

Vitamin D Deficiency and Association With Body Mass Index and Lipid Levels in Hispanic American Adolescents

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Abstract

In this retrospective study, vitamin D deficiency was examined with body mass index (BMI) and lipid levels in a sample of Hispanic American adolescents. The prevalence of vitamin D deficiency among 234 subjects aged 13 to 19 years was 27.8%. Vitamin D deficiency was significantly associated with a BMI of 85 kg/m² or higher (odds ratio = 2.02, 95% confidence interval = 1.11–3.69, $\chi^2 = 5.37$, $P = .021$), and 55.6% of the sample were overweight or obese (BMI ≥ 85). In the overweight or obese subjects, vitamin D deficiency was significantly associated with higher mean lipid levels compared with those with adequate vitamin D levels: total cholesterol = 165 \pm 28.6 mg/dL versus 145.7 \pm 27.5 mg/dL, $P = .0003$; low-density lipoprotein = 92.7 \pm 25.7 mg/dL versus 80.8 \pm 21.4 mg/dL, $P = .007$; and triglycerides = 148.9 \pm 97.1 mg/dL versus 90.6 \pm 40.7 mg/dL, $P = .0000$. The mean triglyceride level of 148.9 mg/dL in the overweight or obese subjects was in the dyslipidemic range. In the underweight and healthy weight subjects (BMI ≤ 84), there was no statistically different lipid levels between the vitamin D adequate and vitamin D deficient groups. The effect of vitamin D on lipid levels was confirmed by regression analysis. Elevated lipids and dyslipidemic triglyceride levels, associated with vitamin D deficiency in overweight or obese Hispanic American adolescents, indicates a need for clinical monitoring and appropriate intervention.

Keywords

vitamin D, general pediatrics, obesity, childhood obesity, adolescents, cholesterol, lipids

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Introduction

The best indicator of vitamin D status is the serum 25-hydroxyvitamin D [25(OH)D] concentration.¹ The Institute of Medicine defines vitamin D deficiency as serum 25(OH)D level of less than 20 ng/mL.^{1,2} By this definition, the prevalence of vitamin D deficiency in a cross-sectional study of healthy urban adolescents in Boston, Massachusetts, was 42%.³ The authors concluded that vitamin D deficiency was present in many US adolescents, with prevalence being highest in African American teenagers and during winter, although the problem seems to be common across sex, season, and ethnicity.³ In the 2001 to 2006 National Health and Nutrition Examination Survey, the prevalence of vitamin D deficiency in healthy weight US adolescents and children was 21%. The prevalence dramatically increased to 29%, 34%, and 49%, respectively, in overweight, obese, and severely obese children and adolescents.⁴

The primary role of vitamin D is the mineralization of bone by regulating osteoblast activity and facilitating the absorption of calcium and phosphorus from the intestines and calcium from the kidneys via its active metabolite 1,25-dihydroxyvitamin D.^{5,6} However, many studies have shown an association between vitamin D deficiency and chronic diseases including cardiovascular disease and its risk factors including dyslipidemia.⁵⁻⁹ In a nationally representative sample of children aged 1 to 21 years, in the National Health and Nutrition Examination Survey of 2001 to 2004, the authors

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Table 1. Summary Description of Sample.

	Female (n = 111)	Male (n = 123)	Total (N = 234)
BMI groups, n (%)			
Under/healthy weight (BMI < 85%)	50 (45 %)	54 (43.9%)	104 (44.4%)
Overweight/obese (BMI ≥ 85%)	61 (55%)	69 (56.1%)	130 (55.6%)
Vitamin D status, n (%)			
Vitamin D deficient, 25(OH)D < 20 ng/mL	40 (36%)	25 (20.3%)	65 (27.8%)
Vitamin D adequate, 25(OH)D ≥ 20 ng/mL	71 (64%)	98 (79.7%)	169 (72.2%)

Abbreviations: BMI, body mass index; 25(OH)D, serum 25-hydroxyvitamin D.

concluded that vitamin D deficiency is common in the general US pediatric population and is associated with adverse cardiovascular risks.¹⁰ In a cross-sectional study of children aged 1 to 5 years from Canada, 25(OH)D levels were inversely associated with circulating lipids in early childhood, suggesting that vitamin D exposure in early life may be a modifiable risk for cardiovascular disease.⁹ In African American adolescents residing in the Midwestern United States, 25(OH)D levels were inversely correlated to TC (total cholesterol) and non-HDL-C (high-density lipoprotein cholesterol) levels.¹¹

From the studies to date, it is clear that vitamin D deficiency is prevalent in US adolescents and is highly prevalent in minority and obese populations, and it may be associated with elevated lipid panels. However, there are no studies to date on the association between vitamin D deficiency, obesity, and lipid levels in Hispanic American adolescents. The purpose of the present study is to determine the relationship of vitamin D deficiency with body mass index (BMI) and lipid levels in otherwise healthy Hispanic American adolescents.

Subjects and Methods

A retrospective chart review of data collected from February 2016 to August 2017 was conducted at a pediatric clinic in Huntington Beach, California. From an initial 264 adolescents aged 13 to 19 years presenting for routine physical examinations, 238 were Hispanic. None were taking vitamin D supplementation. Four were excluded for chronic medical illnesses (specifically diabetes and hypertension), resulting in a final sample of 234 healthy Hispanic adolescents.

As part of routine physical examinations all subjects had BMI and vital signs recorded. Fasting blood sugar (FBS), 25(OH)D level, and a standard lipid panel were drawn. The standard lipid panel reports TC, low-density lipoprotein (LDL), HDL, triglycerides (TG), and TC/HDL ratio.

In this study, vitamin D deficiency is defined as a 25(OH)D level <20 ng/mL, and vitamin D adequacy is defined as a 25(OH)D level of ≥20 ng/mL, according to

Institute of Medicine parameters.^{1,2} Dyslipidemia in adolescents is defined as TC ≥ 170 mg/dL, LDL ≥ 110 mg/dL, and TG ≥ 90 mg/dL, either individually or in combination, according to the guidelines from the National Institutes of Health and the National Cholesterol Education Program.¹² BMI is defined as weight in kilograms/height in meters squared. Per Centers for Disease Control and Prevention guidelines, BMI < 5% is underweight, 5% to 84% is healthy weight, 85% to 94% is overweight, and 95% or higher is obese.¹³

SPSS 24 and Epi Info 7 were used in the analyses. Chi-square test of association was applied to binary vitamin D status and BMI percentile groups. ANOVA of vitamin D levels and BMI percentile was performed. Comparison of means for lipid tests, blood sugar, and blood pressure was done by *t* test according to vitamin D status, and further analyzed according to BMI percentile. Pearson's correlation coefficient was determined for key study variables. Linear regression of the vitamin D status and BMI was done for each lipid test with significant correlation to vitamin D. Statistical significance was set at a $P \leq .05$.

Results

The final sample of 234 Hispanic American adolescents consisted of 111 females (47.4%) and 123 males (52.6%). The mean sample age was 16 years. The 25(OH)D levels ranged from 6.7 ng/mL to 58 ng/mL, with a sample mean of 24.4 ng/mL. Of the total sample, 27.8% (n = 65) were vitamin D deficient and 72.2% (n = 169) were vitamin D adequate. A summary of sample characteristics related to sex, BMI, and vitamin D status is presented in Table 1.

Of the 65 subjects who were vitamin D deficient, 44 (67.7%) were overweight or obese compared with 21 (32.3%) who were healthy or underweight. This difference was significant, odds ratio = 2.02, 95% confidence interval = 1.11-3.69, $\chi^2 = 5.37$, $P = .021$, indicating that the odds of overweight and obese subjects to be vitamin D deficient was twice that of normal and underweight subjects. The mean vitamin D level in the overweight

Table 2. One-Way ANOVA of BMI Percentile and Vitamin D Level.

BMI % Category	Total (N = 234)	Mean Vitamin D, ng/mL	Standard Deviation
Underweight; BMI < 5%	5	26.5	5.8
Healthy weight; BMI 5% to 84%	99	26	7.9
Overweight; BMI 85% to 94%	55	24	6.6
Obese; BMI 95% to >99%	75	22.5	6.5

Abbreviation: BMI, body mass index.

Table 3. Overweight and Obese Subjects, BMI 85% to >99%; Means of Lipid Panel Levels, FBS, and BP by Vitamin D Status.

	Vitamin D Deficient (n = 44), Mean ± SD	Vitamin D Adequate; (n = 86), Mean ± SD	t	P ^a
Lipid panel				
Total Cholesterol	165 ± 28.56	145.67 ± 27.52	3.74	.0003
LDL	92.65 ± 25.67	80.84 ± 21.41	2.74	.007
Triglycerides	148.9 ± 97.1	90.6 ± 40.74	4.82	.0000
HDL	45.67 ± 11.34	46.58 ± 11.12	-0.44	.661
TC/HDL	3.83 ± 1.11	3.24 ± 0.73	3.60	.0005
Other tests				
FBS	82.61 ± 14.88	83.88 ± 10.78	-0.55	.5803
Systolic BP	117.41 ± 14.1	116.98 ± 14	0.17	.8683

Abbreviations: LDL, low-density lipoprotein; HDL, high-density lipoprotein; TC, total cholesterol; FBS, fasting blood sugar; BP, blood pressure.
^aSignificant *P* values are bolded.

and obese subjects combined was 23.1 ± 6.6 , and in the underweight and healthy weight subjects combined it was 26.1 ± 7.8 ($t = -3.11$, degrees of freedom [df] = 232, $P = .002$). In Table 2, ANOVA demonstrates the significant difference in mean vitamin D levels according to BMI percentile category ($F = 3.64$, $df = 3$, $P = .014$).

A comparison of lipid means for those with vitamin D deficiency compared with those with adequate vitamin D in the sample as a whole shows significant differences in TC (160 ± 28.5 vs 147.1 ± 26.22 , $P = .0012$), LDL (87.2 ± 24 vs 77.6 ± 21.8 , $P = .0067$), and TG (127 ± 88.2 vs 84.8 ± 42.5 , $P = .000$). However, given that a large percentage of the sample is overweight or obese, a factor known to influence vitamin D levels, the analyses skew to that portion. It is more accurate and meaningful to separate the underweight and healthy weight subjects from the overweight and obese subjects to discern the true effect of vitamin D on lipid levels. This is done with independent samples *t* tests in Tables 3 and 4, demonstrating that there is a significant influence of vitamin D deficiency on lipid levels in the overweight and obese subjects, but not in the underweight and healthy weight subjects.

The correlation of key study variables, vitamin D, and BMI, along with the lipid panel tests, is presented in Table 5.

As expected, vitamin D is significantly, negatively correlated with BMI, TC, LDL, and TG. BMI is significantly,

positively correlated with LDL and TG. Most of the lipids are significantly, positively correlated with each other, with the exception of HDL and LDL, which has a modest negative correlation. HDL is significantly, negatively correlated with BMI, TC, and TG.

To further probe the respective influence of vitamin D and BMI on lipid levels, simultaneous linear regression of the 2 variables was performed for each of the lipid tests significantly correlated to vitamin D: TC, LDL, and TG. The results are shown in Table 6.

The regression analyses shown in Table 6 indicate that vitamin D is statistically significant in predicting TC while BMI is not. Both vitamin D and BMI are significant in predicting LDL. Both vitamin D and BMI are significant predictors of TG; however, the influence of vitamin D is stronger than that of BMI. The negative, significant correlations between vitamin D and TC, LDL, and TG identified in the Table 5 correlation matrix are confirmed. The R^2 (correlation coefficient) is relatively small for the panel of regressions as the independent cholesterol tests influence each other.

Discussion

Overweight and obese adolescents comprised 55.6% of the study sample, and 33.9% of them were vitamin D deficient. The overweight or obese subjects in this

Table 4. Under and Healthy Weight Subjects, BMI <5% to 84%; Means of Lipid Panel Levels, FBS, and BP by Vitamin D Status.

	Vitamin D Deficient (n = 21), Mean ± SD	Vitamin D Adequate, (n = 83), Mean ± SD	t	P
Lipid panel				
Total cholesterol	149.48 ± 25.94	148.55 ± 24.88	0.15	.8805
LDL	76.29 ± 15.83	74.23 ± 21.88	0.40	.6865
Triglycerides	81.1 ± 36.88	78.8 ± 43.71	0.22	.8256
HDL	58.05 ± 15.32	57.67 ± 13.35	0.11	.915
TC/HDL	2.73 ± 0.56	2.67 ± 0.67	0.36	.7186
Other tests				
FBS	83.33 ± 5.75	83.77 ± 10.63	-0.18	.856
Systolic BP	108.95 ± 14.04	107.6 ± 11.82	0.45	.6532

Abbreviations: LDL, low-density lipoprotein; HDL, high-density lipoprotein; TC, total cholesterol; FBS, fasting blood sugar; BP, blood pressure.

Table 5. Correlation Matrix: Vitamin D, BMI, and Lipid Tests^a.

		Vitamin D	BMI	Total Cholesterol	LDL	Triglycerides
Vitamin D	Pearson correlation	1	-.132*	-.198**	-.168*	-.301**
	P		.043	.002	.010	.000
BMI	Pearson correlation	-.132*	1	.086	.183**	.183**
	P	.043		.188	.005	.005
Total cholesterol	Pearson correlation	-.198**	.086	1	.834**	.429**
	P	.002	.188		.000	.000
LDL	Pearson correlation	-.168*	.183**	.834**	1	.314**
	P	.010	.005	.000		.000
Triglycerides	Pearson correlation	.301**	.183**	.429**	.314**	1
	P	.000	.005	.000	.000	
HDL	Pearson correlation	.069	-.252**	.231**	-.125	-.362**
	P	.296	.000	.000	.056	.000

Abbreviations: BMI, body mass index; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

^aN = 234. Two-tailed significance, significant P values are bolded.

*Correlation significant at the .05 level. **Correlation significant at the .01 level.

sample were twice as likely to be vitamin D deficient as the underweight or healthy weight subjects. As shown in Table 2, higher BMI levels were associated with lower vitamin D levels. Obesity is recognized to be associated with vitamin D deficiency as adipose tissue sequesters 25(OH)D, resulting in an inverse relationship between vitamin D and BMI.^{5,14-17} Therefore, our results are in agreement with previous researchers who concluded that vitamin D deficiency is more prevalent in those who are obese.

In the study sample as a whole, the means of TC, LDL, TC/HDL ratio, and TG in those with vitamin D deficiency and elevated lipid panels were significantly higher compared with those with adequate vitamin D. However, these results reflect the large percentage of overweight and obese subjects in the sample. Furthermore, analysis according to BMI percentile shows that within the overweight or obese group the

lipid panels of those with vitamin D deficiency were significantly higher compared with those with adequate vitamin D levels (Table 3). Notably, mean TG was in the dyslipidemic range as it was greater than 90 mg/dL (according to National Institute of Health/National Cholesterol Education Program parameters) in the overweight or obese vitamin D deficient group. In the healthy/underweight group, there were no statistically significant differences in any lipid tests between those with vitamin D deficiency and those with vitamin D adequacy (Table 4). In Table 6, regression analysis of the key variables, vitamin D and BMI, demonstrates that vitamin D level has a significant predictive effect on TC, LDL, and TG. The relationship to vitamin D is inverse, that is, lower vitamin D is associated with higher TC, LDL, and TG. BMI is also positively related to LDL and TG; however, the influence of BMI on TG is weaker than that of vitamin D. Additional comparison of means

Table 6. Linear Regression of Vitamin D and BMI With Lipid Panel^a.

Lipid:	Total Cholesterol			LDL			Triglycerides		
	Coefficient (SE)	F Test	P	Coefficient (SE)	F test	P	Coefficient (SE)	F test	P
Vitamin D	-0.72 (0.25)	8.57	.0038*	-0.463 (0.2)	5.18	.0238	-2.39 (0.53)	20.2	.00001
BMI	6.6 (7.01)	0.89	.3473	14.75 (5.8)	6.46	.0117	35.37 (15.18)	5.43	.0207
Constant	163.14 (8.75)	347.35	.0000	80.24 (7.25)	122.68	.0000	127.65	45.35	.00000
R ²		0.04			0.05			0.11	
F statistic		5.19			6.65			14.45	

Abbreviations: BMI, body mass index; LDL, low-density lipoprotein; SE, standard error.

*Significant P values are bolded.

for fasting blood sugar and systolic blood pressure revealed no significant differences between those with vitamin D deficiency or adequacy in either BMI group (Tables 3 and 4).

A number of factors influence the blood level of vitamin D in humans. Diet, exposure to sunlight, vitamin D supplementation, and gastrointestinal, hepatic, and renal diseases are some of the well-documented factors.⁵ In addition, lower 25(OH)D levels have been associated with older age, winter season, higher BMI, black race/ethnicity, and female gender.¹⁸⁻²¹ Some of these confounding factors were controlled by including only healthy Hispanic adolescents living in Southern California in the study. The higher prevalence of vitamin D deficiency in female Hispanic adolescents compared with male Hispanics (36% and 20.3%, respectively, in this study) is in accordance with data from other epidemiological studies where females were noted to have a higher prevalence of vitamin D deficiency.¹⁹⁻²¹

In a systematic review of the literature for the US Preventive Services Task Force, Lozano et al reported that there have been no randomized controlled studies relevant to selective or universal screening for multifactorial dyslipidemia in children and adolescents.²² The elevated lipid panels and dyslipidemic TG in overweight or obese Hispanic adolescents associated with vitamin D deficiency in our study indicates a need for lipid screening in this population. The clinical implications and possibility of future cardiovascular risk needs to be ascertained by longitudinal studies.

This study did not include assessment of specific dietary intake, outdoor sun exposure, and family history of hyperlipidemia, nor does it include data analysis by season. The study was limited to Hispanic adolescents in Southern California, and the conclusions may not be applicable to other ethnic groups and to all healthy adolescents in the United States.

We conclude that vitamin D deficiency is prevalent in healthy Hispanic American adolescents and highly

prevalent in those who are overweight or obese. Vitamin D deficiency is associated with higher mean TC, LDL, and TG in overweight or obese Hispanic adolescents when compared with those with adequate vitamin D. Although both BMI and vitamin D influence lipid levels, in regression analysis with TC, vitamin D enters the model at a statistically significant level while BMI does not. Vitamin D deficiency is also significantly predictive of higher mean LDL and TG along with BMI, but with a stronger correlation to TG than BMI. Vitamin D deficiency was associated with dyslipidemic TG levels in the overweight or obese adolescents. There was no significant difference in lipid levels related to vitamin D level in the underweight/healthy weight adolescents. These findings suggest a need for future research on the clinical implications of vitamin D deficiency and elevated lipid panels in overweight or obese Hispanic American adolescents, as well as appropriate clinical monitoring and intervention.

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Author Contributions

MK: Principal Author. Contributed to study design, data analysis, writing paper.

GE: Co-author, contributed to data analysis, writing paper.

JC: Co-author, contributed to data analysis, writing paper.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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