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Vitamin D status is inversely associated with obesity in a clinic-based sample in Puerto Rico

Lilliana González, MHSN^a, Grisel Ramos-Trautmann, MHSN, LND^a, Giselle M. Díaz-Luquis, MHSN, LND, RD^a, Cynthia M. Pérez, PhD^b, and Cristina Palacios, PhD.^a

^aDepartment of Human Development, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico

^bDepartment of Biostatistics and Epidemiology, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico

Abstract

Studies show that vitamin D status is associated to obesity but data in Hispanic individuals is scarce. The aim of this study was to assess the association between vitamin D status and obesity in a clinic-based sample in Puerto Rico. We hypothesized that subjects with a higher adiposity would have a lower vitamin D status. We extracted the following data from medical records of a private clinic: age, gender, serum 25(OH)D levels, weight, height, and waist circumference. BMI (kg/m²) and waist-to-height ratio were calculated and categorized according to standard guidelines. Statistical analyses included ANCOVA, Pearson correlations and Chi-square test. From 797 individuals (mean age 53.7±15.4y; 63.5% females), 35.6% were overweight and 43.7% obese. Mean 25(OH)D levels were 24.7±8.7 ng/mL; 5.3% had levels <12 ng/mL, 30.6% had levels 12–20 ng/mL, and 43.5% had levels 21–30 ng/mL. Mean 25(OH)D levels were significantly higher in normal weight and overweight males compared to obese males (p<0.05); and in overweight females compared to obese females (p<0.05). Levels were also higher in those with low-risk compared to high-risk of waist circumference and waist-to-height ratio (p<0.001). BMI, waist circumference, and waist-to-height ratio were inversely correlated to 25(OH)D levels (p<0.001). A greater proportion of obese individuals (41.4%) were vitamin D deficient or insufficient compared to the normal weight (33.9%) and overweight individuals (30.3%) (p<0.05). In conclusion, in this clinic-based sample of Puerto Rican adults, those with higher BMI, WC, and WHtR had a significantly lower vitamin D status.

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Corresponding author: Cristina Palacios, PhD, Nutrition Program, Graduate School of Public Health, Medical Sciences Campus, University of Puerto Rico, PO Box 365067, San Juan PR 00936-5067, Phone: (787) 758-2525 Ext. 1460, Fax: (787) 759-6719, cristina.palacios@upr.edu.

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Keywords

obesity; body mass index; waist circumference; waist-to-height ratio; vitamin D; 25(OH)D; Hispanics; Puerto Rico

1. Introduction

Vitamin D is a liposoluble molecule that can be synthesized in the skin as a result of sun exposure or can be obtained from foods containing this nutrient naturally (e.g., cod liver oil and fatty fishes), vitamin D fortified products, and supplements [1]. Serum vitamin D or 25(OH)D levels are widely accepted as a biomarker to estimate the vitamin D status [2]; it reflects the vitamin D synthesized in the skin and the vitamin D obtained from foods or supplements. Although there are no universally accepted cutoff points for the optimal serum 25(OH)D levels, the Institute of Medicine (IOM) established that levels above 20 ng/mL (>50 nmol/L) are adequate. However, the Endocrinology Society considers that levels 30 ng/mL (75 nmol/L) and above are optimal [3].

Vitamin D deficiency is a public health concern around the world [4, 5]. There is a high prevalence of vitamin D deficiency and insufficiency worldwide [6]. In the United States (US), 32% of the total population and 43% of the Hispanics had vitamin D levels below 20 ng/mL [7]. Moreover, in a large sample of Puerto Ricans (n=4,090), 65.8% had vitamin D levels below 30 ng/mL and 24.9% had levels below 20 ng/mL [8].

Several studies have shown a consistent association between adiposity and vitamin D status, in which an increase in adiposity results in lower serum 25(OH)D levels [9–12]. Hence, obese subjects are more likely to have suboptimal vitamin D levels. This association was also found in Hispanics and African Americans in the US [13]. In Puerto Rico (PR), the only study that has addressed this association among 94 overweight and obese adults found a significant inverse correlation of 25(OH)D levels with percent body fat [14]. Further research is needed, particularly in Hispanic populations, to understand the factors that contribute to the high prevalence of vitamin D deficiency, such as obesity [8]. This is important as obesity is now recognized as one of the leading health threats worldwide [15], which is highly prevalent in Hispanics. In the US, 35% of adults (20 years) are obese [16]. Similarly, Behavioral Risk Factor Surveillance System (BRFSS) data collected in 2013 showed that 28% of adults were obese and 39% were overweight [17]. However, a study conducted in a representative sample of Puerto Ricans living in the San Juan metropolitan area of PR showed an even higher prevalence of overweight and obesity (40.8% obesity and 36.7% overweight) [18].

To start addressing this gap in knowledge, we sought to assess the association of vitamin D status with obesity in a clinic-based sample from Puerto Rico. Our specific objectives were to (1) assess the correlations of serum 25(OH)D with body composition measures, (2) evaluate the associations of vitamin D status with obesity status, and (3) compare serum 25(OH)D levels across obesity status. Based on prior research, it was hypothesized that subjects with higher adiposity would have a lower vitamin D status. To test our hypothesis,

we analyzed a large data set of medical records of individuals attending a private endocrinology clinic with information on vitamin D status and obesity.

2. Methods and Materials

2.1 Study Population

A retrospective medical record review of all patients who attended the *Endocrinology, Diabetes, and Metabolism Clinic* located in Utuado, PR was performed between 2005 and 2013. Those medical records that had complete information on body composition measures and laboratory test results for serum 25(OH)D levels were included in the study. The institutional review board of the Medical Sciences Campus of the University of Puerto Rico approved this study.

2.2 Demographic, body composition, and clinical data

A data collection form was used to extract demographic information, body composition measures, and medical history from the medical records. Demographic data included age and sex, and body composition data included weight, height, and waist circumference (WC). Weight (pounds) and height (inches) were measured by the clinic staff using a physician scale (Detecto, Model 338, MO, USA) with height rod and WC (inches) was measured using a measurement tape. These were converted to kg, m and cm, respectively.

Obesity was assessed using the body mass index (BMI), WC, and waist-to-height ratio (WHtR). BMI, calculated as weight in kilograms (kg) divided by height in meters squared (m^2), was used as an index of general obesity [19]. Subjects were classified using the World Health Organization (WHO) cutoff points: normal $<25.0 \text{ kg}/m^2$; overweight $25.0 - 29.9 \text{ kg}/m^2$; and obese $\geq 30 \text{ kg}/m^2$ [20]. The WHtR and WC were used as central or abdominal obesity indices [19]. WHtR was calculated by dividing the WC (cm) by height (cm). High WHtR was defined as values greater than 0.5 [21], whereas elevated WC was defined as $\geq 102 \text{ cm}$ (40 in) in men and $\geq 88 \text{ cm}$ (35 in) in women [22]. In addition, co-morbidities including hypertension, diabetes, and hyperlipidemia were collected.

2.3 Circulating 25(OH)D

Blood test results for serum 25(OH)D levels in nanograms per milliliter (ng/mL) were extracted from the records. We also extracted the method used to measure vitamin D levels. Most of the serum vitamin D tests in our sample (96.9%) were performed using immunoassays (92.9% immunochemiluminometric assay [ICMA]; 0.9% chemiluminescence immunoassay [CLIA]; and 3.1% IDS enzymeimmunoassay [IDS-EIA]). The remaining tests (3.1%) were performed with liquid chromatography–mass spectrometry (LC/MS/MS).

There is an ongoing debate on the cutoff values for vitamin D status. The IOM established that a person with levels below $12 \text{ ng}/mL$ ($<30 \text{ nmol}/L$) is at risk of deficiency, levels between 12 and $20 \text{ ng}/mL$ ($30 - 50 \text{ nmol}/L$) are inadequate, and levels of $20 \text{ ng}/mL$ and above ($\geq 50 \text{ nmol}/L$) are adequate [2]. However, the Endocrine Society classifies the vitamin D status as deficient if serum 25(OH)D levels are $20 \text{ ng}/mL$ or below ($< 50 \text{ nmol}/L$), insufficient if levels are between 21 and $29 \text{ ng}/mL$ ($52 - 72 \text{ nmol}/L$), and sufficient if levels

are 30 ng/mL and above (75 nmol/L) [3]. For the present study, the cutoff values used to describe the vitamin D status were: <12 ng/mL for deficiency, 12 – 20 ng/mL for inadequacy, >20 ng/mL for adequacy (sub-classified as insufficiency if levels were 21 – 29 ng/mL and optimal if levels were 30 ng/mL).

2.4 Statistical Analyses

We conducted sex-specific analyses given the sex differences in vitamin D levels and obesity observed in previous studies. Baseline characteristics of patients were summarized by age-adjusted means for the continuous variables and age-adjusted percentages for the categorical variables. Sex-specific comparisons of baseline characteristics were performed using Student's t-test or chi-square test. Age-adjusted Pearson's correlation coefficients were used to assess the relationship of serum 25(OH)D with body composition measures (BMI, WC, and WHtR). The chi-square test (linear-by-linear association) was used to evaluate the association of vitamin D status with obesity status. Analysis of covariance (ANCOVA) was used to assess differences in age-adjusted means of serum 25(OH)D levels across BMI status, WC, and WHtR categories. Post hoc pair-wise comparisons were assessed using Bonferroni's method where indicated. A p value below 0.05 was considered as statistically significant. Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) Software, version 21.0 (Chicago, IL, USA).

3. Results

A total of 1,379 medical records were reviewed, of which, 914 met the inclusion criteria. Fifty-one records of children and adolescents and 66 individuals (7.2%) who reported the use of vitamin D supplements were excluded. Thus, a total of 797 records (291 males and 506 females) were included in the present analysis. Baseline characteristics of patients are summarized in Table 1. The mean age of patients was 53.7 ± 15.4 years, and women outnumbered men by a ratio of 1.7:1. Mean BMI was 30.0 ± 6.5 kg/m², which was significantly higher in males than in females ($p=0.032$). Overall, 35.6% were overweight and 43.7% were obese. Although males had significantly higher WC compared to females ($p<0.001$), a greater proportion of females were classified in the high-risk WC category compared to males ($p<0.001$). Males also had significantly higher WHtR than females ($p=0.016$). With respect to co-morbidities, diabetes, hypertension, and hyperlipidemia were significantly ($p<0.05$) more common among men than among women.

Pearson's correlations coefficients determined that serum 25(OH)D levels are inversely correlated with BMI, WC, and WHtR ($p<0.001$), and were stronger for males than for females (Table 2).

Associations between BMI categories and vitamin D status (Table 3) showed that the vitamin D status was significantly associated to BMI status in the overall sample, whereas a greater proportion of individuals in the obese group (41.4%) were categorized as vitamin D deficient or insufficient compared to normal weight (33.9%) and overweight individuals (30.3%) ($p=0.02$). When analyzed by sex, the association only remained significant in males ($p=0.008$), whereas a greater proportion of individuals in the overweight (25%) and obese (40%) categories were also categorized as vitamin D deficient or insufficient compared to

the normal weight individuals (18.6%). Moreover, 71.5% of overweight and 77.9% of obese subjects had levels below 30 ng/mL (data not shown).

Mean 25(OH)D levels were 24.7 ± 8.7 ng/mL, which was significantly lower in females compared to males ($p=0.023$). Vitamin D deficiency (<12 ng/mL) was only observed in 5.3% of the participants but vitamin D inadequacy (12 – 20 ng/mL) was observed in 30.6%. According to the IOM cutoff points, most (64.1%) had adequate vitamin D levels (>20 ng/mL); however, according to the Endocrine Society cutoff points, only 20.6% had optimal levels (≥ 30 ng/mL). Serum 25(OH)D levels by BMI categories according to sex (Figure 1) indicated that mean 25(OH)D levels were significantly higher in normal weight males (28.2 ± 8.8 ng/mL) and overweight males (26.7 ± 8.5 ng/mL) compared to obese males (24.0 ± 7.9 ng/mL) ($p<0.05$). Overweight females (25.5 ± 9.8 ng/mL) had significantly higher vitamin D levels than obese females (23.3 ± 8.5 ng/mL) ($p=0.038$), but no significant differences were detected between normal weight women and overweight or obese women. Overall, overweight individuals had higher mean 25(OH)D level compared to obese individuals ($p=0.001$).

Serum 25(OH)D levels were significantly lower in individuals with a high-risk WC in both males ($p<0.001$) and females ($p=0.034$) (Figure 2). Similarly, serum 25(OH)D levels were significantly lower in individuals in the high-risk category of WHtR in both males ($p=0.009$) and females ($p=0.001$) (Figure 3).

4. Discussion

There was a high prevalence of overweight and obesity in our clinic-based sample. Most of the participants (79%) had insufficient vitamin D levels (levels <30 ng/mL) [3]. However, when using the IOM cutoff points, only 35.9% of the study sample had an inadequate vitamin D status (<20 ng/mL) [2]. We also found that most overweight or obese individuals were vitamin D insufficient or deficient and serum vitamin D levels were inversely correlated to adiposity indices (BMI, WC, and WHtR).

The prevalence of low vitamin D status in our study was higher than the prevalence described in previous studies in PR. A study with a smaller sample ($n=219$) found that 60.3% had low vitamin D status (<30 ng/mL) [23], while in another study ($n=4,090$), 68.5% had low vitamin D [8]. However, individuals from the present study were different from other studies conducted in PR, as they were selected among an endocrinology health clinic attenders and thus were unlikely to be representative of all individuals from such area. Thus, confirmation of findings from this clinic-based study in population-based samples is necessary.

The analysis of serum 25(OH)D levels by BMI categories according to sex showed that vitamin D levels were significantly higher in normal weight and overweight males compared to obese males; however, in females, only those overweight had significantly higher vitamin D levels compared to those obese, while vitamin D levels in normal weight females were similar to levels among overweight or obese women. However, when obesity was assessed using WC or WHtR, serum 25(OH)D levels were significantly higher in the low-risk category of WC and WHtR consistently in both males and females. We have previously

shown that WC and WHtR are better adiposity measures as related to cardiometabolic risk factors [24], as these take into account fat distribution while BMI does not. Studies have suggested the importance of both visceral and subcutaneous fat in this association [25], but it is in the subcutaneous adipose tissue where vitamin D is more likely to be stored or sequestered [26]. This is important to differentiate as vitamin D is a fat-soluble vitamin that can be stored in the adipose tissue and some researchers have suggested that when more subcutaneous fat is available (e.g. in obese individuals), more vitamin D is sequestered there, resulting in less circulating 25(OH)D levels [26, 27]. Therefore, WC and WHtR may be more appropriate than BMI to assess the association between obesity and vitamin D status.

Other studies have also found that obesity is inversely correlated to serum 25(OH)D levels in different populations, including non-Hispanic White individuals and White adults from New Zealand [28–32, 25], but only a few have included Hispanics [13, 33]. Similarly, others have also reported a higher prevalence of vitamin D inadequacy (<30 ng/mL) among obese subjects (72.0%) compared to non-obese [28]. Moreover, a study conducted in Florida showed that among Hispanics, there was a significantly higher prevalence of vitamin D insufficiency (<30 ng/mL) in obese (63.2%) compared to non-obese individuals (35.8%) [33]. Furthermore, we also reported in another sample of Puerto Ricans that 55.9% of overweight and 61.8% of obese individuals had vitamin D insufficiency (<30 ng/mL) [23].

Gender differences have been previously described in some studies [34–36], while others have not found these differences [37]. The stronger associations observed in the present study in men could be explained by other conditions and co-morbidities in women. Although we controlled our analyses for age, it has been suggested that age is an independent predictor of vitamin D levels in women but not in men [36]. Previous studies have found differences in vitamin D levels among pre- and post-menopausal women [38–40]. Interestingly, the menopause onset varies within females [41–43] and this may be altering our results, but we did not collect such information. Also, gender differences could be explained by differences in the presence of conditions or disorders that affect vitamin D metabolism, such as reduced or altered absorption, abnormal metabolism due to chronic kidney disease or hepatic dysfunction [44], and use of medications, such as anticonvulsants, steroids and glucocorticoids [45]. However, we were unable to assess the effects of such variables as these were not collected in the study.

The present study provided the opportunity to describe the association between serum 25(OH)D levels and obesity indices using a large sample of Hispanics living in PR. Moreover, serum 25(OH)D levels were measured in most samples using immunoassays, thereby reducing the inter-method variability between laboratory results. Also, the measurement of serum 25(OH)D levels is the most objective measure to describe the vitamin D status, which reflects both vitamin D intake and the vitamin D synthesized in the skin. Nevertheless, the present study has some limitations that merit discussion. First, the use of a clinic-based sample and the cross-sectional design of our study do not allow us to generalize our findings or infer causality. In addition, variables such as menopausal status and pharmacologic treatment that could affect vitamin D metabolism were not available and thus not accounted in the analysis.

Our results support our hypothesis confirming that obesity is inversely associated to low vitamin D status in this group of Hispanic adults living in Puerto Rico. These findings, if confirmed by additional research, would have important public health implications. There is a need for developing recommendations to increase vitamin D status in overweight and obese individuals by either increasing sun exposure and/or increasing vitamin D intake through foods or supplementation. These findings can also help to develop health promotion programs to encourage healthy behaviors (e.g., weight loss) that may be important to increase vitamin D levels.

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Abbreviations

25(OH)D	25-hydroxyvitamin D or vitamin D
BMI	body mass index
WC	waist circumference
WHtR	waist-to-height ratio
IOM	Institute of Medicine
WHO	World Health Organization
BRFSS	Behavioral Risk Factor Surveillance System
US	United States
PR	Puerto Rico

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Highlights

- We examined the association between vitamin D status and obesity in a large Clinic-based sample in Puerto Rico.
- Vitamin D levels were higher in normal weight and overweight males compared to obese males and in overweight females compared to obese females as assessed by BMI.
- Subjects in the low-risk categories of WC and WHtR had higher vitamin D levels compared to those in the high-risk categories.
- Serum vitamin D levels were inversely correlated to BMI, WC, and WHtR.
- A greater proportion of individuals in the obese category were categorized as vitamin D insufficient or deficient compared to normal weight and overweight subjects.

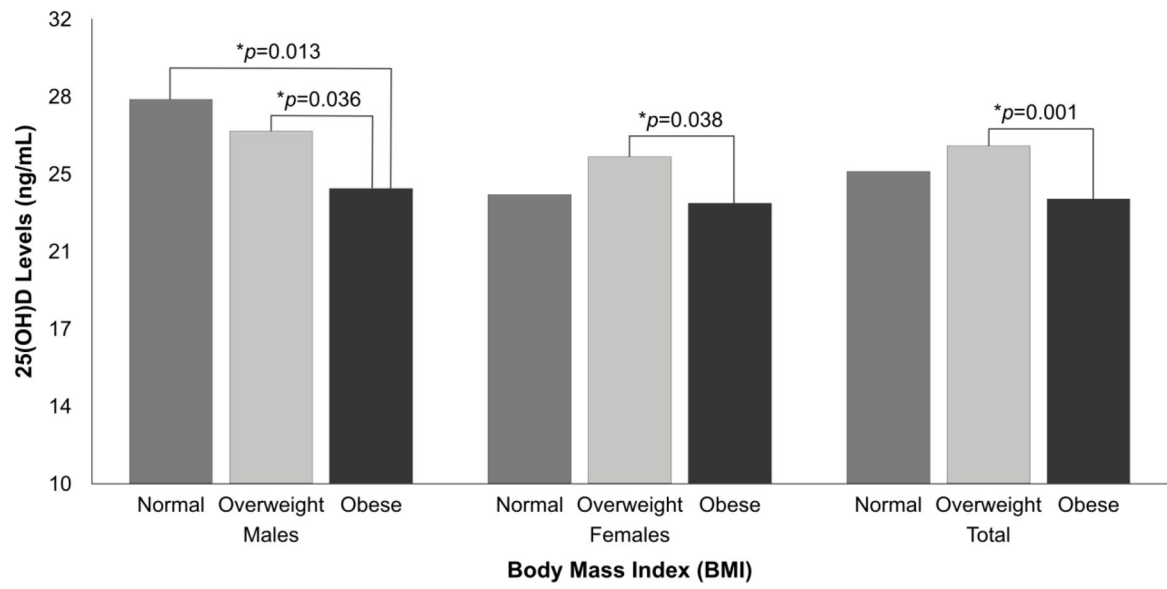


Figure 1.
Differences in 25(OH)D levels by BMI categories according to sex.
Data were analyzed using ANCOVA, adjusting by age.

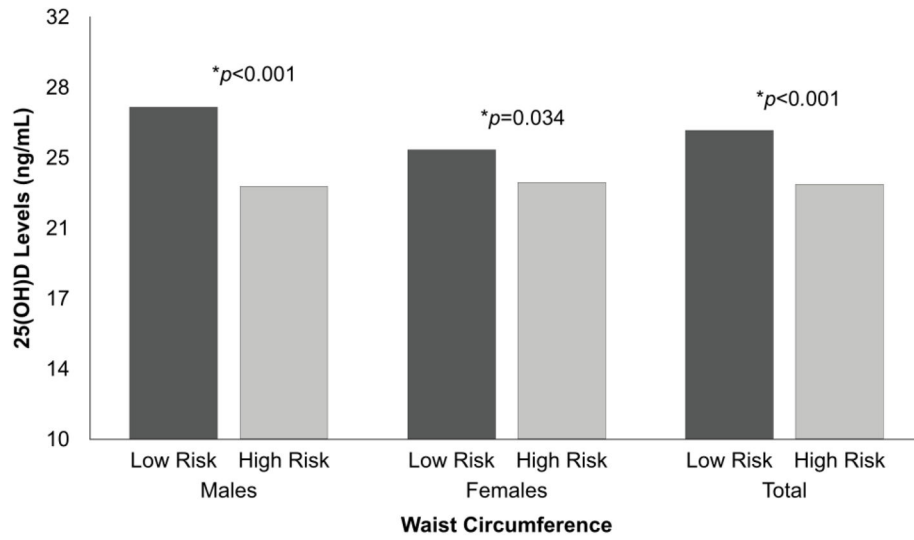


Figure 2.
Differences in 25(OH)D levels by WC according to sex.
Data were analyzed using ANCOVA, adjusting by age.

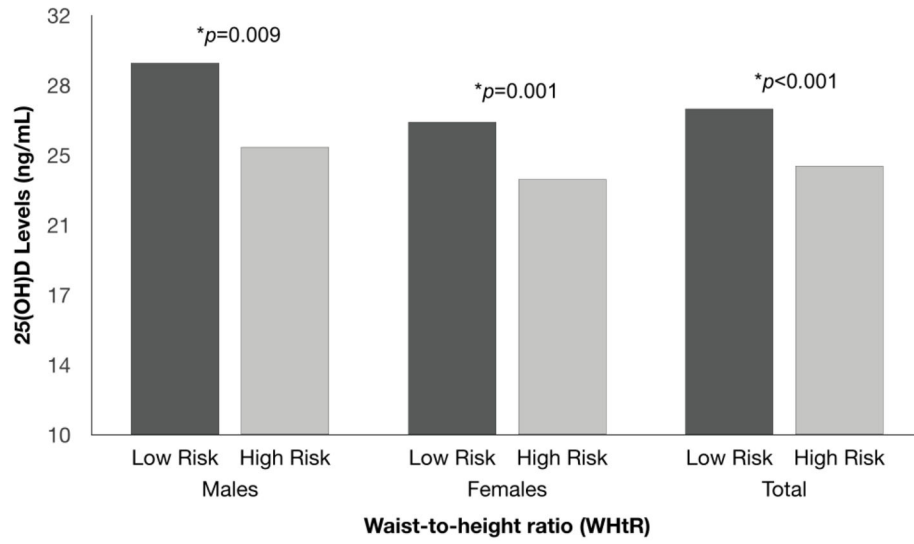


Figure 3. Differences in 25(OH)D levels by WHtR according to sex. Data were analyzed using ANCOVA, adjusting by age.

Table 1

Baseline characteristics of study participants

Characteristic	n	Males	n	Females	n	Total
Age (years)	291	53.5±14.4	506	53.8±15.9	797	53.7±15.4
BMI (kg/m ²)	291	30.6±6.1	506	29.6±6.6*	797	30.0±6.5
Normal weight (<25 kg/m ²)	43	14.8%	122	24.1%*	165	20.7%
Overweight (25.0 – 29.9 kg/m ²)	108	37.1%	176	34.8%*	284	35.6%
Obese (≥ 30 kg/m ²)	140	48.1%	208	41.1%*	348	43.7%
WC (cm)	287	102±12.8	505	92.0±15.1**	792	95.8±15.1
Low risk ^a	162	56.4%	213	42.2%*	375	47.3%
High risk ^b	125	43.6%	292	57.8%*	417	52.7%
WHR	287	0.59±0.08	505	0.58±0.10*	792	0.58±0.09
Low risk (< 0.50)	28	9.8%	126	25.0%*	154	19.4%
High risk (>0.50)	259	90.2%	379	75.0%*	638	80.6%
25(OH)D (ng/mL)	291	25.6±8.4	506	24.1±8.9*	797	24.7±8.7
Vitamin D Status						
Deficient (<12 ng/mL)	11	3.8%	31	6.1%*	42	5.3%
Inadequate (12 – 20 ng/mL)	80	27.5%	164	32.4%*	244	30.6%
Adequate (>20 ng/mL)	200	68.7%	311	61.5%*	511	64.1%
Insufficient (21 – 29 ng/mL)	132	45.4%	215	42.5%*	347	43.5%
Optimal (< 30 ng/mL)	68	23.4%	96	19.0%*	164	20.6%
Co-morbidities						
Diabetes	135	46.4%	180	35.6%*	315	39.5%
Hypertension	120	41.2%	132	26.1%**	252	31.6%
Hyperlipidemia	156	53.6%	199	39.3%**	355	44.5%

Values are presented as age-adjusted means±SD or percentage (%).

* $p < 0.05$ compared to males (Student's t-test or χ^2).

** $p < 0.001$ compared to males (Student's t-test or χ^2).

Defined as <102 cm in males and >88 cm in females;
Defined as 102 cm in males and 88 cm in females.

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Table 2

Pearson's correlation coefficients of 25(OH)D levels and obesity indices

Obesity indices	Pearson's <i>r</i>		
	Males	Females	Total
BMI	-0.20**	-0.11*	-0.14**
WC	-0.21**	-0.15**	-0.14**
WHtR	-0.21**	-0.15**	-0.17**

Values are age-adjusted Pearson's correlation coefficients.

*
 $p < 0.01$;**
 $p < 0.001$.

Table 3

Associations between BMI categories and vitamin D status

	Vitamin D status			<i>p</i> value*
	<12 ng/mL	12 – 20 ng/mL	>20 ng/mL	
Males				
Normal weight	2.3%	16.3%	81.4%	0.008
Overweight	4.6%	20.4%	75.0%	
Obese	3.6%	36.4%	60.0%	
Females				
Normal weight	4.9%	34.4%	60.7%	0.177
Overweight	3.4%	30.1%	66.5%	
Obese	9.1%	33.2%	57.7%	
Total				
Normal weight	4.2%	29.7%	66.1%	0.020
Overweight	3.9%	26.4%	69.7%	
Obese	6.9%	34.5%	58.6%	

* Chi-Square test (Linear-by-linear Association).

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