Vitamin D Status Is Associated with Metabolic Syndrome in a Clinic-Based Sample of Hispanic Adults

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Abstract

Background: Vitamin D status has been associated with metabolic syndrome (MetSyn) and its components in different populations, but few studies have assessed this among Hispanics. The objective of this analysis was to assess such association in a clinic-based sample of Hispanic adults.

Methods: Medical records were reviewed retrospectively for the years 2005–2013. MetSyn was assessed using the revised NCEP-ATP III criteria. Vitamin D status was evaluated from reported serum 25(OH)D levels. A multivariable logistic regression model was used to assess the association between MetSyn risk and vitamin D status, controlling for important confounders.

Results: From 1379 medical records evaluated, 712 met the inclusion criteria. Most were females (62.6%), with a mean age of 53.8 ± 14.1 years, mean body mass index (BMI) of 30.1 ± 6.4 kg/m², and mean serum 25(OH)D levels of 24.4 ± 8.3 ng/mL. MetSyn was identified in 40.5% of the participants. Serum 25(OH)D levels in those with MetSyn (22.7 ± 8.0 ng/mL) were significantly lower compared to those without MetSyn (25.5 ± 8.4 ng/mL; $P < 0.001$). Serum 25(OH)D levels were inversely correlated to triglycerides, waist circumference, and fasting blood glucose ($P < 0.05$). In the multivariable logistic regression model, decreased serum 25(OH)D levels were associated with higher odds of MetSyn, even after adjusting for age, gender, BMI, and seasonality.

Conclusion: In this clinic-based sample, the odds of MetSyn increased as serum 25(OH)D levels decreased. These results have important public health implications for developing recommendations directed to increase vitamin D status in this sample.

Introduction

METABOLIC SYNDROME (MetSyn) is a major public health concern because it is associated with type 2 diabetes mellitus, cardiovascular disease (CVD), and kidney disease.^{1–5} The epidemiological concept of MetSyn initiated from the observation that patients with CVD had a combination of metabolic risk factors, such as abnormal values of waist circumference (WC), blood pressure (BP), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and fasting blood glucose (FBG).⁴ In the United States, individuals with MetSyn have higher annual healthcare costs compared to those without MetSyn.⁶ According to the American Heart Association, 34% of US adults have MetSyn.⁷ In Hispanic adults living in Puerto Rico, the burden of MetSyn is slightly higher, with an age-adjusted prevalence

of 38%, as estimated from a representative sample of 859 adults from the San Juan metropolitan area.¹

Recent evidence shows that vitamin D deficiency is associated with a higher prevalence of MetSyn and its components.^{8–11} Vitamin D is a vitamin needed for adequate calcium absorption, but recent studies have shown its action on different tissues.¹² Currently, vitamin D deficiency [25(OH)D levels < 20 ng/mL] is a public health problem worldwide, with a high prevalence among individuals with darker skin.¹³ In the United States, it has been estimated that vitamin D deficiency affects 32% of adults.¹⁴ Similarly, a high prevalence of vitamin D deficiency (25%) and vitamin D insufficiency [25(OH)D levels < 30 ng/mL; 44%] has been reported in a large sample of adults in Puerto Rico ($n = 4090$), an island with plenty of sunshine all year round.¹⁵

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Although the association between vitamin D status and MetSyn has been found in some populations,^{8–11} data in Hispanics, a group at high risk of MetSyn and its components, are scarce. To start addressing this gap in the literature, the present study examined the association between vitamin D status and MetSyn and its components in a group of Hispanic adults living in Puerto Rico.

Materials and Methods

Research design

In this clinic-based study, the medical records of noninstitutionalized individuals attending the “Endocrinology, Diabetes, and Metabolism Clinic,” a private clinic located in the municipality of Utuado, Puerto Rico, were reviewed retrospectively during the years 2005–2013. The inclusion criteria for selecting the medical records were as follows: age ≥ 20 years old; having complete data on weight, height, WC, and BP; and with laboratory test results for serum 25(OH)D, TG, HDL-C, and FBG. Subjects who did not have serum 25(OH)D levels measured within 30 days of the anthropometric measurements or other pertinent laboratory test results were excluded from the study.

Data collection

A data collection sheet was used to extract the information from the medical records, which included demographics (age and sex), anthropometrics, and blood test results. Weight and height were routinely measured using a physician scale with a height rod (Model 338; Detecto), and WC was routinely measured using a standardized tape. These measurements were taken by the clinic staff following standard procedures. Serum levels for 25(OH)D (including the laboratory method used), HDL-C, TG, FBG, and systolic and diastolic BP were extracted from the medical records. The blood test results were collected all year round, and the date of the serum 25(OH)D was recorded to adjust for seasonality (although the weather in Puerto Rico is warm and humid year round and there are only two seasons, rainy and dry). BP was measured by the clinical staff using a digital monitor (Omron HBP-1300) with participants seated quietly in a chair for at least 1 min before taking the measurement, with feet on the floor and arm supported at chest level. Finally, prescribed antihypertensive, hypoglycemic, and lipid-lowering medications were also recorded.

Data management

Serum 25(OH)D levels were mainly analyzed by immunoassay methods (97%). Vitamin D status was classified using two cutoff points, as established by the Institute of Medicine and the Endocrinology Society. Cutoff points established by the Institute of Medicine¹⁶ were used to define vitamin D deficiency [25(OH)D levels <12 ng/mL] and inadequacy (12–19 ng/mL). However, we also used the cutoff points from the Endocrinology Society to classify levels as insufficient, if levels were 20–29 ng/mL, and as optimal, if levels were ≥ 30 ng/mL.¹⁷

MetSyn was defined according to the revised National Cholesterol Education Program’s Adult Treatment Panel III report (NCEP-ATP III),² which requires at least three or more of the following criteria to be met: (1) abdominal obesity (WC

≥ 102 cm in men and ≥ 88 cm in women), (2) hypertriglyceridemia (TG level ≥ 150 mg/dL or 1.7 mM or taking lipid modifying medication), (3) low HDL-C (<40 mg/dL or 1.0 mM in men and <50 mg/dL or 1.3 mM in women or lipid modifying medication), (4) elevated FBG (≥ 100 mg/dL or 5.6 mM or taking antihyperglycemic medication), and (5) elevated BP (systolic BP ≥ 130 mmHg, diastolic BP ≥ 85 mmHg, or taking antihypertensive medication).

The Institutional Review Board of the Medical Sciences Campus of the University of Puerto Rico approved the study. To assure confidentiality, a unique identification number was assigned to each medical record, which was not associated to the original record number.

Statistical analyses

Baseline characteristics were summarized using descriptive statistics (mean and standard deviation) for continuous variables and frequency distributions for categorical variables. Student’s *t*-test was used to assess differences in serum 25(OH)D in subjects with and without the MetSyn. Analysis of covariance was used to compare differences across individual MetSyn components. Pearson’s correlation coefficient was used to assess the relationship between serum 25(OH)D and each MetSyn component level. Logistic regression was used to assess the association between vitamin D and MetSyn after adjustment for age, gender, body mass index (BMI), and date of serum 25(OH)D analysis (to account for possible seasonal variation). All analyses were performed using SPSS Statistical Package (SPSS version 21.0 for Windows, 2012; SPSS, Inc.). Statistical significance was set at $P < 0.05$.

Results

From 1379 medical records evaluated, 712 (51.6%) met the inclusion criteria for the analysis. The characteristics of the study sample are shown in Table 1. Participant’s mean age was 53.8 ± 14.1 years and most were females (62.6%). A total of 80.8% of the sample was overweight (36.1%) or obese (44.7%). Men had significantly higher mean BMI compared to women, but fewer men were classified as having high WC compared to women. Men had higher mean levels of TG and lower mean levels of HDL-C compared to women ($P < 0.05$). Mean serum 25(OH)D levels were 24.4 ± 8.3 ng/mL, which were higher in men compared to women ($P < 0.05$). Only 5.1% of the participants were considered deficient and 30.9% had inadequate levels according to the Institute of Medicine’s cutoff points. However, using the Endocrinology Society-recommended cutoff points, 76.2% was considered as having nonoptimal levels. MetSyn (three or more components) was identified in 40.5% ($n = 289$) of the study population.

Mean serum 25(OH)D levels by MetSyn status and its components is presented in Table 2. Serum 25(OH)D levels in those with MetSyn (22.7 ± 8.0 ng/mL) were significantly lower compared to those without MetSyn (25.5 ± 8.4 ng/mL; $P < 0.001$). In addition, women with MetSyn had significantly lower 25(OH)D levels compared to men with MetSyn (21.8 ± 8.0 ng/mL vs. 23.5 ± 7.9 ng/mL; $P < 0.001$). When each component was analyzed separately, serum 25(OH)D levels were significantly lower in those with high WC and TG and low HDL-C compared to those without these components in men ($P < 0.01$). In women, serum 25(OH)D levels were significantly lower in those with

TABLE 1. DEMOGRAPHICS, CLINICAL, AND BIOCHEMICAL CHARACTERISTICS OF STUDY PARTICIPANTS

Parameters	Total (N = 712)	Men (n = 266)	Women (n = 446)	P value
Age (years)	53.6 ± 15.1	53.8 ± 14.1	53.4 ± 15.6	
BMI (kg/m ²)	30.1 ± 6.4	30.8 ± 5.9	29.7 ± 6.6	<0.001
Systolic BP (mmHg)	127 ± 18.6	130 ± 19.4	125 ± 17.8	<0.001
Diastolic BP (mmHg)	78.2 ± 10.7	80.4 ± 9.7	76.9 ± 11.1	<0.001
High BP ^a (%)	18.5	22.9	15.9	<0.001
FBG (mg/dL)	122 ± 56.1	133 ± 63.5	116 ± 50.2	<0.001
High FBG ^b (%)	52.5	65.0	45.0	<0.001
HDL-C (mg/dL)	45.8 ± 12.4	40.6 ± 9.2	49.0 ± 13.0	<0.001
Low HDL-C ^c (%)	46.6	84.9	23.7	<0.001
WC (cm)	96.1 ± 15.2	103 ± 12.6	92.2 ± 15.2	<0.001
High WC ^d (%)	52.6	44.3	52.6	<0.001
TG (mg/dL)	152 ± 116.7	174 ± 149.4	139 ± 89.4	<0.001
High TG ^e (%)	37.0	43.2	33.4	<0.001
25(OH)D levels (ng/mL)	24.4 ± 8.3	25.2 ± 8.1	23.9 ± 8.4	<0.001
Deficient (<12 ng/mL) (%)	5.1	3.8	5.8	<0.001
Inadequate (12–19 ng/mL) (%)	30.9	28.9	32.1	<0.001
Insufficiency (20–29 ng/mL) (%)	40.2	41.4	39.5	<0.001
Optimal (≥30 ng/dL) (%)	23.9	25.9	22.9	<0.001
Presence of MetSyn ^f (%)	40.5	54.5	32.2	<0.001
Presence of MetSyn components (%)				
1	23.3	13.2	29.4	<0.001
2	22.2	27.8	18.8	
3	24.4	29.7	21.3	
4–5	16.2	24.8	11.0	

Age-adjusted means or percentages.

^aHigh BP was defined as systolic BP ≥130 mmHg/≥85 mmHg for diastolic.

^bHigh FBG ≥100 mg/dL.

^cLow HDL-C as <50.0 mg/dL in men and <40.0 mg/dL in women.

^dHigh WC as ≥102 cm in men and ≥88 cm in female.

^eHigh TG as ≥150 mg/dL.

^fMetSyn was defined as having at least three components.

BMI, body mass index; BP, blood pressure; FBG, fasting blood glucose; HDL-C, high-density lipoprotein cholesterol; MetSyn, metabolic syndrome; TG, triglycerides; WC, waist circumference.

TABLE 2. SERUM 25(OH)D (NG/ML) LEVELS BY METSYN STATUS

	Component	MetSyn present	MetSyn absent	P value
Total	High BP ^a	24.4 ± 8.6	24.4 ± 8.3	0.99
	High FBG ^b	23.9 ± 8.3	24.9 ± 8.3	0.09
	Low HDL-C ^c	24.5 ± 8.2	24.3 ± 8.4	0.70
	High WC ^d	23.2 ± 8.0	25.7 ± 8.5	0.01
	High TG ^e	22.7 ± 8.5	25.4 ± 8.1	0.01
	MetSyn ^f	22.7 ± 8.0	25.5 ± 8.4	0.01
Men	High BP	26.0 ± 8.9	24.9 ± 7.9	0.37
	High FBG	25.2 ± 8.3	25.2 ± 7.7	0.99
	Low HDL-C	24.6 ± 8.1	28.3 ± 7.8	0.01
	High WC	23.4 ± 7.5	26.7 ± 8.3	0.01
	High TG	23.2 ± 7.8	26.7 ± 8.1	0.01
	MetSyn	23.5 ± 7.9	27.2 ± 8.0	0.01
Women	High BP	22.9 ± 8.2	24.1 ± 8.5	0.31
	High FBG	22.7 ± 8.1	24.8 ± 8.6	0.01
	Low HDL-C	24.2 ± 8.6	23.8 ± 8.4	0.67
	High WC	23.1 ± 8.2	25.0 ± 8.6	0.02
	High TG	22.3 ± 9.0	24.7 ± 8.0	0.01
	MetSyn	21.8 ± 8.0	24.9 ± 8.4	0.01

^aHigh BP was defined as systolic BP ≥130 mmHg/≥85 mmHg for diastolic.

^bHigh FBG as ≥100 mg/dL.

^cLow HDL-C as <50.0 mg/dL in men and <40.0 mg/dL in women.

^dHigh WC as ≥102 cm in men and ≥88 cm in female.

^eHigh TG as ≥150 mg/dL.

^fMetSyn was defined as having at least three components.

high FBG, WC, and TG compared to those without these components ($P < 0.01$).

Figure 1 shows serum 25(OH)D levels by number of MetSyn components. Those with one or two components had a significantly higher serum of 25(OH)D levels compared to those with three or more components ($P < 0.001$).

Age-adjusted correlations between 25(OH)D levels with each metabolic component are shown in Table 3. Significant inverse correlations ($P < 0.05$) were noted between 25(OH)D levels and WC, FBG, and TG in men and between 25(OH)D levels and WC, FBG, TG, and diastolic BP in women.

The multivariable logistic regression model showed that as serum 25(OH)D levels decreased, the odds of MetSyn increased, after adjusting for age, gender, BMI, and seasonality variations (Table 4).

Discussion

The present study found that low vitamin D status was inversely associated with MetSyn, and most components were significantly correlated to serum 25(OH)D levels in a clinic-based sample of predominantly overweight and obese (81%) Hispanic adults in Puerto Rico. The results are consistent with those of previous studies in the United States and Canada.^{3,8,18} For example, data from NHANES III using a representative sample of 8421 US adults 20 years and older also found that those with MetSyn had significantly lower mean serum 25(OH)D levels (28.0 ng/mL) compared

FIG. 1. Mean of 25(OH)D levels according to number of metabolic syndrome (MetSyn) components. Serum 25(OH)D was significantly higher in those with only one or two MetSyn components compared to those with three or with four to five MetSyn components by ANCOVA ($P < 0.001$).

to those without MetSyn (31.6 ng/mL; $P < 0.001$).⁸ In addition, a study in 1818 adults 20 years and older from the Canadian Health Measures Survey found that participants with at least three components of MetSyn had significant lower mean serum 25(OH)D levels (25.1 ng/mL) compared with participants with two components or less (29.5 ng/mL; $P < 0.0001$).³

These studies consistently showed that those without MetSyn had circulating 25(OH)D levels about 30 ng/mL. These levels are higher than the adequate cutoff point established by the Institute of Medicine (>20 ng/mL), which was proposed with the purpose of maintaining the health of bones and muscles and for preventing the development of rickets and osteomalacia in Americans.¹⁶ The results from the present study in a group of Hispanic adults support the recommendation from the Endocrinology Society that optimal vitamin D status higher levels [25(OH)D levels ≥ 30 ng/mL] may be protective against MetSyn.¹⁷

Among the MetSyn components, the highest correlation found with serum 25(OH)D levels was TG followed by WC and FBG. These findings are consistent with NHANES data, in which an inverse correlation was found between 25(OH)D levels and TG and WC.¹⁸ In addition, similar results were observed in a cross-sectional study of 343

TABLE 4. UNADJUSTED AND ADJUSTED ODDS RATIOS FROM LOGISTIC REGRESSION EXAMINING THE ASSOCIATION BETWEEN 25(OH)D LEVELS AND METSYN

25(OH)D (ng/mL)	Odds ratio (95% CI)			
	Crude	P value	Adjusted ^a	P value
<12	3.47 (1.65–7.30)	0.001	2.87 (1.26–6.53)	0.012
12–19.9	2.05 (1.35–3.12)	0.001	2.03 (1.27–3.25)	0.003
20.0–29.9	1.34 (0.90–2.00)	0.155	1.51 (0.96–2.36)	0.074
≥ 30.0	1.00		1.00	

^aAdjusted for age, gender, BMI, and seasonality. CI, confidence interval.

overweight or obese Caucasian individuals,¹⁹ suggesting that this association is independent of the degree of obesity, as also observed in the present study. Other studies in non-Hispanic White individuals have also found significant correlations between 25(OH)D levels and FBG,^{20,21} WC,²¹ and HDL-C.²¹ However, a small study conducted in Greece among 52 individuals with MetSyn and 58 health controls only found an inverse correlation between 25(OH)D levels and TG ($r = -0.416$, $P = 0.003$), but not with the other component criteria of MetSyn (WC, BP, HDL-C, and FBG).²² We also found in our study a significant association with diastolic BP in women, but not with systolic BP. This is consistent with results among non-Hispanic Whites ($n = 257$)²³ and with a previous study done by our group in a sample of 300 Puerto Rican adults.²⁴

The mechanisms by which vitamin D may influence the MetSyn are not fully understood. There is growing evidence suggesting that vitamin D is linked to insulin resistance and insulin secretion, which are considered key pathophysiological mechanisms for MetSyn, especially in relation to central adiposity, hyperglycemia, and dyslipidemia.²⁵ In addition, central obesity may lead the appropriation of vitamin D causing low 25(OH)D serum levels.²⁶ The role of 25(OH)D in dyslipidemia has been less investigated compared to other MetSyn factors.²⁷ In mice, optimal 25(OH)D levels could increase vitamin D receptors, energy expenditure, and oxygen consumption, which lead to a decrease in body fat, plasma TG, and total cholesterol.²⁸ With respect to BP, vitamin D has been shown to regulate the renin-angiotensin-aldosterone system.²⁹ It has been postulated that vitamin D levels suppresses renin gene expression, thereby inhibiting the renin-angiotensin system.

The present study provided the opportunity to assess the association between serum 25(OH)D levels and MetSyn in a large group of Hispanic adults. Vitamin D status was assessed using an objective measure, which reflects vitamin D consumption as well as vitamin D synthesized in the skin with sun exposure. However, there are some limitations that should be considered when interpreting the results. This was a cross-sectional study; thus, it cannot establish the temporal relationship between vitamin D status and MetSyn. In addition, the sample included is from a private clinic and may not be representative of the Puerto Rican population. Although we did not record ethnicity, 92% of individuals living in the Island are Puerto Ricans.³⁰ In addition, 92% of the population has health insurance and, therefore, have access to private clinics.³¹ In addition, as assessed by the CDC, most Puerto Ricans are overweight or obese.³² Therefore, the sample included in this study could be

TABLE 3. PARTIAL PEARSON'S CORRELATIONS BETWEEN 25(OH)D LEVELS AND METSYN COMPONENTS

Parameters	Total (N=712)	Men (n=266)	Women (n=446)
FBG	-0.11 (0.02)	-0.17 (≤ 0.01)	-0.09 (0.04)
HDL-C	0.02 (0.53)	0.19 (≤ 0.01)	-0.01 (0.85)
TG	-0.22 (≤ 0.01)	-0.27 (≤ 0.01)	-0.21 (≤ 0.01)
WC	-0.13 (≤ 0.01)	-0.18 (≤ 0.01)	-0.15 (≤ 0.01)
Systolic BP	-0.01 (0.52)	-0.07 (0.287)	0.02 (0.71)
Diastolic BP	-0.07 (0.05)	-0.03 (0.67)	-0.11 (0.02)

P values are indicated in parenthesis.

considered a homogenous sample and not different from the rest of the population. We did not collect other known and suspected risk factors for MetSyn and vitamin D status, such as physical activity, smoking, alcohol drinking, family history of CVD and diabetes, and inflammatory factors [C-reactive protein (CRP) and interleukin-6 (IL-6)], precluding our ability to control for other potential confounding factors. Longitudinal studies are needed to confirm these results.

In conclusion, the odds of MetSyn increased as the vitamin D status decreased in this clinic-based sample. These results have important public health implications for developing recommendations directed to increase vitamin D status in this sample, such as increasing sun exposure or promoting the use of vitamin D supplements. Improving vitamin D status may reduce the risk of MetSyn and its components, which may help prevent its progression to type 2 diabetes mellitus and cardiovascular conditions. However, longitudinal studies are needed to confirm such results.

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Author Disclosure Statement

No competing financial interests exist.

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