00100 OR

Prevalence of vitamin D deficiency in patients with risk factors: an observational, multicentre, cross-sectional study (PREVIFAC project)

Carmen Valdés Llorca

Centro de Salud Fuencarral. Madrid, Spain

Received: 09/30/2025
Accepted: 06/01/2025

Correspondence: Carmen Valdés Llorca. Centro de Salud Fuencarral. Calle de la Isla de Java, 53. 28034 Madrid. Spain
e-mail: mamenvll@icloud.com

Acknowledgments: The author thanks Saned from Medscape for its support in the development of the project and coordination of the study, and Dr. Marta Pulido for her collaboration in drafting the manuscript and providing editorial support.

Funding: This study was funded by Ferrer Internacional, S.A., which had no involvement in the study design, implementation, or interpretation of the results.

Ethical considerations: This study was conducted in full compliance with the Declaration of Helsinki. All participants provided informed consent before participating in the study.

Conflict of interest: The authors declare no conflict of interest.

Artificial intelligence: The author declares that no artificial intelligence (AI) or AI-based tools were used in the preparation of this article.

ABSTRACT

Introduction: vitamin D deficiency may be the cause or a predisposing factor in many diseases.

Objective: to determine the prevalence of vitamin D deficiency in patients with risk factors.

Materials and methods: a multicentre, cross-sectional observational study in which researchers from across the country selected the first three patients with risk factors for vitamin D deficiency on three consecutive days. During the consultation, the Vitamin D Test® (PRIMA Home Test) self-test was administered to classify vitamin D levels as "excessive", "sufficient", "insufficient" or "deficient".

Results: a total of 261 researchers selected 771 patients (76.3 % women) with a mean age of 62.0 ± 15.6 years and a body mass index (BMI) of 27.7 ± 5.3 kg/m². 70.8 % of patients had vitamin D levels classified as "insufficient" or "deficient". Significant risk factors in the bivariate analysis included: insufficient dietary intake, low exposure to sunlight, osteoporosis, obesity, chronic kidney disease and hyperparathyroidism. In the multivariate analysis, the independent risk factors were osteomalacia (odds ratio [OR] 4.12), low sun exposure (OR 2.49), osteoporosis (OR 1.97) and obesity (BMI > 30 kg/m²) (OR 1.65).

Conclusions: a high prevalence of vitamin D deficiency (71 %) was detected using a screening test, and osteomalacia, low exposure to sunlight, osteoporosis and obesity were identified as factors associated with deficient or insufficient levels of vitamin D.

Keywords: Vitamin D deficiency. Risk factors. Obesity. Osteoporosis. Prevalence. Sun exposure.

INTRODUCTION

Vitamin D is a fat-soluble vitamin essential for calcium homeostasis and bone mineralization; dietary intake and, especially, cutaneous synthesis through sunlight exposure are the main sources of cholecalciferol (vitamin D_3) (1-4). Measurement of the plasma concentration of 25-hydroxyvitamin D, abbreviated as 25(OH)D, is the standard method for determining vitamin D status, although some discrepancies remain

regarding the minimum levels considered normal for the general population (> 20 ng/mL or 30-50 ng/mL) (5-7), as well as the criteria for hypovitaminosis D (20-30 ng/mL), insufficiency (10-20 ng/mL), and deficiency (< 10 ng/mL) (8).

The relevance of vitamin D deficiency as a causal factor or a factor associated with numerous chronic diseases has attracted increasing interest because of its rising prevalence in recent decades, affecting different age groups and substantially increasing the global burden of disease worldwide (9,10). Data from observational studies indicate that approximately 40 % of the European population has hypovitaminosis D and 13 % has severe vitamin D deficiency (11). In Spain, 4 out of 10 inhabitants younger than 65 years and 8 out of 10 people older than 65 years have vitamin D insufficiency or deficiency (12). In addition to its critical importance in calcium metabolism and musculoskeletal health, vitamin D is an essential nutrient involved in the regulation of cell growth, the cardiovascular system, and innate and acquired immunomodulation, and the nuclear vitamin D receptor has been identified in almost all cells in the body (13). Vitamin D deficiency stimulates parathyroid hormone (PTH) secretion, increases bone remodeling, reduces bone mineral density and bone quality, and thereby increases the risk of osteoporosis, bone fragility, and osteoporotic fractures. In a meta-analysis of 86 studies including more than 103 million individuals aged 15-105 years, the overall prevalence of osteoporosis was 18.3 %, increasing to 23.1 % among women compared with 11.7 % among men (14). The overall incidence of osteoporotic fractures ranges from 500 to 1000 per 100,000 person-years among adults older than 50 years, increases with age, and is higher among women (15). Therefore, osteoporosis associated with vitamin D deficiency represents a major health problem with important consequences for patients' quality of life and the economic burden on health care systems (16,17).

Risk factors for vitamin D deficiency are numerous and include low sun exposure, advanced age, dark skin, body mass index (BMI), reduced dietary intake or absorption of the vitamin (e.g., celiac disease), decreased endogenous synthesis due to liver cirrhosis, renal failure, or hypoparathyroidism, and increased hepatic catabolism due to the use of certain drugs that affect hepatic cytochrome P450 enzymes, thereby accelerating the degradation of vitamin D into inactive metabolites (18-21).

Although risk factors for vitamin D deficiency in general have been extensively studied, evidence on vitamin D deficiency in individuals with risk factors remains limited.

Therefore, a real-world data study was conducted to determine the prevalence of vitamin D deficiency in Spain among patients with risk factors for, or factors associated with, hypovitaminosis D.

METHODS

Design and participants

We designed an observational, cross-sectional, multicenter study covering the entire Spanish territory (PREVIFAC project, an acronym for prevalence of vitamin D deficiency in patients with risk factors) within the setting of medical consultations across different specialties, including Family and Community Medicine/Primary Care, Endocrinology and Nutrition, Internal/General Medicine, Rheumatology, and Geriatrics, among others. These specialties comprised health care professionals who routinely attended patients with risk factors for vitamin D deficiency. The primary endpoint of the study was to determine the prevalence of vitamin D deficiency among patients with risk factors. Secondary endpoint were to assess the sociodemographic and clinical characteristics of patients with vitamin D deficiency, identify the predominant risk factors for hypovitaminosis D, and analyze the relationship between risk factors and vitamin D deficiency.

The patient inclusion criteria were as follows: age > 18 years and the presence of at least 1 of the following risk factors for, or factors associated with, vitamin D deficiency: rickets, osteomalacia, osteoporosis, chronic kidney disease, intestinal malabsorption syndromes, celiac disease, obesity (BMI > 30 kg/m^2), low sun exposure (< 2 minutes/day without sun protection), advanced age (> 65 years), non-Caucasian ethnicity, use of drugs that could affect 25(OH)D levels (anticonvulsants, glucocorticoids, antifungals, cholestyramine, and antiretroviral agents used to treat HIV), hyperthyroidism, granulomatous diseases (tuberculosis, coccidioidomycosis, etc.), older adults with a history of falls or nontraumatic fractures (at least 2 falls or nontraumatic fractures in the previous year), pregnancy, and breastfeeding, as well as provision of signed informed consent. Exclusion criteria were age < 18 years, institutionalization, and refusal to provide signed informed consent.

The study protocol was approved by the *Hospital Clínico San Carlos* Drug Research Ethics Committee (Madrid, Spain) (code 22/698-E; approved on December 23, 2022). All patients provided written informed consent.

Study procedures

A total of 136 medical centers were selected to participate in the study, with at least 1 specialist practicing at each center. To ensure nationally representative participation, at least 1 center from each autonomous community in Spain was required to participate. Physician participation was anonymous and voluntary. After providing consent, each investigator recruited 3 patients who met the inclusion criteria and provided signed informed consent. To make patient selection as random as possible, investigators were instructed to include the first eligible patient attending the consultation on each of 3 consecutive days.

During the consultation, sociodemographic data (sex, age, marital status, living arrangements, educational level, and occupation), clinical and lifestyle variables (anthropometric data, smoking status, alcohol consumption, and caffeine consumption), and risk factors for, or factors associated with, vitamin D deficiency corresponding to the variables established in the inclusion criteria (rickets, osteomalacia, osteoporosis, etc.) were collected for each patient included in the study. In addition, vitamin D deficiency screening was performed using the Vitamin D Test® (PRIMA Home Test, PRIMA Lab, S.A., Balerna, Switzerland) (https://primalabsa.ch/en/home/check-up/vitamin-d-test/). This is a rapid and easy-to-perform self-test requiring a drop of blood obtained by finger prick. The test is an immunoassay based on the principle of competitive protein binding that classifies vitamin D levels as “excessive,” “sufficient,” “insufficient,” or “deficient,” with a measurement range of 10-100 ng/mL and an accuracy of 94.4 % (95 %CI, 87.6-97.6 %). Vitamin D values correspond to > 100 ng/mL for “excessive,” 30-100 ng/mL for “sufficient,” 10-30 ng/mL for “insufficient,” and 0-10 ng/mL for “deficient,” according to the information provided by the manufacturer.

The study was conducted over a 20-month period (May 2023-December 2024). The PREVIFAC project information leaflet contained the URL where the study materials were available and a personalized access password. In addition to patient information

(Supplementary Table I - https://www.revistadeosteoporosisymetabolismomineral.com/files/535/ADMA1-00100-03.pdf), investigator data were also collected (age and sex, specialty, years of practice, and participation in training programs or research projects on vitamin D).

Statistical analysis

To obtain an unbiased estimator of the distribution of Vitamin D Test® results in the population when the response variable was discrete, and assuming simple random sampling in the study area, a sample size of 822 participants was calculated, considering a 3 % margin of error, a 95 % confidence level, and 50 % heterogeneity. Categorical variables are expressed as frequencies and percentages, and continuous variables as means and SD, with 95 %CI. Fisher's exact test was used to compare qualitative variables, and Student's *t* test or one-way analysis of variance (ANOVA) was used for quantitative variables; alternatively, the nonparametric Mann-Whitney *U* or Kruskal-Wallis tests were used depending on the applicable conditions. In the bivariate analysis, the association between each risk factor and vitamin D deficiency was analyzed by combining the "insufficient" and "deficient" categories, and the results were expressed as odds ratios (ORs) with 95 %CI. Risk factors with a *p* value > 0.1 in the bivariate analysis were included in a logistic regression model to identify independent variables associated with vitamin D deficiency. A statistical significance level of .05 was accepted. All calculations were performed using SAS statistical software (Statistical Analysis System, SAS Institute, Cary, NC, United States), version 9.4.

RESULTS

Investigator data

A total of 261 investigators from throughout Spain participated in this study, including 179 men and 82 women, with a mean age of 54.5 ± 10.9 years. The specialties with the highest participation were Family and Community Medicine, including Primary Care (43.3 %), General/Internal Medicine (26.8 %), Endocrinology and Nutrition (18.4 %), Rheumatology (6.1 %), Orthopedic Surgery and Traumatology (1.1 %), and Obstetrics and Gynecology (1.1 %). Regarding years of professional experience, 86.7 % had > 10 years of experience, 8 % had between 5 and 10 years, and 5 % had < 5 years.

Furthermore, during the previous 12 months, 38.7 % of participants reported having participated in a vitamin D training program, but only 5.4 % had participated in a research project on vitamin D other than the present study.

Patient characteristics

A total of 771 patients (76.3 % women) were included in the study, with a mean age of 62.0 ± 15.6 years (95 %CI, 60.9-63.1) and a BMI of 27.7 ± 5.3 kg/m². The main sociodemographic, clinical, and lifestyle data are shown in table I. Most patients were married or living with a partner (62.0 %), lived with a partner or their own family (69.0 %), had completed university education (36.8 %), were employed (47.6 %) or retired (45.9 %), were nonsmokers (67.1 %), and did not consume alcohol daily (87.0 %). Overall, 12.2 % of participants were current smokers and 20.7 % were former smokers. Current smokers had started smoking at a mean age of 20.2 ± 7.6 years, and former smokers had quit smoking a mean of 15.0 ± 19.3 years previously. Among the 13.0 % of patients who consumed alcoholic beverages daily, the mean number of standard drink units was 2.4 ± 1.6. Finally, most patients (63.8 %) consumed caffeine daily, with a mean consumption of 2.9 ± 1.7 cups of coffee and other caffeinated beverages.

Screening for vitamin D deficiency and risk factors

According to the Vitamin D Test® results, 70.8 % of patients had vitamin D levels corresponding to the “insufficient” or “deficient” categories, whereas only 28.5 % had “sufficient” levels (Fig. 1).

The distribution of risk factors for vitamin D deficiency in the study population is shown in table II. The most frequent factors were low sun exposure (66.5 %), advanced age (> 65 years) (50.8 %), use of sunscreen (sun protection factor > 8) (49.7 %), osteoporosis (42.0 %), obesity (BMI > 30 kg/m²) (34.0 %), generally insufficient dietary intake (22.1 %), chronic renal failure (14.4 %), a history of falls or nontraumatic fractures in older adults (14.1 %), and glucocorticoid therapy (10.5 %). In the bivariate analysis, the risk factors showing a statistically significant association with vitamin D deficiency were hyperparathyroidism (OR, 3.13), low sun exposure (OR, 2.43), insufficient dietary intake (OR, 1.89), osteoporosis (OR, 1.81), chronic renal failure (OR, 1.78), and obesity (OR, 1.52) (Table III). In the multivariate analysis, independent risk factors for vitamin D

deficiency were osteomalacia (OR, 4.12), low sun exposure (OR, 2.49), osteoporosis (OR, 1.97), and obesity (OR, 1.65) (Table IV).

DISCUSSION

The results of this study show that 71 % of the Spanish population sample with risk factors had vitamin D deficiency. Risk factors for, or factors associated with, vitamin D deficiency that reached statistical significance were low sun exposure, osteoporosis, osteomalacia, insufficient dietary vitamin D intake, obesity, chronic renal failure, and hyperparathyroidism. These findings are consistent with data from other studies assessing vitamin D deficiency in populations with specific risk factors.

Low sun exposure, defined as less than a few minutes per day without protection, was present as a risk factor in 66.5 % of patients and emerged as one of the predominant risk factors. Furthermore, the presence of this factor increased the odds of vitamin D deficiency by 2.49-fold. In most individuals, vitamin D production through exposure to solar ultraviolet B (UVB) radiation accounts for > 80 % of total vitamin D. In addition to the duration of sun exposure, skin color, geographical location, season, latitude, and altitude have a substantial impact on the cutaneous synthesis of vitamin D (22-24). Moreover, vitamin D may be involved in the potential preventive effect of sun exposure against certain types of cancer (prostate, breast, and colorectal cancer) (25). For the general Caucasian population, daily sun exposure of approximately 15 minutes to the face and arms between March and October, with a sun protection factor of 15-30 depending on latitude and radiation intensity, is recommended (26).

With regard to specific diseases, osteomalacia and osteoporosis showed a strong association with vitamin D deficiency, particularly osteomalacia (OR, 4.12), which is consistent with the robust evidence supporting the relationship between 25(OH)D levels and bone mineralization (27-32). Confinement due to age, cultural habits, or climate, as well as skin hyperpigmentation, have been associated with insufficient cutaneous synthesis and the development of osteomalacia. A study of Asian immigrants living in England reported an osteomalacia prevalence of 13.5 %, which was associated with strict vegetarian diets and the use of clothing covering most of the body, particularly among women (31). Vitamin D depletion is very common in celiac disease, and some case series have confirmed the development of osteomalacia in up to 50 % of these

patients (32). Severe chronic liver disease, chronic renal failure, increased vitamin D catabolism, and decreased tubular phosphate reabsorption have also been described as causes of osteomalacia (33). Vitamin D levels should be measured in patients with osteomalacia, and appropriate treatment should be initiated.

Osteoporosis was present in 42 % of patients. Osteoporosis, bone fragility, and osteoporotic fractures represent a major global health problem, not only because of the multifactorial complexity of this condition and its association with an increased risk of death, disability, and health care costs, but also because of the high frequency of underdiagnosis and undertreatment. In fact, up to 75 % of women and 90 % of men with a high probability of osteoporosis do not undergo any diagnostic testing, and more than 75 % of patients with osteoporosis do not receive appropriate treatment, despite recommendations and evidence demonstrating the substantial safety and efficacy of bisphosphonates and other pharmacological treatments, either as monotherapy or in combination with vitamin D (35-37). In Spain, according to the latest epidemiological study of osteoporosis in the Spanish population conducted by the Sociedad Española de Reumatología (SER) in 1,522 individuals—the OsteoSER project—54.4 % of people older than 50 years had reduced bone mineral density (BMD), and 10.7 % had osteoporosis, which was more frequent in women (18.6 %) than in men (2.6 %) (38). Among women older than 65 years, who constitute the group at greatest risk of fracture, 24.9 % had osteoporosis. According to data updated to January 1, 2023, from the Spanish National Institute of Statistics, the absolute figure would amount to 1,300,021 Spanish women at high risk of fracture, which reinforces the importance of adopting healthy habits to prevent osteoporosis, such as engaging in physical exercise, following a Mediterranean diet that includes adequate calcium and vitamin D intake, and avoiding smoking and excessive alcohol consumption, among other factors (39). In a recent study using the Delphi methodology on the management of osteoporosis in Primary Care, panelists agreed on the need to appropriately identify patients according to their fracture risk and also emphasized the importance of exercise and nutrition (40).

Obesity (BMI > 30 kg/m^2) was present in 34 % of patients and was an independent risk factor statistically associated with vitamin D deficiency. The pathophysiological mechanisms underlying the association between hypovitaminosis D and obesity include sequestration in adipose tissue, volumetric dilution, alterations in hepatic and renal

hydroxylation, and limited sun exposure (41,42). In addition, hypovitaminosis D in patients with obesity is a risk factor for developing type 2 diabetes mellitus and insulin resistance (43). However, weight loss has little influence on improvements in vitamin D levels (42). An increased risk of vitamin D deficiency has also been reported in pediatric and adolescent populations with obesity (44).

The specialists who recruited the participants were distributed across Spain, predominantly worked in Primary Care, and had more than 10 years of professional experience, although their participation in vitamin D training programs, particularly research projects on the topic, was limited. Furthermore, emphasis should be placed on the need to extend systematic screening of plasma 25(OH)D concentrations to patients with symptoms or signs of deficiency, individuals with risk factors, and those with laboratory and/or radiographic abnormalities suggestive of vitamin D deficiency. Although vitamin D deficiency is highly prevalent, universal measurement of 25(OH)D is not cost-effective, and population-based screening is not recommended (45).

The Vitamin D Test® (PRIMA Home Test) is a simple and straightforward immunochromatographic assay capable of detecting 25(OH)D levels in a blood sample and indicating their concentration according to the intensity of the test line (T) obtained. The result, visible after 10 minutes, makes it possible to determine whether vitamin D levels are sufficient, deficient, insufficient, or excessive, which is of interest as a screening tool for vitamin D deficiency. However, the manufacturer of the Vitamin D Test® (PRIMA Home Test) does not provide detailed sensitivity or specificity data or concordance curves against LC-MS/MS or immunoassays; therefore, no clinical equivalence between the rapid test and standard analytical methods can be established. Consequently, an indicative analytical result obtained with the Vitamin D Test® should be confirmed using a secondary analytical method of greater accuracy. Furthermore, the test *per se* uses a fixed cutoff point of 30 ng/mL, with an estimated variability margin of ± 4 ng/mL, which may influence the classification of some participants, particularly those with concentrations close to the threshold. As with any diagnostic test, the results should be interpreted in conjunction with all other available clinical information. Therefore, when values are uncertain or considered inconsistent with the clinical context, additional measurements using standardized methods are recommended.

The results of the present study should be interpreted in light of its limitations, including its cross-sectional design, nonrandom patient selection, and use of a semiquantitative test that is not equivalent to the standard method for measuring 25(OH)D levels. Both the selection method (3 consecutive patients over 3 days), which was not free from bias, and the use of the Vitamin D Test® facilitated study logistics with the aim of obtaining an approximation of vitamin D deficiency detection using a screening test and risk factors under real-world conditions. Finally, the study was conducted between May 2023 and December 2024, but data on the regions and latitudes corresponding to the study population were not collected. Furthermore, the data were not adjusted for age and sex.

CONCLUSIONS

In conclusion, the findings highlight the high prevalence of vitamin D deficiency (71 %) detected in the Spanish population studied using a screening test, as well as the identification of osteomalacia, low sun exposure, osteoporosis, and obesity as independent risk factors statistically associated with deficient or insufficient vitamin D levels.

REFERENCES

1. Benedik E. Sources of vitamin D for humans. Int J Vitam Nutr Res 2022;92(2):118-25. DOI: 10.1024/0300-9831/a000733
2. Engelsen O. The relationship between ultraviolet radiation exposure and vitamin D status. Nutrients 2010;2(5):482-95. DOI: 10.3390/nu2050482
3. Saponaro F, Saba A, Zucchi R. An update on vitamin D metabolism. Int J Mol Sci 2020;21(18):6573. DOI: 10.3390/ijms21186573
4. Bikle DD. Vitamin D: newer concepts of its metabolism and function at the basic and clinical level. J Endocr Soc 2020;4(2):bvz038. DOI: 10.1210/jendso/bvz038
5. Varsavsky M, Rozas Moreno P, Becerra Fernández A, Luque Fernández I, Quesada Gómez JM, Ávila Rubio V, et al. Recommended vitamin D levels in the general population. Endocrinol Diabetes Nutr 2017;64(Suppl 1):7-14. DOI: 10.1016/j.endinu.2016.11.002

6. Demay MB, Pittas AG, Bikle DD, Diab DL, Kiely ME, Lazaretti-Castro M, et al. Vitamin D for the prevention of disease: An Endocrine Society Clinical Practice Guideline. J Clin Endocrinol Metab 2024;109(8):1907-47. DOI: 10.1210/clinem/dgae290
7. Casado E, Blanch-Rubió J, Peris P, Neyro JL, Giner M, Del Pino J, et al. Recomendaciones de la SEIOMM en la prevención y tratamiento del déficit de Vitamina D. Rev Osteoporos Metab Miner 2021;13(2):84-97. DOI: 10.4321/S1889-836X2021000200007
8. Gómez Alonso C, Naves Díaz M, Rodríguez García M, Fernández Martín JL, Cannata Andía JB. Revisión del concepto de "suficiencia e insuficiencia" de Vitamina D. Nefrologia 2003;23(Suppl 2):73-7.
9. Quraishi SA, Camargo CA Jr, Manson JE. Low vitamin D status in Europe: moving from evidence to sound public health policies. Am J Clin Nutr 2016;103(4):957-8. DOI: 10.3945/ajcn.116.132274
10. Cui A, Zhang T, Xiao P, Fan Z, Wang H, Zhuang Y. Global and regional prevalence of vitamin D deficiency in population-based studies from 2000 to 2022: A pooled analysis of 7.9 million participants. Front Nutr 2023;10:1070808. DOI: 10.3389/fnut.2023.1070808
11. Cashman KD, Dowling KG, Škrabáková Z, Gonzalez-Gross M, Valtueña J, De Henauw S, et al. Vitamin D deficiency in Europe: pandemic? Am J Clin Nutr 2016;103(4):1033-44. DOI: 10.3945/ajcn.115.120873
12. Fundación de Ciencias del Medicamento y Productos Sanitarios (Fundamed). Grupo de Trabajo LA HORMONA D EN 2021. Retos y estrategias ante el déficit generalizado en la población. Available at: https://www.fundacionfundamed.org/GT-Informe-Hormona-D-2021.aspx (Accessed July 8 2025).
13. Navarro Valverde C, Quesada Gómez JM. Deficiencia de Vitamina D en España: ¿realidad o mito? Rev Osteoporos Metab Miner 2014;6 (Suppl 1):S5-10. DOI: 10.4321/S1889-836X2014000500002
14. Salari N, Ghasemi H, Mohammadi L, Behzadi MH, Rabieenia E, Shohaimi S, et al. The global prevalence of osteoporosis in the world: a comprehensive systematic review and meta-analysis. J Orthop Surg Res 2021;16(1):609. DOI: 10.1186/s13018-021-02772-0

15. Chandran M, Brind'Amour K, Fujiwara S, Ha YC, Tang H, Hwang JS, et al. Prevalence of osteoporosis and incidence of related fractures in developed economies in the Asia Pacific region: a systematic review. Osteoporos Int 2023;34(6):1037-53. DOI: 10.1007/s00198-022-06657-8
16. Lips P, van Schoor NM. Quality of life in patients with osteoporosis. Osteoporos Int 2005;16(5):447-55. DOI: 10.1007/s00198-004-1762-7
17. Keen RW. Burden of osteoporosis and fractures. Curr Osteoporos Rep 2003;1(2):66-70. DOI: 10.1007/s11914-003-0011-x
18. Parva NR, Tadepalli S, Singh P, Qian A, Joshi R, Kandala H, Nookala VK, Cheriyath P. Prevalence of vitamin D deficiency and associated risk factors in the US population (2011-2012). Cureus 2018;10(6):e2741. DOI: 10.7759/cureus.2741
19. Kaur J, Khare S, Sizar O, Givler A. Vitamin D Deficiency. (Updated 2025 Feb 15). In: StatPearls (Internet). Treasure Island (FL): StatPearls Publishing; 2025 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK532266/ (Accessed July 8 2025).
20. Shi S, Feng J, Zhou L, Li Y, Shi H. Risk Factors for vitamin D deficiency in inflammatory bowel disease: a systematic review and meta-analysis. Turk J Gastroenterol 2021;32(6):508-18. DOI: 10.5152/tjg.2021.20614
21. Mithal A, Wahl DA, Bonjour JP, Burckhardt P, Dawson-Hughes B, Eisman JA, et al. Global vitamin D status and determinants of hypovitaminosis D. Osteoporos Int 2009;20(11):1807-20. DOI: 10.1007/s00198-009-0954-6
22. Raymond-Lezman JR, Riskin SI. Benefits and risks of sun exposure to maintain adequate vitamin D levels. Cureus 2023;15(5):e38578. DOI: 10.7759/cureus.38578
23. Oliver SL, Santana KV, Ribeiro H. The Effect of sunlight exposure on vitamin D status in countries of low and high latitudes: a systematic literature review. Curr Nutr Rep 2023;12(1):1-13. DOI: 10.1007/s13668-022-00443-y
24. Leary PF, Zamfirova I, Au J, McCracken WH. Effect of latitude on vitamin D levels. J Am Osteopath Assoc 2017;117(7):433-9. DOI: 10.7556/jaoa.2017.089
25. Van der Rhee H, Coebergh JW, de Vries E. Is prevention of cancer by sun exposure more than just the effect of vitamin D? A systematic review of epidemiological studies. Eur J Cancer 2013;49(6):1422-36. DOI: 10.1016/j.ejca.2012.11.001

26. Asociación Española contra el Cáncer. Vitamina D y sol: ¿qué relación existe? Available at: https://blog.contraelcancer.es/vitamina-d-sol/ (Accessed July 11 2025).
27. Bhan A, Rao AD, Rao DS. Osteomalacia as a result of vitamin D deficiency. Rheum Dis Clin North Am 2012;38(1):81-91, viii-ix. DOI: 10.1016/j.rdc.2012.03.008
28. Minisola S, Colangelo L, Pepe J, Diacinti D, Cipriani C, Rao SD. Osteomalacia and Vitamin D status: a clinical update 2020. JBMR Plus 2020;5(1):e10447. DOI: 10.1002/jbm4.10447
29. Segheto KJ, Pereira M, Silva DCGD, Carvalho CJ, Massardi FR, Kakehasi AM, et al. Vitamin D and bone health in adults: a systematic review and meta-analysis. Cien Saude Colet 2021;26(8):3221-44. DOI: 10.1590/1413-81232021268.15012020
30. Cianferotti L. Osteomalacia is not a single disease. Int J Mol Sci 2022;23(23):14896. DOI: 10.3390/ijms232314896
31. Finch PJ, Ang L, Eastwood JB, Maxwell JD. Clinical and histological spectrum of osteomalacia among Asians in south London. Q J Med 1992;83(302):439-48
32. Peris P. Diagnóstico y tratamiento de la osteomalacia por el reumatólogo. Reumatología Clínica 2011;7(S2):22-27. DOI: 10.1016/j.reuma.2011.05.005
33. Arboleya L, Braña I, Pardo E, Loredo M, Queiro R. Osteomalacia in adults: a practical insight for clinicians. J Clin Med 2023;12(7):2714. DOI: 10.3390/jcm12072714
34. Nguyen TV, Center JR, Eisman JA. Osteoporosis: underrated, underdiagnosed and undertreated. Med J Aust 2004;180(S5):S18-22. DOI: 10.5694/j.1326-5377.2004.tb05908.x
35. Nayak S, Greenspan SL. Osteoporosis treatment efficacy for men: a systematic review and meta-analysis. J Am Geriatr Soc 2017;65(3):490-5. DOI: 10.1111/jgs.14668
36. Ayers C, Kansagara D, Lazur B, Fu R, Kwon A, Harrod C. Effectiveness and safety of treatments to prevent fractures in people with low bone mass or primary osteoporosis: a living systematic review and network meta-analysis for the American College of Physicians. Ann Intern Med 2023;176(2):182-95. DOI: 10.7326/M22-0684
37. Yang Y, Yang M, Su X, Xie F. Efficacy of combination therapy of vitamin D and bisphosphonates in the treatment of postmenopausal osteoporosis: a systematic

review and meta-analysis. Front Pharmacol 2024;15:1422062. DOI: 10.3389/fphar.2024.1422062

38. Gómez-Vaquero C, Domínguez-Álvaro M, Seoane-Mato D, Bernal PP, Castañeda S, Kanterewicz Binstock E, et al. An update in bone mineral density status in Spain: the OsteoSER study. Arch Osteoporos 2025;20(1):37. DOI: 10.1007/s11657-025-01520-9
39. Fundación Española de Reumatología. El 20 de octubre se celebra el Día Mundial de la Osteoporosis. Available at: https://inforeuma.com/en-espana-el-544-de-los-mayores-de-50-anos-sufren-osteopenia-y-el-107-osteoporosis/ (Accessed July 12 2025).
40. Carbonell-Abella C, Micó-Pérez RM, Vargas Negrín F, Bastida-Calvo JC, Aguado Acín P. Consenso Delphi sobre el manejo de pacientes con osteoporosis en atención primaria. Rev Osteoporos Metab Mineral 2025;17(1):42-55. DOI: 10.20960/RevOsteoporosMetabMiner.00074
41. Pourshahidi LK. Vitamin D and obesity: current perspectives and future directions. Proc Nutr Soc 2015;74(2):115-24. DOI: 10.1017/S0029665114001578
42. Karampela I, Sakelliou A, Vallianou N, Christodoulatos GS, Magkos F, Dalamaga M. Vitamin D and obesity: current evidence and controversies. Curr Obes Rep 2021;10(2):162-80. DOI: 10.1007/s13679-021-00433-1
43. Greco EA, Lenzi A, Migliaccio S. Role of hypovitaminosis D in the pathogenesis of obesity-induced insulin resistance. Nutrients 2019;11(7):1506. DOI: 10.3390/nu11071506
44. Fiamenghi VI, Mello ED. Vitamin D deficiency in children and adolescents with obesity: a meta-analysis. J Pediatr (Rio J) 202197(3):273-9. DOI: 10.1016/j.jped.2020.08.006
45. Kennel KA, Drake MT, Hurley DL. Vitamin D deficiency in adults: when to test and how to treat. Mayo Clin Proc 2010;85(8):752-7; quiz 757-8. DOI: 10.4065/mcp.2010.0138

Figure 1. Distribution of patients according to Vitamin D Test® (PRIMA Home Test) results.

Table I. Sociodemographic, clinical, and lifestyle characteristics of the 771 patients included in the study

Variables	**Number (%)**
Sex	
Male	183 (23.7)
Female	588 (76.3)
Age, years, mean ± SD (95 %CI)	62.0 ± 15.6 (60.9-63.1)
Marital status	
Married/living with a partner	478 (62.0)
Widowed	148 (19.2)
Single	91 (11.8)
Separated/divorced	54 (7.0)
Living arrangements	
With a partner or own family	532 (69.0)
Alone	175 (22.7)
With family of origin	64 (8.3)
Educational level	
Completed primary education, or equivalent	190 (24.6)
Secondary education, high school, or intermediate vocational training	129 (16.7)
Advanced vocational training/completed upper secondary education or pre-college education	130 (16.9)
Completed university education	284 (36.8)
No formal education	38 (4.9)
Employment status	
Work disability	9 (1.2)
Sick leave	13 (1.7)
Unemployed, without work disability	28 (3.6)
Employed/student/homemaker	367 (47.6)
Retired	354 (45.9)
Body mass index (BMI), kg/m², mean ± SD (95 %CI)	27.7 ± 5.3 (27.3-28.1)
Smoking status	

Variables	**Number (%)**
Current smoker	94 (12.2)
Age at smoking initiation, years, mean ± SD (95 %CI)	20.2 ± 7.6 (18.6-21.7)
Former smoker	160 (20.7)
Years since smoking cessation, mean ± SD (95 %CI)	15.0 ± 19.3 (13.4-16.6)
Duration of smoking, years, mean ± SD (95 %CI)	23.2 ± 11.7 (21.4-25.0)
Never smoker	517 (67.1)
Daily alcohol consumption	
No	671 (87.0)
Yes	100 (13.0)
Number of standard drink units consumed, mean ± SD (95 %CI)	2.4 ± 1.6 (2.1-2.7)
Daily caffeine consumption	
No	279 (36.2)
Yes	492 (63.8)
Cups of coffee, mean ± SD (95 %CI)	2.2 ± 1.1 (2.1-2.3)
Glasses of caffeinated beverages, mean ± SD (95 %CI)	0.7 ± 1.2 (0.6-0.8)
Total of both, mean ± SD (95 %CI)	2.9 ± 1.7 (2.7-3.0)

SD, standard deviation; 95 %CI, 95 % confidence interval; standard drink unit, equivalent to 10 g of alcohol. Data are expressed as frequencies and percentages unless otherwise indicated.

Table II. Distribution of risk factors for, or factors associated with, vitamin D deficiency in the study population

Risk factor	**Number (%)**
Low sun exposure (less than a few minutes per day without protection) (*n* = 770)	512 (66.5)
Advanced age (> 65 years) (*n* = 770)	391 (50.8)
Use of UV radiation-filtering creams (sun protection factor > 8) (*n* = 726)	361 (49.7)
Osteoporosis (*n* = 742)	312 (42.0)
Obesity (BMI > 30 kg/m^2) (*n* = 768)	261 (34.0)
Insufficient dietary intake (*n* = 728)	161 (22.1)
Chronic renal failure (*n* = 765)	110 (14.4)
Older adult with a history of falls or nontraumatic fractures (at least 2 falls or nontraumatic fractures in the previous year) (*n* = 767)	108 (14.1)
Glucocorticoid therapy (*n* = 764)	80 (10.5)
Intestinal diseases and GI surgery (*n* = 764)	72 (9.4)
Non-Caucasian population (*n* = 763)	63 (8.3)
Hyperthyroidism (*n* = 765)	50 (6.5)
Pregnancy and breastfeeding (*n* = 765)	43 (5.6)
Hyperparathyroidism (*n* = 760)	41 (5.4)
Chronic cholestasis and primary biliary cirrhosis (*n* = 763)	40 (5.2)
Osteomalacia (*n* = 757)	36 (4.8)
Nephrotic syndrome (*n* = 765)	23 (3.0)
Hypoparathyroidism (*n* = 759)	22 (2.9)
Anticonvulsant therapy (*n* = 762)	21 (2.8)
Severe chronic liver disease/liver cirrhosis (*n* = 766)	20 (2.6)
Primary biliary cirrhosis (*n* = 763)	18 (2.4)
Antifungal therapy (*n* = 761)	16 (2.1)
Cholestyramine therapy (*n* = 763)	15 (2.0)
Pancreatic insufficiency (e.g., cystic fibrosis) (*n* = 763)	14 (1.8)
Antiretroviral therapy for HIV (*n* = 764)	12 (1.6)
Pseudohyperparathyroidism (*n* = 760)	12 (1.6)
Rickets (*n* = 762)	12 (1.6)
Paget disease of bone (*n* = 764)	12 (1.6)

Risk factor	Number (%)
Antituberculosis therapy (*n* = 765)	11 (1.4)
Chronic granulomatous diseases (*n* = 766)	11 (1.4)

BMI, body mass index; HIV, human immunodeficiency virus. The number of patients assessed for each risk factor is shown in parentheses.

Table III. Risk factors associated with vitamin D deficiency

Risk factors	**"Deficient-insufficient" categories (Vitamin D Test®)**	
	Odds ratio (95 %CI)	***p* value**
Hyperparathyroidism (yes *vs* no)	3.13 (1.21-8.09)	< 0.05
Low sun exposure (less than a few minutes per day without protection) (yes *vs* no)	2.43 (1.76-3.35)	< 0.05
Insufficient dietary intake (yes *vs* no)	1.89 (1.24-2.88)	< 0.05
Osteoporosis (yes *vs* no)	1.81 (1.30-2.53)	< 0.05
Chronic renal failure (yes *vs* no)	1.78 (1.09-2.93)	< 0.05
Obesity (BMI > 30 kg/m²) (yes *vs* no)	1.52 (1.08-2.14)	< 0.05

95 %CI, 95 % confidence interval; BMI, body mass index.

Table IV. Results of the multivariate analysis: probability of vitamin D deficiency according to the presence of risk factors

Risk factor	**Wald χ^2 test (degrees of freedom)**	**Odds ratio (95 %CI)**	***p* value**
Osteomalacia (yes *vs* no)	5.05 (1)	4.12 (1.20-14.18)	0.0246

Risk factor	**Wald χ^2 test (degrees of freedom)**	**Odds ratio (95 %CI)**	***p* value**
Low sun exposure (less than a few minutes per day without protection) (yes *vs* no)	26.37 (1)	2.49 (1.76-3.52)	< 0.001
Osteoporosis (yes *vs* no)	13.38 (1)	1.97 (1.37-2.82)	0.0003
Obesity (BMI > 30 kg/m²) (yes *vs* no)	6.60 (1)	1.65 (1.13-2.42)	0.010

95 %CI, 95 % confidence interval; BMI, body mass index. Hosmer-Lemeshow test, p = 0.8429, for overall model fit. The relationships among the factors included in the final model were analyzed, and no statistically significant associations were detected among them.