BMI is associated with lower levels of 25-OH-D and a slight increase in the BMI, with a reduction in the concentrations of 25-OH-D, with the resulting recommendation to reduce obesity, whereby a reduction of VDD is expected.[17] Obese persons have a larger body surface area on which to receive a larger amount of UV irradiation and therefore have higher VD synthesis rates. They documented that after 24 hours of exposure to sunlight, the increase in 25-OH-D serum concentrations was 53% less in obese than in non-obese persons, and explained that this was due to the large VD stores in the fat.[51] In Mexico, 35.5% of adult women are overweight, and 37.5% are obese.[52] Therefore, this population is more susceptible to VDD and has a higher risk of the pathologies associated to VDD: bone diseases, metabolic syndrome, cardiovascular diseases, infections and general mortality.[15-24]

Conclusions

In Mexico, the prevalence of VDD and VDI is a public health issue among women aged 20-49 years**.** Obesity was associated with VDD when no other factors that can predict it are present. The dietary intake of VD was not associated with serum concentrations of 25-OH-D. Women living in rural dwellings, and in the southern region of the country, and belonging to the lowest tertile of SES, had better VD status probably because of a higher sun exposure. The high prevalence of VDD/VDI in Mexican women calls for stronger actions from the health authorities, such as straightening the actual policy of food supplementation and recommending a reasonable exposure to sunlight.

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Taskworks S. V. and A.C. designed the overall project, interpreted the data and drafted the manuscript; A. C. performed the statistical analysis. R.R. developed the laboratory determination of 25-OH-D.

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