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Hypovitaminosis D and Calcium Intake in Adult Population*

Renato Antonio Guzmán Moreno^a ■ Luis Gabriel Piñeros Ricardo^b
■ Aníbal Alfonso Teherán Valderrama^c ■ Luis Miguel Pombo Ospina^d
■ Jonth Alberth Flechas Lopez^e ■ María Camila Mejía Guatibonza^f

Abstract: Background: Daily dietary calcium intake below the requirements has been related to low levels of vitamin D (Vit-D) and osteoarticular diseases. **Objective:** To determine the prevalence of Vit-D deficiency in the general population living in Bogotá, its relationship to dietary calcium intake, and the influence of socio-demographic factors and sunlight exposure. **Materials and methods:** In a pro-spective cohort of the general population (randomly selected), excluding individuals with conditions affecting calcium absorption or adequate Vit-D action, the prevalence of hypovitaminosis D (95 % CI) and regular consumption of calcium (RCI, mg/day) is measured according to socio-demographic, anthropometric, biochemical, and sunlight exposure variables. A multiple regression model is implemented (no intercept) to predict Vit-D concentration based on the factors described. **Results:** Ninety-seven patients are included, 61 % of which are women, with a median age of 23 years, a weight of 65 kg (IQR: 55.2–70.5), a height of 165 cm ± 8.9, and BMI of 22.8 kg/m² (IQR: 21.2–25.2). The RCI was 393.7 mg/day, less than the benchmark for Colombian adults ($p < 0.001$); serum calcium concentration was 9.7 mg/dL. The mean Vit-D concentration (95 % CI) was 23.7 ng/mL (22.6–24.7); hypovitaminosis D was identified in 87 % of the sample (80.6–94.7 %), 24.7 % were classified as poor (15.6–33.8 %)

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a Specialist in Internal Medicine, Rheumatology and Immunology, Complexus Research Group. Juan N. Corpas University. Bogotá, Colombia. E-mail: renato.guzman@juanncorpas.edu.co

b Specialist in Family Medicine and Alternative Therapeutics and Plant Pharmacology, GIFVTA Research Group. Juan N. Corpas University. Bogotá, Colombia. E-mail: luis.pineros@juanncorpas.edu.co.
ORCID: <https://orcid.org/0000-0001-8912-2458>

c Emergency Medicine fellow, Epidemiologist, Complexus Research Group. Juan N. Corpas University. Bogotá, Colombia. E-mail: anibal.teheran@juanncorpas.edu.co.
ORCID: <https://orcid.org/0000-0002-7666-8766>

d Chemical Engineer, GIFVTA Research Group. Juan N. Corpas University. Bogotá, Colombia.
E-mail: miguel.pombo@juanncorpas.edu.co. ORCID: <https://orcid.org/0000-0002-7277-1838>

e Physician, Internal Medicine student, Complexus Research Group. Juan N. Corpas University. Bogotá, Colombia. E-mail: jonth-flechas@juanncorpas.edu.co

f Corresponding author. Physician, Epidemiology student, Complexus Research Group. Juan N. Corpas University. Bogotá, Colombia. E-mail: maria-mejia@juanncorpas.edu.co.
ORCID: <https://orcid.org/0000-0003-1771-8214>

and 62.9 % as insufficient (52.8–73 %). Vit-D concentration was predicted in a quadratic function by the interaction between sex, sunlight exposure, and RCI ($R^2 > 90 \%$). **Conclusion:** The suspected high prevalence of Vit-D deficiency is confirmed in the general Colombian adult population as a result of low dietary calcium intake, demographic factors, and sunlight exposure.

Keywords: calcium; dietary; cholecalciferol; avitaminosis; bone diseases; developmental

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Hipovitaminosis D y la ingesta de calcio en población adulta

Resumen: El consumo diario de calcio en la dieta por debajo de los requerimientos se ha relacionado con bajos niveles de Vitamina D (Vit-D) y con enfermedades osteoarticulares. **Objetivo:** determinar la prevalencia de la deficiencia de Vit-D en la población general **que** vive en Bogotá, su relación con la ingesta de calcio en la dieta y la influencia de factores sociodemográficos y de la exposición a la luz solar. **Materiales y métodos:** en una cohorte prospectiva seleccionada aleatoriamente de la población general, excluyendo individuos con condiciones que afectaran la absorción de calcio o la acción de la Vit-D, se midió la prevalencia de hipovitaminosis D (IC 95 %) y el consumo habitual de calcio (CHC, mg/día), según variables sociodemográficas, antropométricas, bioquímicas y de exposición solar; se implementó un modelo de regresión múltiple (sin el intercepto) para predecir la concentración de Vit-D en función de los factores descritos. **Resultados:** se incluyeron 97 pacientes, edad mediana 23 años, 61 % mujeres; con peso mediano 65 kg (RIC; 55,2-70,5), estatura 165 cm \pm 8,9 e IMC 22,8 kg/m² (RIC; 21,2-25,2). El CHC fue 393,7 mg/día, menor que el recomendado para adultos colombianos ($p < 0,001$); la concentración de calcio sérico fue 9,7 mg/dL. La concentración media (IC 95 %) de Vit-D fue 23,7 ng/mL (22,6-24,7), se identificó hipovitaminosis D en 87 % (80,6-94,7 %); 24,7 % se clasificaron como deficientes (15,6-33,8 %) y 62,9 % como insuficientes (52,8-73 %). La concentración de Vit-D se logró predecir, en función cuadrática, por la interacción entre el sexo, la exposición solar y el CHC ($R^2 > 90 \%$). **Conclusiones:** teniendo en cuenta los resultados obtenidos, se confirma la sospecha de alta prevalencia de hipovitaminosis D en población general colombiana adulta, relacionada con un bajo consumo de calcio en la dieta habitual, factores demográficos y de exposición solar.

Palabras clave: calcio en la dieta; colecalciferol; avitaminosis; enfermedades de los huesos; desarrollo

Hipovitaminose de ingestão de cálcio em população adulta

Resumo: Introdução: o consumo diário de cálcio na dieta abaixo dos requerimentos necessários tem sido relacionado com baixos níveis de vitamina D (Vit-D) e com doenças osteoarticulares. Objetivo: determinar a prevalência da deficiência de Vit-D na população geral que vive em Bogotá, Colômbia, sua relação com a ingestão de cálcio na dieta, a influência de fatores sociodemográficos e a exposição à luz solar. Materiais e métodos: em uma coorte prospectiva selecionada aleatoriamente da população geral, excluindo indivíduos com condições que afetassem a absorção de cálcio ou a ação de Vit-D, foi medida a prevalência de hipovitaminose D (IC 95 %) e o consumo habitual de cálcio (CHC, mg/dia), segundo variáveis sociodemográficas, antropométricas, bioquímicas e exposição solar; foi

implementado um modelo de regressão múltipla (sem o intercepto) para prever a concentração de Vit-D em função dos fatores descritos. Resultados: foram incluídos 97 pacientes, com idade média 23 anos, 61 % mulheres; com peso médio de 65 kg (RIC; 55,2-70,5), estatura 165 cm \pm 8,9 e IMC 22,8 kg/m² (RIC; 21,2-25,2). O CHC foi 393,7 mg/dia, menor do que o recomendado para adultos colombianos ($p < 0,001$); a concentração sérica de cálcio foi 9,7 mg/dL. A concentração média (IC 95 %) de Vit-D foi 23,7 ng/mL (22,6-24,7), foi identificada hipovitaminose D em 87 % (80,6-94,7 %), foram classificados deficientes 24,7 % (15,6-33,8 %) e insuficientes 62,9 % (52,8-73 %). A concentração de Vit-D foi possível prever, em função quadrática, pela interação entre sexo, exposição solar e CHC ($R^2 > 90$ %). Conclusões: a partir dos resultados obtidos, é confirmada a suspeita de alta prevalência de hipovitaminose D em população geral colombiana adulta, relacionada com um baixo consumo de cálcio na dieta habitual, fatores demográficos e exposição solar.

Palavras-chave: cálcio na dieta; colecalciferol; avitaminose; doenças dos ossos; desenvolvimento

Background

Daily calcium intake below the necessary daily requirements has been linked to low vitamin D (Vit-D) and the appearance of osteoarticular diseases, osteoporosis, and fractures, among others (1–3).

Calcium and Vit-D influence metabolic and immunologic processes and their deficiency has also been linked to the occurrence of connective tissue diseases such as systemic lupus erythematosus and rheumatoid arthritis (4–6). There are two fundamental pillars in achieving adequate skeletal health: calcium levels and the preponderant role of Vit-D (7–10), although some researchers have recently discussed their role in therapeutics, specifically, their osteoprotective action (11–13).

Hypovitaminosis D appears in the context of a multifactorial model caused by changes in lifestyle, eating habits, sleep patterns, and other conditions produced by stress. This combination of factors may end up in connective tissue pathology, with syndromic features, predominantly affecting young or post-menopausal women (14).

The environmental conditions related to the geographical location are determinants that establish social and cultural patterns: apparel type and walking to work directly influence the degree of sunlight exposure, a necessary physiological component for Vit-D production. Interaction between these variables and those derived from lifestyle, eating habits, age, and sex transform into a risk

formula that impacts the incidence or prevalence of Vit-D deficiency (15,16).

This diagnosis is common in Asian countries where 96 % of infants, 91 % of schoolgirls, 78 % of health professionals, and 84 % of pregnant women suffer from this condition; in Europe, between 2–30 % of the adult population and 75 % of older people showed Vit-D deficiency, most often in men (16). In North America, the NHANES III study identified a relationship between calcium intake and Vit-D deficiency, and low levels were found in 23 % of men, 56 % of women between 20–70 years old, and 97 % of older people (17).

In Latin America, even if there is weak evidence, the perspective is consistent. In Mexico, Chile, and Brazil, the incidence of Vit-D deficiency in the general population ranges between 42–67 %. In Colombia, there are studies only in post-menopausal women and patients with renal and metabolic diseases, reporting frequencies of 55 % and 92 %, respectively (18, 19). There are no studies in the general population in Colombia, a country located in the tropics with a variety of climate zones and sociocultural patterns that may predispose inhabitants to the occurrence and prevalence of this condition.

Therefore, this study aims to determine the prevalence of Vit-D deficiency in a specific group of people in Bogotá, its relationship to dietary calcium intake, and the influence of sociodemographic factors and sunlight exposure.

Materials and methods

Design and place of study

A prospective descriptive study was conducted in the School of Medicine at the Fundación Universitaria Juan N. Corpas (FUJNC) in Bogotá, Colombia, which also has a University Hospital (Juan N. Corpas Hospital) that together with other entities forms the Corpas Social Group (CSG). It has around 3,084 people, including students, faculty, staff, clinical, and services personnel; most of them study and work during daylight, except those who provide security services. The study was approved by the FUJNC Ethics and Research Committees (Code of Ethics Committee approval).

Selection of participants and collection of information

Consecutively, in November 2016, participants were selected randomly; with the benchmark of hypovitaminosis D in 76.9% of post-menopausal women, we calculated a sample of 66 participants to achieve 95% CI, with 10% amplitude and a 5% margin of error (19).

Two surveys were designed to collect data; the first one contained sociodemographic, anthropometric variables, and exclusion criteria; the second one, items to estimate daily dietary calcium intake and body sunlight exposure.

Individuals between 18–70 years old were included, who belonged to the CSG during the established study period, signed informed consents, and kept the required fast for sampling. Exclusion criteria were people with a Body Mass Index (BMI) < 16 or > 35, consumption of mineral or vitamin supplements, a Charlson Index > 2, surgical history (endocrine or gastrointestinal) that affects calcium absorption or Vit-D action; autoimmune or rheumatic diseases, osteoporosis, osteomalacia, stage C or D heart failure, dysthyroidism venous thromboembolism; treatment with loop diuretics, corticosteroids, antiplatelet or anticoagulant agents; lack of monitoring, and problems when filling questionnaires.

Surveys were administered by fifth-year medicine students previously trained and supervised by

three researchers (AAT, LMP, LGP). The information related to calcium intake was collected with open questions asking to describe the food eaten the day before the interview.

A week before and during the collection phase, CSG staff and patients attending the outpatient unit were informed of research and the need for fasting from 8 to 12 hours to ensure their inclusion, in case of being selected at random.

Information related to age, sex, weight, height, occupation, working hours, socioeconomic status (SES), and monthly income was collected; the calcium intake data was converted into mg/day using the Food Frequency Questionnaire/Recall Method instrument, validated for the Colombian population (20,21). Immediately after filling out the instruments, between 07:00 and 09:00 hours, the blood sample was frozen at -20 ° C and processed at < 12 hours to measure serum calcium (mg/dL) and collected Vit-D (ng/mL), both of them through the chemiluminescent immunoassay technique (BioImagen).

The second survey was carried out by phone on the third and fifth day after the first evaluation to calculate the average daily calcium intake during a week.

The hours of sunlight exposure were determined by calculating the weekly average in three evaluations at different times; we asked about the daily use of clothing to determine the number of sun-exposed body parts: 0 (none), 1 (only one area exposed: face, back, upper or lower area) and > 1 (more than one area exposed: face, back, upper or lower area).

Outcome measures

Individuals were classified as having adequate, insufficient, or deficient levels of Vit-D to determine the prevalence of hypovitaminosis (22).

The average daily dietary calcium intake was compared to that suggested for the Colombian population (23,24).

Also, the relationship between Vit-D concentration, sociodemographic, anthropometric, and physiological variables, and sunlight exposure was evaluated.

Statistical analysis

Minitab-V17 software was used to present and analyze the results. Data were expressed as means, medians, and proportions (95 % CI); normality was determined with the Shapiro Wilks test. Continuous data comparisons for two independent groups were performed using the U Mann-Whitney test or Kruskal Wallis for three or more independent groups. Categorical data were compared with the chi-square test (χ^2); $p < 0.05$ (two-tailed) was established as significant.

Following a univariate analysis, which identified variables related to Vit-D concentration ($p < 0.2$), a multiple regression model that evaluated the most favorable interaction was run to predict Vit-D concentration. The model was applied without the intercept, steps forward, and included variables with $p < 0.05$.

Results

During the study, 106 potential participants were evaluated, six were excluded for not meeting the inclusion criteria, two for not monitoring their food consumption, and one due to a technical failure while processing laboratory samples (Figure 1).

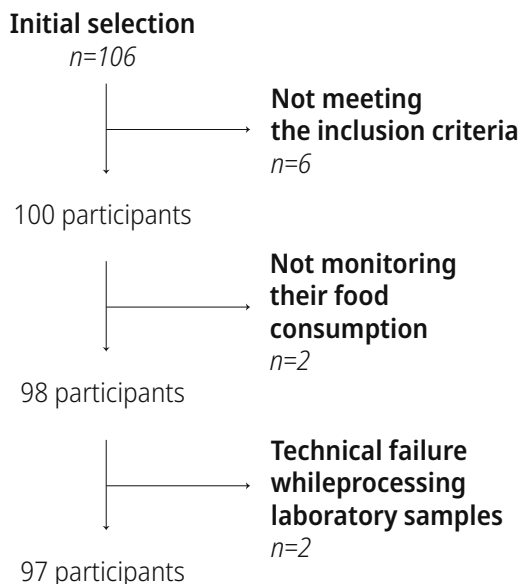


Figure 1. Participant selection process.

Source: Own elaboration.

Ninety-seven subjects were included, most of them with a median age of 23, 60.8 % were women, 36 % belonged to middle SES, 83 % worked in the health field, and 47.7 % had a monthly income between 1-2 statutory minimum wages (Table 1).

Baseline features	n: 97
Age, median (Q1–Q3)	23 (22–31)
Sex, n (%)	
Female	59 (60.8)
Male	38 (39.2)
SES, n (%) ^a	
Low	33 (34.0)
Medium	35 (36.1)
High	29 (29.9)
Occupation, n (%)	
Health care	80 (83.3)
Sales and services	13 (13.5)
Finance and administration	3 (3.1)
Monthly income, n (%)	
≤ 1 SMMLV	7 (7.2)
> 1–2 SMMLV	46 (47.4)
> 2–4 SMMLV	20 (20.6)
> 4 SMMLV	24 (24.7)

Table 1. Sociodemographic Features of Participants

Q1: p25; Q3: p75; SES: Socioeconomic status, low (1–2), medium (3–4), high (5–6); SMMLV: Statutory monthly minimum wage in force; ^a: No significant differences were found between participants by SES.

Source: Own elaboration.

Anthropometric and physiological characteristics

Two of the three anthropometric variables and all physiological variables showed skewed distributions; the results were analyzed according to the SES, given the influence of this condition in

the studied variables. No differences in weight, BMI, intake, or serum levels of calcium and Vit-D were found when comparing SES subgroups. Subjects belonging to low SES showed shorter height (mean \pm SD) compared to the

other two subgroups, but no influence on BMI ($p = 0.001$) (Table 2). Further analysis between levels of monthly income or physiological and anthropometric variables was performed, and no relationship was found (Table 3).

Features	High SES	Medium SES	Low SES	Total	<i>p</i> -Value
Weight (kg) ^a	65 (59.5–77.5)	62 (53–75)	61 (55.3–67)	62 (55.2–70.5)	0.152
Height (cm) ^b	168.5 \pm 7.3	168.1 \pm 8.9	161.2 \pm 8.7	165.9 \pm 8.9	0.001
BMI (kg/m ²) ^a	24 (21.5–25.8)	22.2 (20.7–24.2)	23.1 (21.3–25.1)	22.8 (21.2–25.2)	0.244
Calcium intake (daily mean) ^a	345.7 (281.8–515)	441.3 (304–597.3)	362 (282.8–457.5)	393.7 (291.8–525)	0.154
Serum calcium (mg/dL) ^a	9.7 (9.5–9.9)	9.8 (9.5–9.9)	9.7 (9.4–9.9)	9.7 (9.4–9.9)	0.847
Vitamin D (ng/mL) ^b	23.6 \pm 4.3	23.9 \pm 4.9	23.5 \pm 5.8	23.7 \pm 5.02	0.947

Table 2. Anthropometric and Physiological Features of Participants

SES: Socioeconomic status; ^a: median (p25–p75); ^b: mean \pm SD; BMI: Body mass index. The median differences were established using a Kruskal-Wallis test and ANOVA.

Source: Own elaboration.

Characteristics	<i>p</i> -Value
Sex	0.196 ^a
Age (years)	0.417
Occupation	0.821
SES	0.947
Monthly income (SMMLV)	0.170 ^a
Weight (kg)	0.915
Height (cm)	0.454
BMI (kg/m ²)	0.436
Calcium intake (mg/day)	0.068 ^a
Serum calcium (mg/dL)	0.022 ^a
Sunlight exposure (hours)	0.615
Sun-exposed body parts	0.194 ^a

Table 3. Relationship between Vit-D Concentration and Sociodemographic, Anthropometric, Physiological, and Sunlight Exposure Characteristics.

^a: Characteristics with *p*-value < 0.2 will be evaluated using an interaction model.

Source: Own elaboration.

The daily calcium intake (mg/day) in each of the SES and overall was lower than the recommended for the Colombian adult population (800 mg/day) (Wilcoxon test, $p < 0.001$); median (p25–p75) intake in men and women was 348.2 mg/day (285.4–536.7) and 408.3 mg/day (296–520.3), respectively, both being lower than that recommended for our population (Table 2).

Frequency of hypovitaminosis D

Some degree of hypovitaminosis D was identified in 87 % of individuals: 24.7 % were classified as deficient (95 % CI, 15.6–33.8 %), 62.9 % as insufficient (95 % CI, 52.8–73 %), and 12.4 % as sufficient (95 % CI, 5.3–19.4 %). The average Vit-D concentration (ng/mL) (95 % CI) was 17.6 (16.8–18.4) in the deficient group, 24.3 (23.7 to 24.7) in the insufficient group, and 32.7 (30.6 to 34.8) in the sufficient group (Figures 2 and 3).

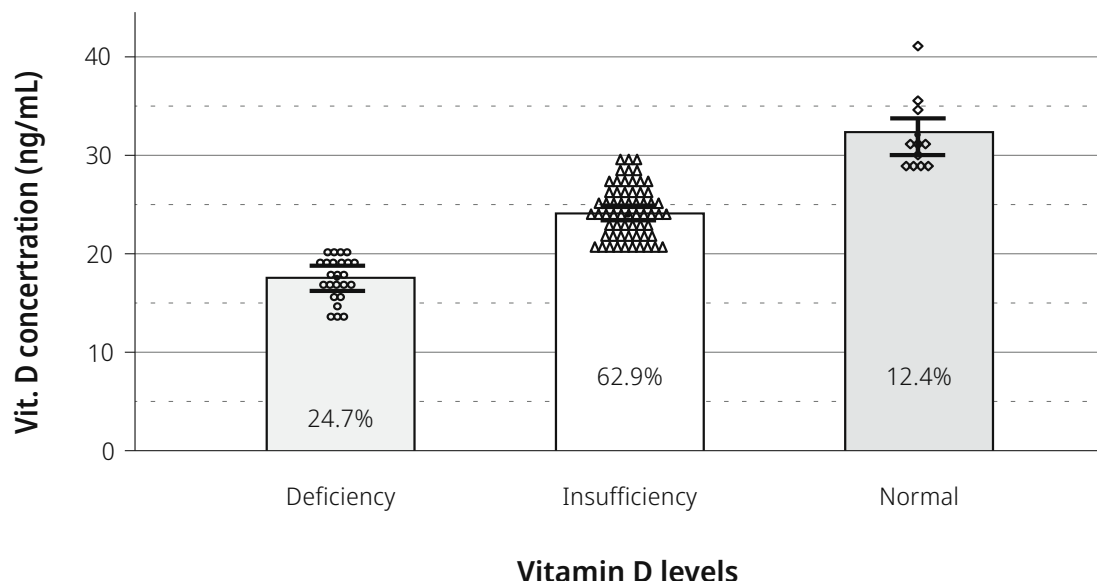


Figure 2. Vit-D concentration and Hypovitaminosis D prevalence. Vit. D: Vitamin D; Deficient: [Vit-D] ≤ 20 ng/mL; Insufficient: [Vit-D] 21–29 ng/mL; Normal: [Vit-D] ≥ 30 ng/dL.

Source: Own elaboration.

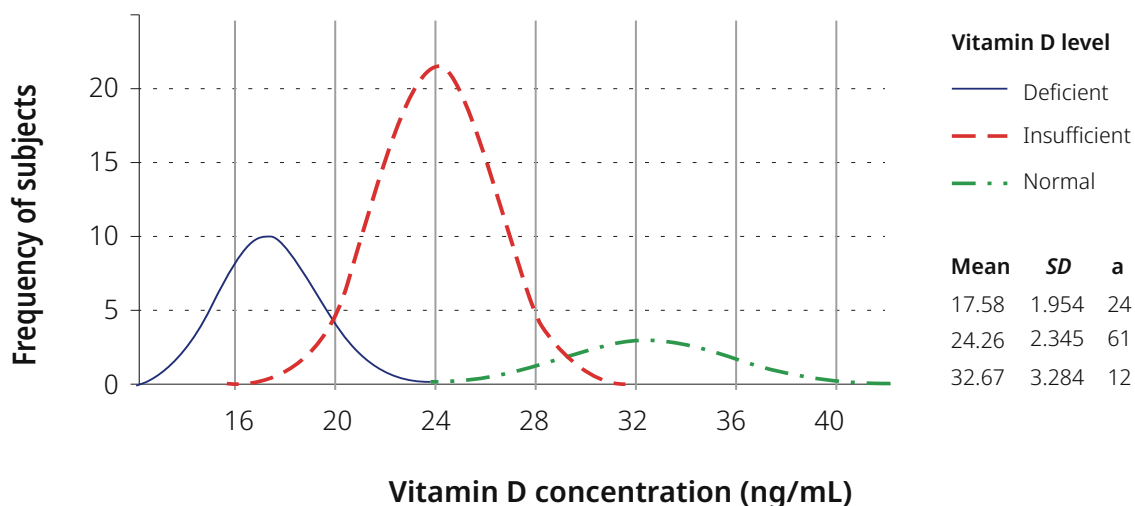


Figure 3. Vit-D concentration in the study subjects.

Source: Own elaboration.

Factors related to Vit-D concentration

About half of the individuals (50/97; 51.6%) reported daily sunlight exposure ranging between 2–5 hours; the others had one hour (44/97; 45.4%) or no hours during the day (3/97; 3.1%). Most of

the people exposed one complete body part only (57/97; 58.8%), followed by those who exposed more than one part (36/97; 37.1%). A trend related to the hours of daily sunlight exposure, the number of body parts exposed, and the levels of Vit-D was identified, showing no statistical relationship between variables (Figure 4).

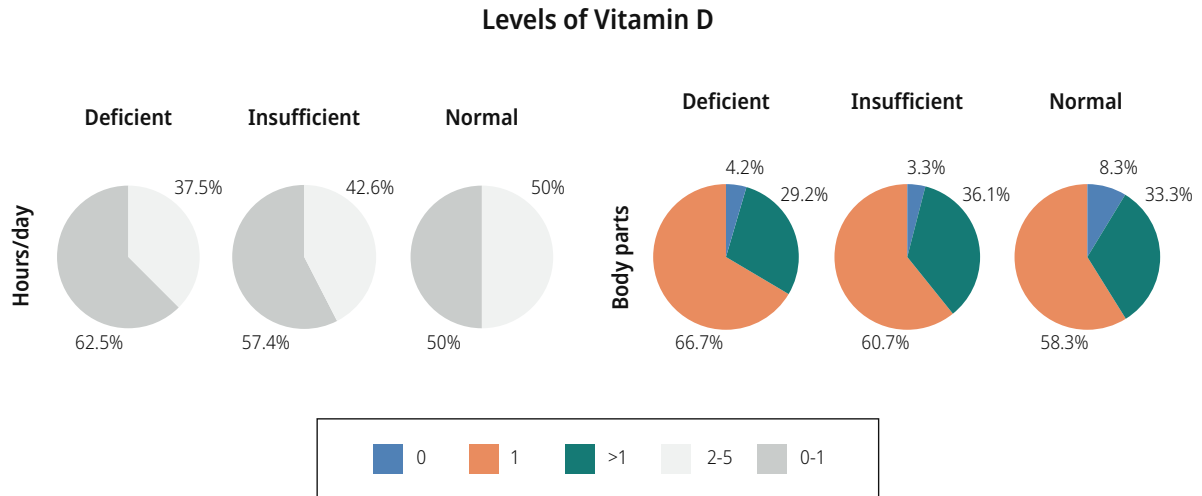


Figure 4. Daily sunlight exposure and serum Vit-D. Sunlight exposure: 0-1 hours, 2-5 hours; Sun-exposed body parts (hours/day): 0, 1, > 1 parts.

Source: Own elaboration.

The univariate analysis showed that the variables with a $p < 0.2$ statistical relationship were sex, monthly income level, calcium intake, serum calcium, and the number of daily sun-exposed body parts.

Interaction between calcium intake and the number of daily sun-exposed body parts was identified with differences when stratifying between men and women ($p < 0.05$); men had a higher concentration of Vit-D, preferably when consuming higher levels of dietary calcium (Figure 5).

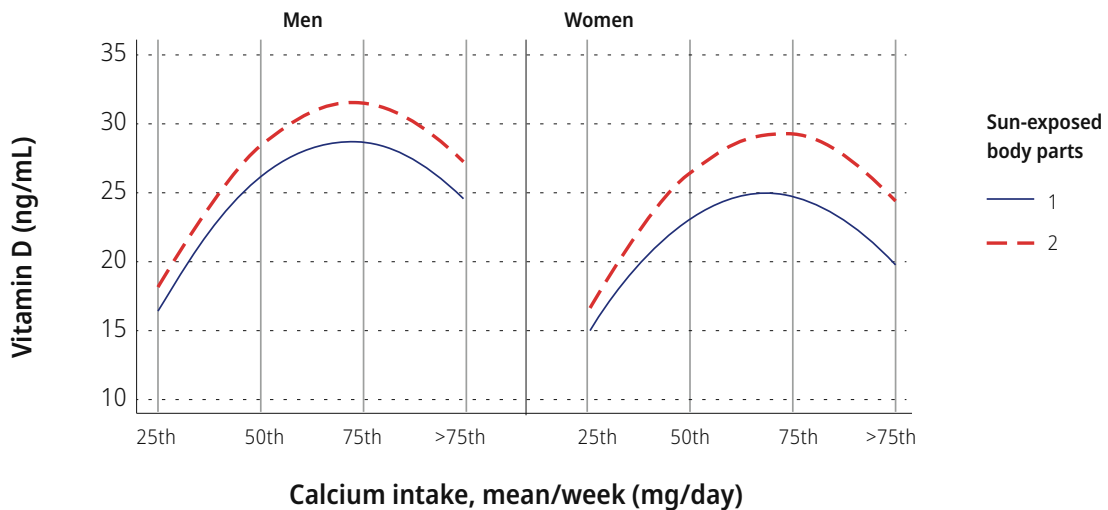


Figure 5. Vit-D concentration related to calcium intake, sunlight exposure, and sex. SEBP: Sun exposed body parts; R^2 Men, 0-1 SEBP: 96.2%; R^2 Men, > 1 SEBP: 98%; R^2 Women, 0-1 SEBP: 94.2%; R^2 Women, > 1 SEBP: 94.1%.

Source: Own elaboration.

Dietary calcium intake was divided into quartiles: ≤ 291.8 mg/day (p25), $> 291.8\text{--}393.7$ mg/day (p50), $> 393.7\text{--}525$ mg/day (p75), and > 525 mg/day. Table 4 details the equations of the regression model.

Factor	Equation
Man	
Sunlight exposure	
0-1	$20.0 * \text{calcium intake level} - 3.461 * \text{calcium intake level}^2$
>1	$21.75 * \text{calcium intake level} - 3.739 * \text{calcium intake level}^2$
Woman	
Sunlight exposure	
0-1	$18.39 * \text{calcium intake level} - 3.372 * \text{calcium intake level}^2$
>1	$20.92 * \text{calcium intake level} - 3.716 * \text{calcium intake level}^2$

Table 4. Prediction of Vit-D Concentration Related to Calcium Intake Level, Sunlight Exposure, and Sex

Sunlight exposure: Sun-exposed body parts; Calcium intake level: Level 1 (\leq p25), level 2 ($>$ p25–p50), level 3 ($>$ p50–p75), level 4 ($>$ p75). The regression model was adjusted to a quadratic function.

Source: Own elaboration.

Discussion

This research determined the prevalence of hypovitaminosis D among healthy individuals in a specific group of participants; it also contrasted the regular dietary calcium intake with the minimum required for adults and identified possible factors related to Vit-D concentration.

The place of selection of participants allowed identifying individuals with different SES and classify them randomly; this relationship was found in nutritional studies involving biochemical variables (25). In CSG institutions, the activity of their members is related to the provision of health care services, and due to their educational background, they would be expected to apply their knowledge of daily nutritional requirements to their self-care.

Finally, it is noteworthy that, among the participants, no individuals belonged to indigenous communities and other special groups with specific nutritional habits that could influence biological markers.

In general, dietary calcium intake was two times lower than the established for Colombian adults, according to the National Statistics Department; some of the most frequently consumed foods in Bogota are bread, cereals, milk, cheese, and eggs, all of them between 17–212 mg of calcium per 100 grams (26). The research was conducted in a Latin population, two of them in Bogotá, which included only women and students of a public university, respectively, and they were consistent with low dietary calcium intake (27, x, y 19–21). Research with women included staff not related to the health field and the condition of patients, without excluding those with conditions limiting calcium intake, absorption, or metabolism. In the study with university students, more than 90% had breakfast and homemade food, but lunch, an important source of calcium-rich foods, was bought at restaurants, without specifying the type of food eaten at the time.

It was identified that at least eight of ten participants had some level of hypovitaminosis D. A systematic literature review that included 243 publications involving the Latin population determined a deficiency in $< 1\%$. Mexico, the only country with nationally representative samples, showed a prevalence of inadequacy between 8–24% (28). The cut-off points of hypovitaminosis D categories were different than the ones defined for this research, and the population groups included people < 18 or > 40 years old, factors related to the diagnosis and classification of hypovitaminosis D.

The interaction between sex, level of calcium, and degree of sunlight exposure was a non-linear triad predictor of Vit-D concentration. Physiologically, these variables influence the homeostasis process of Vit-D (23–28); besides, each of these factors has been associated, individually or combined, with Vit-D concentration using prediction models (29–32). It is clear that most of the models were uni- or bivariate except for the Sohl model, which included between 10 and 13 predictors and, unlike

our research, did not take into account the usual calcium intake or sun-exposed body parts (33).

This research did not measure Vit-D intake within the usual diet nor the consumption of antacids or laxatives, factors directly related to serum levels or absorption of Vit-D. One of the strengths of the design is the consecutive and random selection of participants, which took into account the SES and allowed including equitably subjects belonging to low, medium, and high socioeconomic levels (34).

Recent studies have not been convincing when trying to associate the calcium content in the diet or calcium supplements with cardiovascular complications (35–41). Moreover, discoveries about the pleiotropic effect of Vit-D in the body, as a result of multiple receptors in different tissues, transformed the conception of this vitamin, from a simple nutritional supplement to a biomolecule with hormonal properties, in which appropriate serum levels are a reflection of homeostasis in humans (42–50).

This new information increases the relevance of population studies like ours because, when rigorously assessing the calcium intake in a population and its relationship to the levels of Vit-D, they reveal a health problem that may impact various human diseases, including those affecting the osteoarticular system.

Given the results obtained, a high prevalence of Vit-D deficiency among the general Colombian adult population is confirmed, and it is also related to low daily dietary calcium, demographic factors, and sunlight exposure.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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