UNIVERSIDAD DE COSTA RICA CCP Centro Centroamericano de Población INISA Instituto de Investigaciones en Salud

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Población y Salud en Mesoamérica

Association of 25-hydroxyvitamin D status with overweight and obesity in Costa Rican adults

Silvia L. Monge-Rodríguez, Rebeca Vindas-Smith & Georgina Gómez.

How to cite this article:

Monge-Rodríguez, S.L., Vindas-Smith, R., & Gómez, G. (2026). Association of 25-hydroxyvitamin D status with overweight and obesity in Costa Rican adults. *Revista Población y Salud de Mesoamérica*, *23*(2). https://doi.org/10.15517/5ejvz191

ISSN-1659-0201 http://ccp.ucr.ac.cr/revista/

Revista electrónica semestral
Centro Centroamericano de Población
Instituto de Investigaciones en Salud
Universidad de Costa Rica

Población y Salud en Mesoamérica

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Association of 25-hydroxyvitamin D status with overweight and obesity in Costa Rican adults

Asociación de 25-hidroxivitamina D plasmática con sobrepeso y obesidad en adultos costarricenses

Silvia L. Monge-Rodríguez [1], Rebeca Vindas-Smith[2] and Georgina Gómez[3]

Abstract: Introduction: Aim: This research aimed to investigate the association between plasma 25-hydroxyvitamin D levels and overweight/obesity in Costa Rican adults with and without type 2 diabetes. **Methods:** 604 adults were involved in a cross-sectional study from a clinical-base urban Costa Rican population. Clinical variables such as glycemic status and arterial hypertension were registered. Blood samples were collected to measure circulating vitamin D levels, fasting plasma glucose, glycated hemoglobin, and lipid profile. The association between plasma levels of 25-hydroxyvitamin D and clinical and biochemical variables was tested using a linear regression model. **Results:** There was an 80% prevalence of overweight and obesity in this sample. Plasma levels of 25-hydroxyvitamin D were in the deficiency range in 28% of subjects, in the insufficiency range in 49%, and only 23% of participants had sufficient levels. 25-hydroxyvitamin D levels were lower in subjects with a body mass index above 25 kg/m^2 (*t*-test, *p*= 0.006). The association between 25-hydroxyvitamin D levels and body mass index remained significant (β: -0.15, CI 95%: -0.21 – -0.10) even after adjusting for classical risk factors such as lipid profile, glycemic status, and hypertension. **Conclusion:** Plasma 25-hydroxyvitamin D concentrations were suboptimal in 77% of the sample. Additionally, low plasma 25-hydroxyvitamin D levels were associated with overweight/obesity in Costa Rican subjects.

Keywords: body mass index; body weight, vitamin D deficiency

Resumen: Objetivo: Este estudio tuvo como objetivo investigar la asociación entre los niveles plasmáticos de 25-hidroxivitamina D y el sobrepeso/obesidad en adultos costarricenses con y sin diabetes tipo 2. **Métodos:** Participaron 604 adultos en un estudio transversal de una población urbana costarricense procedente de un centro clínico. Se registraron variables clínicas como estado glicémico e hipertensión arterial. Se recogieron muestras de sangre para medir los niveles circulantes de vitamina D, glucosa, hemoglobina glicada y perfil lipídico. La asociación entre los niveles plasmáticos de 25-hidroxivitamina D y las variables clínicas y bioquímicas se analizó mediante un modelo de regresión lineal. **Resultados:** La prevalencia de sobrepeso y obesidad fue del 80%. Los niveles plasmáticos de 25-hidroxivitamina D se encontraron en el rango de deficiencia para el 28% de los sujetos, en el de insuficiencia para el 49%, y en el de suficiencia para el 23% de los participantes. Los niveles de 25-hidroxivitamina D fueron más bajos en sujetos con un índice de masa corporal superior a 25 kg/m^2 (prueba t, p= 0,006). Hubo asociación entre los niveles de 25-hidroxivitamina D y el índice de masa corporal (β: -0,15, IC 95%: -0,21 – -0,10), incluso después de ajustar por factores de riesgo clásicos como el perfil lipídico, el estado glicémico y la hipertensión arterial. **Conclusión:** Los niveles plasmáticos de 25-hidroxivitamina D fueron subóptimos en el 77% de la muestra. Además, se identificó que niveles bajos de 25-hidroxivitamina D en plasma se asociaron con sobrepeso/obesidad en sujetos costarricenses.

Palabras clave: índice de masa corporal, peso corporal, vitamina D

Received: 23 mar, 2024 | **Corrected:** 01 oct, 2025 | **Accepted:** 04 dec, 2025

[1] Universidad de Costa Rica, COSTA RICA. leticia.monge@ucr.ac.cr
[2] Universidad de Costa Rica, COSTA RICA. rebeca.vindas@ucr.ac.cr
[3] Universidad de Costa Rica, COSTA RICA. georgina.gomez@ucr.ac.cr

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

1. Introduction

Overweight and obesity are multifactorial pathophysiological conditions affecting 1.9 billion and 609 million adults worldwide, respectively (Chooi et al., 2019). The most widespread definition of obesity has been established as body mass index (BMI) greater than 30 kg/m^2 in adults (WHO, 2000). However, obesity encompasses a broader spectrum of biological and social characteristics associated with increased morbidity and mortality (Lin & Li, 2021).

Latin American countries report an adult prevalence of overweight exceeding 60% (Kovalskys et al., 2018), contributing to an increased incidence of chronic non-communicable diseases such as type 2 diabetes (DM2) and ischemic heart disease (Lin & Li, 2021). According to the Latin American Nutrition and Health Study (ELANS), a prevalence of overweight and obesity of 68.5% was found among adults living in urban regions of Costa Rica (Gómez et al., 2020).

Vitamin D deficiency is recognized as a global health issue. Vitamin D is a hormone with pleiotropic actions, such as bone homeostasis, calcium and phosphates metabolism, antioxidant activity, anti-inflammatory effects, and the maintenance of adequate carbohydrate and lipid metabolism (Christakos et al., 2016; Pilz et al., 2016). Vitamin D deficiency has been associated with chronic diseases such as DM2, arterial hypertension (AHT), ischemic heart disease, and obesity (Bouillon et al., 2022; Zhang et al., 2022), although vitamin D supplementation has not been shown to modify the risk of these conditions (Cosentino et al., 2021; Pittas et al., 2019). There is extensive research linking vitamin D to autoimmune diseases such as type 1 diabetes, asthma, and, more recently, to susceptibility to infectious diseases such as COVID-19 (Ismailova & White, 2022; Sassi et al., 2018).

Regarding vitamin D and body composition, a meta-analysis including data from 25 countries reported that higher plasma 25-hydroxyvitamin D (25(OH)D) levels were associated with a 23% reduction in the overall risk of abdominal obesity (OR: 0.77; 95% CI: 0.71 – 0.83) (Hajhashemy et al., 2021). Furthermore, individuals with obesity exhibited a 35% higher prevalence of vitamin D deficiency compared to those with normal weight (OR: 1.35; 95% CI: 1.21 – 1.50) (Hajhashemy et al., 2021). The relationship between vitamin D and obesity is still a matter of debate, likely reflecting multiple biological phenomena that converge in obesity and relate to the pleiotropic actions of vitamin D (Hyppönen & Power, 2007).

In Costa Rica, a low dietary intake of vitamin D has been previously reported in a healthy urban adult sample (Gómez et al., 2019). However, there is no information on circulating vitamin D levels in individuals with obesity and on whether vitamin D deficiency is associated with this condition. The objective of this study was to examine the association between vitamin D status and BMI categories in an urban Costa Rican population, compromising individual with and without DM2. We hypothesized that lower vitamin D levels would be associated with a higher BMI.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

2. Materials and methods

2.1 Approach

In the present study, we conducted a cross-sectional observational analysis to investigate plasma 25(OH)D levels in relation to different BMI categories in adults living in an urban area of Costa Rica. Data for this analysis was derived from a case-control study originally designed to investigate genetic risk factors for type 2 diabetes (unpublished data); therefore, it included individuals with and without DM2. For the present secondary analysis, participants with abnormal glycemic status were intentionally included to allow representation of both non-diabetic and diabetic individuals, although the overall sample was mainly composed of individuals with altered glycemic status.

2.2 Study population

A total of 604 participants aged 20 years or older were enrolled between 2011 and 2015 at the Marcial Fallas Clinic in Desamparados, Costa Rica, a primary care facility within the National Social Security Health System (see annexes for more information). The clinic was visited twice weekly, and participants were selected through systematic sampling. Subjects from the original study were recruited according to the following criteria:

2.2.1 Controls

No diagnosis of DM2, as confirmed by self-report and clinical records; fasting plasma glucose (FPG) < 100 mg/dL; and no family history of DM2 in first-degree relatives. Controls were excluded if they had a personal history gestational diabetes or had previous or current treatment with hypoglycemic agents.

2.2.2 Cases

All individuals with a diagnosis of DM2 according to the criteria established by the American Diabetes Association (2011).

2.3 Anthropometric and clinical measurements

Information on body weight, height, blood pressure (BP), and AHT diagnosis were extracted from participants' clinical files. BMI was calculated as $BMI = \frac{weight\ (kg)}{height\ (m)^2}$. Participants were classified according to the criteria set by the World Health Organization (WHO, 2000) as having normal body weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2), obesity class I (30-34.9 kg/m^2), and obesity classes II and III (≥ 35 kg/m^2). Glycemic status was classified according to the criteria defined by the American Diabetes Association (ADA, 2022).

2.4 Biochemical measurements

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Blood samples were collected to quantify FPG, glycated hemoglobin (HbA1c), and lipid profile, including total cholesterol (TC), low-density lipoprotein cholesterol (LDL), high-density lipoprotein cholesterol (HDL), and triglycerides (TG), using standard laboratory methods.

Plasma 25(OH)D concentrations were determined using the Architect immunoassay method (Abbott Laboratories, IL, USA), following the manufacturer's instructions. Vitamin D status was defined by plasma concentration according to the Endocrine Society's Clinical Practice Guidelines: deficiency (≤ 20 ng/mL), insufficiency (21-29 ng/mL), and sufficiency (≥ 30 ng/mL) (Holick et al., 2011). Individuals with plasma 25(OH)D levels below 12 ng/mL were classified as being at high risk of developing bone disorders such as rickets or osteomalacia (Giustina et al., 2020).

2.5 Statistical analysis

Analyses of anthropometric, clinical, and biochemical variables were conducted using IBM® SPSS Statistics v22.0 software (IBM Corp., Armonk, NY, USA). Data visualization was performed with Jamovi v2.2 (The Jamovi project, 2021).

Descriptive statistics were calculated for all variables, and the normality of the data was evaluated using the Kolmogorov-Smirnov test. Vitamin D status was compared across all BMI categories using the Kruskal-Wallis test. Subsequently, plasma 25(OH)D levels were compared between subjects with normal body weight and those with excess body weight (BMI ≥ 25 kg/m^2) using Student's *t*-test.

A linear regression analysis using a backward elimination method was performed, with BMI as the dependent variable and age, sex, plasma 25(OH)D levels, lipid profile, glycemic status, and AHT diagnosis as independent variables. Non-standardized regression coefficients (β) and their 95% confidence intervals (CI) were estimated. Additionally, odds ratios (OR) were calculated when applicable.

2.6 Ethical considerations

All participants provided written informed consent prior to participation. This study was conducted in accordance with the Declaration of Helsinki and was approved by the Scientific Ethics Committee of the Universidad de Costa Rica (VI-6467-2017).

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

3 Results

3.1 Anthropometric, clinical, and biochemical characteristics of the study population

As shown in Table 1, of the 604 participants, 32% (n =196) were male and 68% (n =408) were female. Approximately 20% (n =123) of participants had normal body weight, 3 participants with BMI below 18.5 were included in this group, 46% (n =277) were overweight, and 34% (n =204) were classified as having obesity. In addition, 71% (n =429) of the subjects had AHT. Regarding glycemic status, 20% (n =119) were nondiabetic, 21% (n =127) were prediabetic, and 52% (n =315) had DM2.

Table 1. Clinical characteristics of the studied sample according to BMI categories.

Variable	Normal n (%)	Overweight n (%)	Obesity I n (%)	Obesity II and III n (%)	Total n (%)
Sex					
Male	54 (43.9)	97 (35.0)	33 (25.6)	12 (16.0)	196 (32.5)
Female	69 (56.1)	180 (65.0)	96 (74.4)	63 (84.0)	408 (67.5)
Glycemic status					
Non-diabetic	40 (32.5)	57 (20.6)	16 (12.4)	6 (8.0)	119 (19.7)
Prediabetic	36 (29.3)	60 (21.7)	25 (19.4)	6 (8.0)	127 (21.0)
DM2	36 (29.3)	133 (48.0)	85 (65.9)	61 (81.3)	315 (52.2)
Not-known	11 (8.9)	27 (9.7)	3 (2.3)	2 (2.7)	43 (7.1)
Arterial hypertension					
No	53 (43.1)	87 (31.4)	29 (22.5)	6 (8.0)	175 (29.0)
Yes	70 (56.9)	190 (68.6)	100 (77.5)	69 (92.0)	429 (71.0)

BMI: body mass index; n: frequency; %: percentage of the BMI category.

Most subjects in this sample were in their seventh decade of life across all BMI categories (Table 2). FPG and HbA1c levels were higher in individuals with overweight or obesity compared with those of normal weight. No significant differences were observed in plasma cholesterol measurements. TG levels were lower in participants with normal weight than in those with overweight or obesity.

We found that plasma 25(OH)D levels decreased with increasing BMI. The mean plasma 25(OH)D concentration among 556 participants was 24.5 ± 7.9 (range: 5.3-52.0) ng/mL. In the overall sample, 28% (n =157) had vitamin D deficiency, 49% (n =271) were classified as insufficient, and 23% (n=128) had sufficient levels (≥ 30 ng/mL). Additionally, 6% (n =36) of the participants had critically low concentrations (< 12 ng/mL).

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

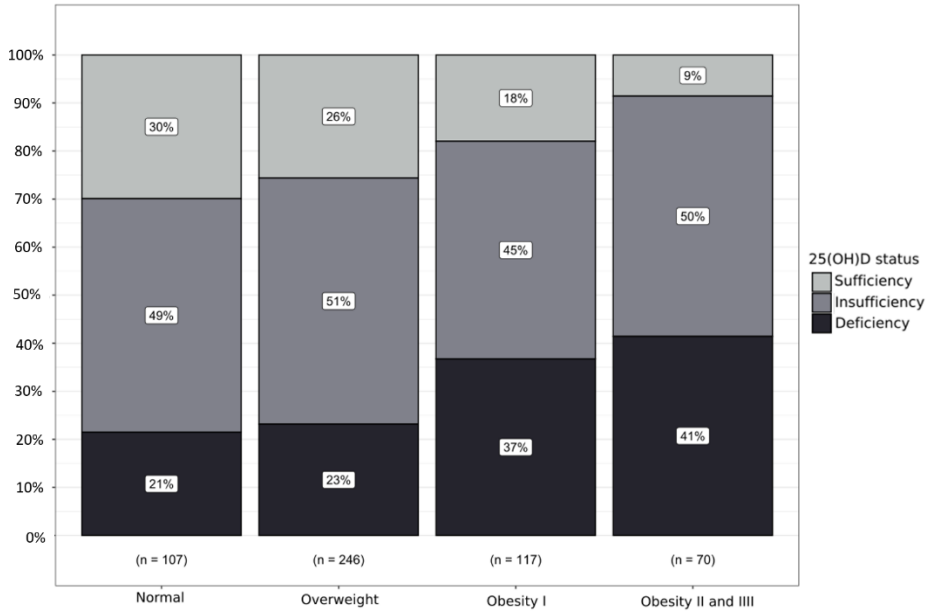
Table 2. Age and biochemical plasma variables (mean values and CI 95%) according to BMI category.

Variable	Normal	Overweight	Obesity I	Obesity II and III
Age (years)	66.3 (64.4-68.3)	62.8 (61.7-63.9)	61.3 (59.5-63.1)	58.6 (56.6-60.5)
FPG (mg/dL)	105.0 (99.2-111.0)	116.9 (112.0-121.8)	128.6 (119.8-137.2)	135.2 (122.4-148.0)
HbA1c (%)	6.1 (5.9-6.3)	6.5 (6.4-6.7)	7.1 (6.8-7.3)	7.5 (7.0-7.9)
TC (mg/dL)	209.0 (200.0-217.0)	205.4 (200.7-210.0)	199.1 (191.3-206.9)	194.9 (186.2-203.6)
HDL (mg/dL)	42.0 (40.3-44.3)	41.1 (39.7-42.6)	39.8 (37.7-41.8)	40.1 (38.4-41.8)
LDL (mg/dL)	133.0 (125.0-140.0)	126.1 (121.9-130.2)	117.7 (111.3-124.1)	116.5 (108.7-124.3)
VLDL (mg/dL)	31.7 (29.2-34.2)	36.0 (33.8-38.3)	36.1 (33.5-38.8)	36.2 (32.9-39.4)
TG (mg/dL)	176.0 (154.0-198.0)	197.6 (182.2-213.1)	202.8 (182.6-223.1)	190.6 (171.5-209.6)
25(OH)D (ng/mL)*	26.2 (24.6-27.8)	25.6 (24.6-26.6)	22.5 (21.2-23.9)	21.3 (19.6-23.0)

95% CI: 95% confidence intervals; BMI: body mass index; FPG: fasting plasma glucose; HbA1c: glycated hemoglobin; TC: total cholesterol; HDL: high-density lipoprotein cholesterol; LDL: low-density lipoprotein cholesterol; VLDL: very low-density lipoprotein cholesterol; TG: triglycerides; 25(OH)D: plasma 25-hydroxyvitamin D levels. *Vitamin D levels were obtained for 92% of the studied sample.

The distribution of vitamin D status–categorized as deficiency, insufficiency, and sufficiency–varied significantly across BMI categories (Kruskal Wallis, p <0.001). Subjects with obesity exhibited a higher proportion of vitamin D deficiency compared to those with normal weight or overweight (Figure 1). Notably, individuals with excess body weight (BMI ≥ 25 kg/m^2, n= 428) had mean plasma 25(OH)D levels of 24.0 ± 7.7 ng/mL, whereas participants with normal body weight (n= 112) had mean levels of 26.2 ± 8.4 ng/mL (t-test, p = 0.006).

Figure 1. Prevalence of vitamin D deficiency, insufficiency, and sufficiency, measured as plasma 25(OH)D levels according to body mass index categories.



ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

3.2 Analysis of the association between vitamin D levels and BMI

The linear regression analysis indicated that younger age, lower HDL, LDL, and 25(OH)D levels were associated with higher BMI. Additionally, elevated HbA1c levels, the presence of AHT, prediabetic or diabetic status, and female sex were linked to increased BMI. Standardized β coefficients revealed that age, sex, glycemic status, 25(OH)D levels, and AHT had the strongest impact on BMI (Table 3). Notably, plasma 25(OH)D levels ranked as the fourth most influential variable associated with obesity (see annexes for more information).

Table 3. Linear regression model between anthropometric, biochemical, and clinical variables with BMI (n=473).

Variable	β	SE	β - CI 95%	β standardized
Constant	42.96	2.03	38.96 – 46.96	
Sex (female)	2.60	0.46	1.66 – 3.47	0.22
Age	-0.19	0.02	-0.23 – -0.15	-0.34
HDL	-0.04	0.01	-0.08 – -0.01	-0.09
LDL	-0.02	0.01	-0.04 – -0.01	-0.13
Glycemic status	1.54	0.29	0.98 – 2.11	0.23
ATH	2.24	0.51	1.24 – 3.24	0.18
25(OH)D	-0.15	0.03	-0.21 – -0.10	-0.21

BMI: body mass index; β: regression coefficients; SE: Standard error; 95% CI: 95% confidence intervals; HDL: high-density lipoprotein cholesterol; LDL: low-density lipoprotein cholesterol; AHT: arterial hypertension; 25(OH)D: 25-hydroxyvitamin D. Summary of linear regression analyses with a backward algorithm.

4 Discussion

In this cross-sectional study, we performed a secondary analysis to evaluate the association between vitamin D status and BMI in a clinical-base sample of urban Costa Rican adults, derived from a case-control study of individuals with DM2. Given the potential role of vitamin D in metabolic health and obesity (Christakos et al., 2016), investigating its status is particularly relevant in Costa Rica, where obesity rates are a growing health concern (Gómez et al., 2020).

Our study demonstrated a high prevalence of vitamin D insufficiency and deficiency, with 77% of participants presenting hypovitaminosis D. Previous studies assessing 25(OH)D levels in Costa Rican adults have reported a prevalence of vitamin D deficiency and insufficiency ranging from 71% to 100% (Acuña, 2018; Gamboa-Gamboa et al., 2015; Ivankovich, 2015; Montero-Arias et al., 2013). These studies consistently showed that approximately one-third of participants exhibited deficiency, while at least half had insufficiency (Acuña, 2018; Gamboa-Gamboa et al., 2015; Holick et al., 2011;

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Ivankovich, 2015; Montero-Arias et al., 2013). Our findings revealed a similar distribution among individuals with 25(OH)D levels below 30 ng/mL. It is also noteworthy that most of these studies recruited participants from health centers and included individuals close to or older than 60 years of age, reflecting the age profile of our sample. In contrast, a study conducted in a younger population of college students (n =120) reported a different distribution, with 3.3% showing deficiency, 21.7% insufficiency, and 75.0% sufficiency (Castro & Holst, 2015). These findings are of particular concern in a tropical country where the sunlight is 12 hours per day and it should not be a limiting factor for vitamin D production. However, factors such as sunscreen use, skin pigmentation, and increased time spent indoors restrict effective sun exposure (Podd, 2015).

Furthermore, we found an inverse association between plasma 25(OH)D levels and BMI, such that participants with overweight and obesity had lower vitamin D concentrations than those with normal weight. This finding is consistent with international evidence linking vitamin D deficiency to excess body adiposity, across different age groups (Borba et al., 2023; Bezerra et al., 2022; Karampela et al., 2021; Rojas et al., 2020; Rontoyanni et al., 2017). The relationship between low vitamin D levels and obesity remains under debate and may be bidirectional. Two mechanisms related to the liposolubility of the vitamin D are that the excess body fat can reduce the bioavailability of 25(OH)D when this hormone is sequestered in the fat deposit (Carrelli et al., 2017; Migliaccio et al., 2019), or cause the "vitamin D dilution" effect where the same amount of vitamin D is distributed over a larger fat mass and lowers circulation 25(OH)D (Carrelli et al., 2017; Drincic et al., 2012; Oosterwerff et al., 2014). Other phenomena associated with obesity could explain this finding, as low physical activity may be linked to limited sun exposure, insulin resistance, low-grade inflammation (Hyppönen & Power, 2007; Ruiz-Ojeda et al., 2018), and reduced dietary vitamin D intake, which has been associated with BMI in a representative sample of urban Costa Rican subjects (Monge-Rodríguez et al., 2024).

Our results should be interpreted with caution, considering the specific characteristics of the sample. The data analyzed comes from a mixed group of individuals with and without DM2, derived from a case-control study on genetic risk factors for diabetes. Consequently, the evaluated population has a high proportion of individuals with altered glycemic status, and older age, both of which could influence vitamin D levels and the observed associations with BMI. Although analyses were adjusted for these variables, residual confounding cannot be ruled out. The overall tendency toward hyperglycemia (evidenced by elevated FPG and HbA1c values across all BMI categories) suggests an altered metabolic profile that may not necessarily represent the general Costa Rican population. Consistent with our findings, a meta-analysis reported an inverse relationship between 25(OH) concentrations and BMI in both subjects with DM2 (r = -0.17, 95% = -0.24 to -0.10) and non-diabetic individuals (r = -0.15, 95% = -0.19 to -0.12) (Rafiq & Jeppesen, 2018). Other limitations of our study include the non-representative sample, the absence of information on sun exposure, diet, and vitamin D supplementation.

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

5 Conclusions

Our study provides valuable evidence of the association between obesity and vitamin D deficiency in a Latin American population with a high prevalence of metabolic disturbances. The findings highlight the potential relevance of vitamin D in metabolic health. Future studies with longitudinal designs and representative samples are warranted to determine whether vitamin D deficiency serves as a relevant metabolic marker or a contributing factor in the development of obesity.

6 Acknowledgments

We thank Dr. Adriana Laclé for her contribution to the enrollment of participants in the original study and Dr. Marianella Vargas for her technical assistance. This work was funded by the Vice-rectory of Research of the Universidad de Costa Rica (B8312 and B0339).

7 References

Acuña, G. (2018). *Análisis de los niveles séricos de vitamina D y determinantes clínicos, nutricionales y funcionales en pacientes mayores de 60 años, en el Servicio de Hospital de Día del Hospital Nacional de Geriatría y Gerontología, durante el período de julio a diciembre del 2017* (Tesis de Especialidades Médicas Universidad de Costa Rica). Repositorio Institucional Kérwá https://repositorio.sibdi.ucr.ac.cr/handle/123456789/10248.

American Diabetes Association. (2022). Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes—2022. *Diabetes Care*, *45*, S17–S38. https://doi.org/10.2337/dc22-S002

Bezerra, F. F., Normando, P., Fonseca, A. C. P., Zembrzuski, V., Campos-Junior, M., Cabello-Acero, P. H., & Faerstein, E. (2022). Genetic, sociodemographic and lifestyle factors associated with serum 25-hydroxyvitamin D concentrations in Brazilian adults: the Pró-Saúde Study. *Cadernos de Saúde Pública*, *38*, e00287820.

Borba, V. Z. C., Lazaretti-Castro, M., Moreira, S. D. S., de Almeida, M. C. C., & Moreira Jr, E. D. (2023). Epidemiology of vitamin D (EpiVida)—a study of vitamin D status among healthy adults in Brazil. *Journal of the Endocrine Society*, *7*(1), bvac171. https://doi.org/10.1210/jendso/bvac171

Bouillon, R., Manousaki, D., Rosen, C., Trajanoska, K., Rivadeneira, F., & Richards, J. B. (2022). The health effects of vitamin D supplementation: evidence from human studies. *Nature Reviews Endocrinology*, *18*(2), 96–110. https://doi.org/10.1038/s41574-021-00593-z

Carrelli, A., Bucovsky, M., Horst, R., Cremers, S., Zhang, C., Bessler, M., Schrope, B., Evanko, J., Blanco, J., Silverberg, S. J., & Stein, E. M. (2017). Vitamin D Storage in Adipose Tissue of Obese and

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Normal Weight Women. *Journal of Bone and Mineral Research*, *32*(2), 237–242. https://doi.org/10.1002/jbmr.2979

Castro, N. A., & Holst, I. (2015). *Niveles séricos de 25-hidroxivitamina D3 en población estudiantil de la Universidad de Costa Rica*. Universidad de Costa Rica.

Chooi, Y. C., Ding, C., & Magkos, F. (2019). The epidemiology of obesity. *Metabolism: Clinical and Experimental*, *92*, 6–10. https://doi.org/10.1016/j.metabol.2018.09.005

Christakos, S., Dhawan, P., Verstuyf, A., Verlinden, L., & Carmeliet, G. (2016). Vitamin D: metabolism, molecular mechanism of action, and pleiotropic effects vitamin D analogs. *Physiol Rev*, *96*, 365–408. https://doi.org/10.1152/physrev.00014.2015

Cosentino, N., Campodonico, J., Milazzo, V., De Metrio, M., Brambilla, M., Camera, M., & Marenzi, G. (2021). Vitamin D and Cardiovascular Disease: Current Evidence and Future Perspectives. *Nutrients*, *13*(10). https://doi.org/10.3390/NU13103603

Drincic, A. T., Armas, L. A. G., Van Diest, E. E., & Heaney, R. P. (2012). Volumetric dilution, rather than sequestration best explains the low vitamin D status of obesity. *Obesity*, *20*(7), 1444–1448. https://doi.org/10.1038/oby.2011.404

Gamboa-Gamboa, T., Abarca-Soto, G., & G Jiménez-Montero, J. (2015). Prevalence of 25-hydroxyvitamin D deficiency in healthy personnel from an academic institution of an urban area in Costa Rica. *Research and Reports in Endocrine Disorders*. https://doi.org/10.2147/RRED.S90435

Giustina, A., Adler, R. A., Binkley, N., Bollerslev, J., Bouillon, R., Dawson-Hughes, B., Ebeling, P. R., Feldman, D., Formenti, A. M., Lazaretti-Castro, M., Marcocci, C., Rizzoli, R., Sempos, C. T., & Bilezikian, J. P. (2020). Consensus statement from 2 nd International Conference on Controversies in Vitamin D. *Reviews in Endocrine & Metabolic Disorders*, *21*(1), 89–116. https://doi.org/10.1007/S11154-019-09532-W

Gómez, G., Ramírez Sanabria, A., Sheik Oreamuno, A., Chinnock, A., Nogueira Previdelli, A., Hermes Sales, C., & Quesada Quesada, D. (2019). Prevalencia de ingesta inadecuada de micronutrientes en la población urbana de Costa Rica. *Archivos Latinoamericanos de Nutrición*, *69*(4), 221–232. https://doi.org/10.37527/2019.69.4.003

Gómez, G., Quesada, D., & Monge, R. (2020). Anthropometric profile and prevalence of overweight and obesity in Costa Rican urban population (Aged 20-65 years old) by sex group: Results from the Latin American Study of Nutrition and Health. *Nutricion Hospitalaria*, *37*(3), 534–542. https://doi.org/10.20960/nh.02899

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Hajhashemy, Z., Shahdadian, F., Ziaei, R., & Saneei, P. (2021). Serum vitamin D levels in relation to abdominal obesity: A systematic review and dose–response meta-analysis of epidemiologic studies. *Obesity Reviews*, *22*(2). https://doi.org/10.1111/obr.13134

Holick, M. F., Binkley, N. C., Bischoff-ferrari, H. A., Gordon, C. M., Hanley, D. A., Heaney, R. P., Murad, M. H., & Weaver, C. M. (2011). Evaluation, Treatment , and Prevention of Vitamin D Deficiency: an Endocrine Society Clinical Practice Guideline. *J Clin Endocrinol Metab*, *96*(7), 1911–1930. https://doi.org/10.1210/jc.2011-0385

Hyppönen, E., & Power, C. (2007). Hypovitaminosis D in British adults at age 45 y: nationwide cohort study of dietary and lifestyle predictors. *The American Journal of Clinical Nutrition*, *85*(3), 860–868. https://doi.org/10.1093/AJCN/85.3.860

Ismailova, A., & White, J. H. (2022). Vitamin D, infections and immunity. *Reviews in Endocrine & Metabolic Disorders*, *23*(2), 265–277. https://doi.org/10.1007/S11154-021-09679-5

Ivankovich, N. (2015). *Perfil del paciente con deficiencia e insuficiencia de vitamina D, atendido en la consulta del Hospital de Dia del Hospital Nacional de Geriatria y Gerontologia, desde septiembre del 2010 a septiembre del 2014*. Universidad de Costa Rica.

Karampela, I., Sakelliou, A., Vallianou, N., Christodoulatos, G. S., Magkos, F., & Dalamaga, M. (2021). Vitamin D and Obesity: Current Evidence and Controversies. *Current Obesity Reports*, *10*(2), 162–180. https://doi.org/10.1007/S13679-021-00433-1

Kovalskys, I., Fisberg, M., Gómez, G., Pareja, R. G., Yépez García, M. C., Cortés Sanabria, L. Y., Herrera-Cuenca, M., Rigotti, A., Guajardo, V., Zalcman Zimberg, I., Nogueira Previdelli, A., Moreno, L. A., & Koletzko, B. (2018). Energy intake and food sources of eight Latin American countries: Results from the Latin American Study of Nutrition and Health (ELANS). *Public Health Nutrition*, *21*(14), 2535–2547. https://doi.org/10.1017/S1368980018001222

Lin, X., & Li, H. (2021). Obesity: Epidemiology, Pathophysiology, and Therapeutics. *Frontiers in Endocrinology*, *12*. https://doi.org/10.3389/FENDO.2021.706978

Migliaccio, S., Di Nisio, A., Mele, C., Scappaticcio, L., Savastano, S., & Colao, A. (2019). Obesity and hypovitaminosis D: causality or casualty? *International Journal of Obesity Supplements*, *9*(1), 20–31. https://doi.org/10.1038/s41367-019-0010-8

Monge-Rodríguez, S., Arriola Aguirre, R., & Gómez, G. (2024). Ingesta de calcio y vitamina D: relación con exceso de peso en población costarricense. *Archivos Latinoamericanos de Nutrición*, *74*(1), 22-32. https://doi.org/10.37527/2024.74.1.003

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Montero-Arias, F., Sedó-Mejía, G., & Ramos-Esquivel, A. (2013). Vitamin D insufficiency and asthma severity in adults from Costa Rica. *Allergy, Asthma and Immunology Research*, *5*(5), 283–288. https://doi.org/10.4168/aair.2013.5.5.283

Oosterwerff, M. M., Eekhoff, E. M. W., Van Schoor, N. M., Boeke, A. J. P., Nanayakkara, P., Meijnen, R., Knol, D. L., Kramer, M. H. H., & Lips, P. (2014). Effect of moderate-dose vitamin D supplementation on insulin sensitivity in vitamin D-deficient non-Western immigrants in the Netherlands: A randomized placebo-controlled trial. *American Journal of Clinical Nutrition*, *100*(1), 152–160. https://doi.org/10.3945/ajcn.113.069260

Pilz, S., Verheyen, N., Grübler, M. R., Tomaschitz, A., & März, W. (2016). Vitamin D and cardiovascular disease prevention. *Nature Reviews Cardiology*. https://doi.org/10.1038/nrcardio.2016.73

Pittas, A. G., Dawson-Hughes, B., Sheehan, P., Ware, J. H., Knowler, W. C., Aroda, V. R., Brodsky, I., Ceglia, L., Chadha, C., Chatterjee, R., Desouza, C., Dolor, R., Foreyt, J., Fuss, P., Ghazi, A., Hsia, D. S., Johnson, K. C., Kashyap, S. R., Kim, S., … Staten, M. (2019). Vitamin D Supplementation and Prevention of Type 2 Diabetes. *New England Journal of Medicine*, *381*(6), 520–530. https://doi.org/10.1056/nejmoa1900906

Podd, D. (2015). Hypovitaminosis D: A common deficiency with pervasive consequences. *JAAPA : Official Journal of the American Academy of Physician Assistants*, *28*(2), 20–26. https://doi.org/10.1097/01.JAA.0000459810.95512.14

Rafiq, S., & Jeppesen, P. B. (2018). Body Mass Index, Vitamin D, and Type 2 Diabetes: A Systematic Review and Meta-Analysis. *Nutrients*, *10*(9). https://doi.org/10.3390/NU10091182

Rojas, L. Z., Quintero-Lesmes, D. C., Gamboa-Delgado, E. M., Guio, E., & Serrano, N. C. (2020). Prevalence of vitamin D status and its association with overweight or obesity in a population of Colombian children and adolescents. *Journal of nutritional science*, *9*, e55. https://doi.org/10.1017/jns.2020.47

Rontoyanni, V. G., Avila, J. C., Kaul, S., Wong, R., & Veeranki, S. P. (2017). Association between obesity and serum 25 (OH) D concentrations in older Mexican adults. Nutrients, 9(2), 97. https://doi.org/10.3390/nu9020097

Ruiz-Ojeda, F. J., Anguita-Ruiz, A., Leis, R., & Aguilera, C. M. (2018). Genetic Factors and Molecular Mechanisms of Vitamin D and Obesity Relationship. *Annals of Nutrition & Metabolism*, *73*(2), 89–99. https://doi.org/10.1159/000490669

Sassi, F., Tamone, C., & D'amelio, P. (2018). Vitamin D: Nutrient, Hormone, and Immunomodulator. *Nutrients*, *10*(11). https://doi.org/10.3390/NU10111656

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

The Jamovi project. (2021). *jamovi* (2.2). Jamovi. https://www.jamovi.org

WHO. (2000). *Obesity: preventing and managing the global epidemic*.

Zhang, P., Guo, D., Xu, B., Huang, C., Yang, S., Wang, W., Liu, W., Deng, Y., Li, K., Liu, D., Lin, J., Wei, X., Huang, Y., & Zhang, H. (2022). Association of Serum 25-Hydroxyvitamin D With Cardiovascular Outcomes and All-Cause Mortality in Individuals With Prediabetes and Diabetes: Results From the UK Biobank Prospective Cohort Study. *Diabetes Care*, *45*(5), 1219–1229. https://doi.org/10.2337/DC21-2193

8 Annexes

Annex A. Sample calculation for the proportion of subjects with vitamin D sufficiency.

Parameter	Value or equation
Alpha (α)	0.05
Sampling error (e)	0.1
Z value α (Z_α)	1.96
Proportion (p)	0.3
Sample (n)	$n = \frac{{Z_\alpha}^2 \times p(1-p)}{e^2}$

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Annex B. Linear regression model, backwards method. BMI as a response variable.

		β non standardized coefficient	SE	β standaridized coefficient	t	P value	CI 95% for β non standardized coefficient	
1	Constant	41.505	2.497		16.619	.000	36.597	46.412
	Sex (female)	2.636	.463	.227	5.696	.000	1.727	3.545
	Age	-.184	.022	-.334	-8.358	.000	-.227	-.141
	FPG	-.009	.007	-.076	-1.328	.185	-.022	.004
	CT	-.009	.046	-.065	-.194	.846	-.099	.081
	TG	.001	.011	.011	.076	.940	-.021	.023
	HDL	-.031	.047	-.066	-.650	.516	-.123	.062
	LDL	-.012	.046	-.080	-.259	.795	-.103	.079
	VLDL	.009	.025	.028	.374	.709	-.039	.058
	HbA1C	.368	.209	.106	1.756	.080	-.044	.779
	AHT	2.147	.513	.173	4.183	.000	1.138	3.156
	Glycemic status	1.399	.339	.206	4.120	.000	.732	2.066
	25(OH)D	-.143	.028	-.203	-5.130	.000	-.198	-.088
2	(Constant)	41.516	2.490		16.674	.000	36.623	46.409
	Sex (female)	2.636	.462	.227	5.702	.000	1.728	3.544
	Age	-.184	.022	-.335	-8.379	.000	-.227	-.141
	FPG	-.009	.007	-.077	-1.330	.184	-.022	.004
	CT	-.006	.024	-.043	-.247	.805	-.053	.041
	HDL	-.034	.025	-.073	-1.346	.179	-.083	.015
	LDL	-.015	.025	-.099	-.592	.554	-.064	.035
	VLDL	.010	.021	.031	.491	.624	-.031	.051
	HbA1C	.368	.209	.106	1.762	.079	-.043	.779
	AHT	2.149	.512	.173	4.199	.000	1.143	3.155
	Glycemic status	1.399	.339	.206	4.127	.000	.733	2.066
	25(OH)D	-.143	.028	-.203	-5.149	.000	-.198	-.088
3	(Constant)	41.402	2.444		16.940	.000	36.599	46.205
	Sex (female)	2.632	.462	.226	5.703	.000	1.725	3.540
	Age	-.184	.022	-.335	-8.387	.000	-.227	-.141
	FPG	-.009	.007	-.077	-1.340	.181	-.022	.004
	HDL	-.038	.018	-.082	-2.051	.041	-.074	-.002
	LDL	-.021	.006	-.139	-3.514	.000	-.033	-.009
	VLDL	.006	.013	.019	.484	.628	-.019	.031
	HbA1C	.369	.209	.107	1.766	.078	-.042	.779
	AHT	2.143	.511	.173	4.196	.000	1.139	3.146

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

		β non standardized coefficient	SE	β standaridized coefficient	t	P value	CI 95% for β non standardized coefficient	
	Glycemic status	1.396	.338	.205	4.125	.000	.731	2.061
	25(OH)D	-.143	.028	-.203	-5.151	.000	-.197	-.088
4	(Constant)	41.694	2.367		17.618	.000	37.044	46.345
	Sex (female)	2.632	.461	.226	5.706	.000	1.725	3.538
	Age	-.185	.022	-.336	-8.448	.000	-.228	-.142
	FPG	-.009	.007	-.077	-1.335	.183	-.022	.004
	HDL	-.039	.018	-.085	-2.141	.033	-.075	-.003
	LDL	-.021	.006	-.140	-3.536	.000	-.033	-.009
	HbA1C	.372	.209	.107	1.782	.075	-.038	.781
	AHT	2.158	.509	.174	4.237	.000	1.157	3.158
	Glycemic status	1.405	.338	.206	4.160	.000	.741	2.068
	25(OH)D	-.143	.028	-.203	-5.180	.000	-.198	-.089
5	(Constant)	41.494	2.364		17.554	.000	36.849	46.139
	Sex (female)	2.594	.461	.223	5.631	.000	1.689	3.499
	Age	-.182	.022	-.330	-8.347	.000	-.224	-.139
	HDL	-.037	.018	-.080	-2.027	.043	-.072	-.001
	LDL	-.020	.006	-.135	-3.421	.001	-.032	-.009
	HbA1C	.199	.164	.057	1.215	.225	-.123	.520
	AHT	2.184	.509	.176	4.288	.000	1.183	3.184
	Glycemic status	1.334	.334	.196	3.997	.000	.678	1.990
	25(OH)D	-.144	.028	-.204	-5.195	.000	-.198	-.090
6	(Constant)	42.960	2.033		21.129	.000	38.965	46.956
	Sex (female)	2.568	.460	.221	5.578	.000	1.663	3.473
	Age	-.187	.021	-.340	-8.790	.000	-.229	-.145
	HDL	-.039	.018	-.085	-2.169	.031	-.075	-.004
	LDL	-.020	.006	-.131	-3.325	.001	-.031	-.008
	AHT	2.241	.507	.181	4.418	.000	1.244	3.238
	Glycemic status	1.545	.285	.227	5.416	.000	.984	2.105
	25(OH)D	-.148	.028	-.209	-5.355	.000	-.202	-.093

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/

Doi: https://doi.org/10.15517/5ejvz191
Volume 23, Issue 2, Sci. Art. January-June 2026

Población y Salud
en Mesoamérica

¿Quiere publicar en la revista?
Ingrese **aquí**

O escríbanos:
revista.ccp@ucr.ac.cr

Población y Salud en Mesoamérica (PSM) es la revista electrónica que cambió el paradigma en el área de las publicaciones científicas electrónicas de la UCR. Logros tales como haber sido la primera en obtener sello editorial como revista electrónica la posicionan como una de las más visionarias.

Revista PSM es la letra delta mayúscula, el cambio y el futuro.

Indexada en los catálogos más prestigiosos. Para conocer la lista completa de índices, ingrese **aquí.**

Scopus · SciELO · DOAJ · latindex · redalyc.org · Dialnet

Revista Población y Salud en Mesoamérica -
Centro Centroamericano de Población
Instituto de Investigaciones en Salud
Universidad de Costa Rica

ISSN-1659-0201
http://ccp.ucr.ac.cr/revista/