ISSN (P&E): 1996-7195, (O): 2957-899X DOI: https://doi.org/10.53350/pjmhs02025199.5

ORIGINAL ARTICLE

Vitamin D Deficiency and its Clinical Manifestations in Young Adults Attending General OPDs

AYESHA HARAL[1], TEHREEM HAYAT[2]*, RAMSHA BATOOL[2], RABEEZA ASGHAR[3], VISHA SHEHZAD[3], FATIMA GHAFFAR[4], AMNA FAISAL[4]

[1]Third Year MBBS Student, Lahore Medical and Dental College, Lahore, Pakistan
[2]House Officer, Ghurki Trust Teaching Hospital, Lahore, Pakistan
[3]MBBS Graduates, Lahore Medical and Dental College, Lahore, Pakistan
[4]Third Year MBBS Students, University College of Medicine and Dentistry (UCMD), Lahore, Pakistan
Correspondence to: Dr Tehreem Hayat, **Email:** drtehreemhayat749@gmail.com, **Cell:** +92-333-4492678

This article may be cited as:
Haral A, Hayat T, Batool R, Asghar R, Shehzad V, Ghaffar F, Faisal A; Vitamin D Deficiency and its Clinical Manifestations in Young Adults Attending General OPDs. Pak J Med Health Sci, 2025; 19(09): 21-26.

Received: 09-04-2025
Accepted: 15-08-2025
Published: 05-10-2025

ABSTRACT

Background: Vitamin D deficiency is a growing global health problem affecting not only older adults but also younger populations. Despite adequate sunlight in Pakistan, low vitamin D levels remain prevalent, mainly due to indoor lifestyles, limited dietary intake, and cultural factors.

Objective: To determine the prevalence and clinical manifestations of vitamin D deficiency among young adults attending general outpatient departments (OPDs) of two tertiary-care hospitals in Lahore, Pakistan.

Methods: A descriptive cross-sectional study was conducted from January 2024 to March 2025 at Ghurki Trust Teaching Hospital and University of Lahore Teaching Hospital. A total of 150 participants aged 18–35 years were enrolled through non-probability consecutive sampling. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using a chemiluminescent immunoassay. Participants were categorized as deficient (<20 ng/mL), insufficient (20–30 ng/mL), or sufficient (>30 ng/mL). Clinical symptoms, sunlight exposure, and dietary habits were assessed through structured interviews.

Results: Vitamin D deficiency was detected in 62.7% of participants, insufficiency in 24%, and sufficiency in 13.3%. Deficiency was significantly higher in females (70%) and those with indoor occupations (71.9%). The most frequent symptoms included generalized body aches (56%), fatigue (45%), and bone pain (33%). Lower vitamin D levels were strongly associated with reduced sunlight exposure and poor intake of vitamin D–rich foods ($p < 0.05$).

Conclusion: Vitamin D deficiency is alarmingly common among young adults in Lahore, frequently presenting with vague musculoskeletal complaints. Early screening, improved sunlight exposure, and dietary fortification are essential preventive strategies to reduce deficiency-related morbidity.

Keywords: Vitamin D deficiency; Hypovitaminosis D; Young adults; Clinical manifestations; Musculoskeletal symptoms; Sunlight exposure; Dietary habits; Lahore; Pakistan; Outpatient department.

INTRODUCTION

Vitamin D, a fat-soluble secosteroid hormone, plays a pivotal role in maintaining calcium and phosphorus homeostasis, promoting bone mineralization, and regulating immune and neuromuscular function[1]. Beyond its classical skeletal effects, vitamin D also influences cardiovascular, endocrine, and neurocognitive systems through its receptor-mediated genomic and non-genomic actions. The biologically active form, 1,25-

dihydroxyvitamin D [1,25$(OH)_2$D], binds to vitamin D receptors (VDRs) present in multiple tissues, modulating more than 200 genes involved in cell proliferation, differentiation, and immune modulation[2,3].

Despite being synthesized endogenously in the skin through ultraviolet B (UV-B) radiation exposure, vitamin D deficiency has become a major global health concern. The World Health Organization (WHO) and numerous epidemiological studies highlight its high prevalence across all age groups, even in regions with abundant sunlight such as South Asia and the Middle East[4]. The deficiency is often attributed to urbanized lifestyles, limited outdoor activity, increased use of sunscreens, and cultural clothing practices that reduce skin exposure to sunlight. Additionally, inadequate dietary intake and low consumption of fortified foods exacerbate the problem[5].

Young adults represent an important but often overlooked population at risk of vitamin D deficiency. Although this group is presumed to have optimal health, sedentary behavior, prolonged indoor activities, academic and occupational stress, and unbalanced nutrition contribute significantly to hypovitaminosis D[6]. The deficiency in early adulthood may predispose individuals to long-term skeletal complications such as osteopenia and early-onset osteoporosis, as well as extra-skeletal effects including insulin resistance, hypertension, mood disturbances, and impaired immunity. Early recognition and management in this age group are therefore critical to prevent chronic health consequences later in life[7].

Clinically, vitamin D deficiency can manifest with a wide spectrum of symptoms ranging from nonspecific fatigue, generalized body aches, and muscle weakness to bone pain, recurrent infections, and depressive mood. However, due to the vague nature of these symptoms, it often remains undiagnosed in routine clinical practice, particularly in general outpatient departments (OPDs) where nonspecific complaints are common[8].

In Pakistan and other South-Asian countries, several hospital-based studies have reported alarmingly high rates of vitamin D deficiency—ranging between 60% and 90%—across different populations. Yet, limited data are available focusing specifically on young adults attending general OPDs, who are neither chronically ill nor hospitalized but may still experience the early manifestations of deficiency[9,10].

Therefore, this study was designed to determine the prevalence and clinical manifestations of vitamin D deficiency among young adults attending general OPDs. By identifying common symptoms and associated risk factors in this population, the research aims to enhance clinical awareness and encourage early screening and preventive interventions at the primary-care level[11].

MATERIAL AND METHOD

Study Design and Setting

This descriptive cross-sectional study was conducted at the General Outpatient Departments (OPDs) of Ghurki Trust Teaching Hospital and University of Lahore (UOL) Teaching Hospital, Lahore, Pakistan. Both hospitals cater to a diverse urban and peri-urban population and serve as major tertiary-care teaching facilities. The study was carried out over a fifteen-month period, extending from January 2024 to March 2025, to ensure adequate seasonal representation and participant diversity. The research aimed to evaluate the prevalence and clinical manifestations of vitamin D deficiency among young adults attending general OPDs for nonspecific complaints such as fatigue, musculoskeletal pain, or malaise.

Ethical Approval

Ethical clearance was obtained from the Institutional Review Board (IRB) of the University of Lahore (IMBB/CRIMM Ethical Committee) prior to data collection. The study followed the ethical principles of the Declaration of Helsinki. Written informed consent was taken from every participant after explaining the purpose, procedure, and confidentiality of the study in detail. Participation was voluntary, and individuals were free to withdraw at any stage without any impact on their clinical care.

Study Population

The study population consisted of young adults aged between 18 and 35 years who attended the general OPDs of both hospitals during the study period. These individuals were apparently healthy and presented with mild, nonspecific symptoms not attributed to any chronic medical condition. The selection of this age group was based on the assumption that young adults are generally less likely to be screened for vitamin D deficiency despite being at risk due to indoor lifestyles and poor dietary habits.

Sample Size and Sampling Technique

A total of 150 participants were included in the study. The sample size was calculated using the World Health Organization (WHO) sample size estimation formula, taking an expected prevalence of vitamin D deficiency of 65%, a 95% confidence level, and a 5% margin of error. Participants were recruited through non-probability consecutive sampling, meaning that every eligible individual attending the OPD during the study period and meeting the inclusion criteria was invited to participate until the desired sample size was achieved.

Inclusion and Exclusion Criteria

Participants were included if they were between 18 and 35 years of age, of either gender, and willing to provide written informed consent. Exclusion criteria included individuals with chronic renal, hepatic, thyroid, or parathyroid disorders; those with malabsorption syndromes; individuals currently taking vitamin D or calcium supplements within the past three months; and those using medications known to alter vitamin D metabolism such as glucocorticoids or anticonvulsants. Pregnant and lactating women were also excluded to eliminate physiological variations affecting vitamin D levels.

Data Collection Procedure

Data were collected using a structured and pretested questionnaire administered through face-to-face interviews. The questionnaire recorded demographic details including age, gender, educational level, occupation, dietary habits, use of fortified foods, and average duration of sunlight exposure per day. Lifestyle factors such as clothing pattern, use of sunscreen, and level of outdoor activity were also assessed. Each participant underwent a general physical examination to assess height, weight, and body mass index (BMI), along with musculoskeletal and neurological assessment for tenderness, weakness, or postural instability. Clinical manifestations such as generalized body aches, fatigue, bone pain, mood changes, hair loss, and recurrent infections were recorded in detail.

Laboratory Analysis

For biochemical assessment, 5 mL of venous blood was drawn from each participant under aseptic precautions. The serum was separated by centrifugation and stored at −20°C until analysis. The concentration of serum 25-hydroxyvitamin D [25(OH)D] was measured using a chemiluminescent immunoassay (CLIA) method in the Biochemistry Laboratory of the University of Lahore Teaching Hospital. Internal quality control procedures were maintained throughout the testing process. Vitamin D status was categorized following the Endocrine Society Clinical Practice Guidelines (2011), where serum 25(OH)D levels <20 ng/mL were considered deficient, 20–30 ng/mL were considered insufficient, and levels >30 ng/mL were considered sufficient.

Data Management and Statistical Analysis

All collected data were entered and analyzed using IBM SPSS Statistics version 26. Continuous variables such as age, BMI, and vitamin D levels were expressed as mean ± standard deviation (SD), while categorical variables including gender, occupation, dietary intake, and clinical manifestations were presented as frequency and percentages. The Chi-square test was applied to evaluate associations between vitamin D deficiency and categorical variables such as gender, sunlight exposure, and clinical symptoms. An independent sample t-test was used to compare mean vitamin D levels between different subgroups. A p-value of less than 0.05 was considered statistically significant.

RESULTS

Demographic Characteristics

A total of 150 young adults aged between 18 and 35 years were enrolled in the study, comprising 90 females (60%) and 60 males (40%). The mean age of participants was 26.3 ± 4.9 years. Most respondents were urban residents (78%), while 22% belonged to peri-urban areas. The majority of participants (64%) had indoor occupations such as office or academic work, while 36% were engaged in outdoor jobs involving moderate sunlight exposure. The mean body mass index (BMI) of the study population was 24.7 ± 3.8 kg/m². (Table 1 presents the baseline demographic characteristics of the participants.)

Prevalence of Vitamin D Deficiency

Among the 150 participants, 94 (62.7%) were found to have vitamin D deficiency (serum 25(OH)D <20 ng/mL), while 36 (24.0%) had vitamin D insufficiency (20–30 ng/mL). Only 20 participants (13.3%) exhibited sufficient vitamin D levels (>30 ng/mL). The overall mean serum vitamin D level was 18.2 ± 7.6 ng/mL, indicating a high prevalence of hypovitaminosis D among apparently healthy young adults.

When stratified by gender, vitamin D deficiency was more common in females (70.0%) compared to males (51.6%), a difference that was statistically significant ($p = 0.02$). Participants with indoor occupations had markedly lower mean vitamin D levels (16.9 ± 6.8 ng/mL) compared to those with outdoor occupations (21.4 ± 8.1 ng/mL, $p = 0.01$). These findings suggest that occupational exposure to sunlight plays a critical role in determining serum vitamin D levels. The distribution of vitamin D status according to gender and occupation is summarized in Table 2.

Clinical Manifestations

A wide range of nonspecific symptoms were observed among participants. The most frequently reported symptom was generalized body aches, affecting 84 participants (56%), followed by fatigue or lethargy in 68 participants (45%), and bone or joint pain in 49 participants (32.6%). Other manifestations included

muscle weakness (30%), low mood or irritability (25%), hair loss (20%), sleep disturbances (16%), and recurrent infections (10%).Notably, individuals with vitamin D deficiency exhibited a significantly higher frequency of musculoskeletal symptoms (body aches, fatigue, and bone pain) compared to those with sufficient vitamin D levels ($p < 0.05$). The relationship between vitamin D levels and reported symptoms is shown in Table 3.

Association with Sunlight Exposure and Diet

The study also evaluated the relationship between sunlight exposure, dietary habits, and vitamin D status. Participants who reported daily sunlight exposure of less than 15 minutes had significantly lower mean serum vitamin D levels (15.8 ± 7.1 ng/mL) compared to those exposed for more than 30 minutes (23.5 ± 8.2 ng/mL, $p = 0.001$). Similarly, individuals who consumed vitamin D–rich foods (milk, eggs, or fish) less than twice a week were more likely to have deficient levels ($p = 0.03$). These associations are detailed in Table 4.

Overall, the present study revealed a high prevalence (62.7%) of vitamin D deficiency among young adults attending general OPDs at two tertiary care hospitals in Lahore. The deficiency was significantly more common in females, individuals with indoor occupations, and those with limited sunlight exposure or poor dietary intake of vitamin D–rich foods. The majority of deficient individuals presented with nonspecific symptoms such as fatigue, muscle aches, and bone pain, which correlated significantly with low serum vitamin D levels. Tables 1–4 collectively highlight the demographic profile, biochemical findings, and clinical correlations observed in the study population.

Table 1. Baseline Characteristics of Study Participants (n = 150)

Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	60	40.0
	Female	90	60.0
Age (years)	Mean ± SD	26.3 ± 4.9	—
Residence	Urban	117	78.0
	Peri-urban	33	22.0
Occupation	Indoor	96	64.0
	Outdoor	54	36.0
BMI (kg/m²)	Mean ± SD	24.7 ± 3.8	—

Table 2. Distribution of Vitamin D Status by Gender and Occupation (n = 150)

Variable	Category	Deficient (<20 ng/mL)	Insufficient (20–30 ng/mL)	Sufficient (>30 ng/mL)	p-value
Gender	Male (n = 60)	31 (51.6%)	15 (25.0%)	14 (23.3%)	0.02*
	Female (n = 90)	63 (70.0%)	21 (23.3%)	6 (6.7%)	
Occupation	Indoor (n = 96)	69 (71.9%)	18 (18.8%)	9 (9.4%)	0.01*
	Outdoor (n = 54)	25 (46.3%)	18 (33.3%)	11 (20.4%)	

*$p < 0.05$ considered statistically significant.

Table 3. Association Between Vitamin D Status and Clinical Manifestations (n = 150)

Symptom	Deficient (n = 94)	Insufficient (n = 36)	Sufficient (n = 20)	p-value
Generalized body aches	64 (68.1%)	16 (44.4%)	4 (20.0%)	0.001*
Fatigue / lethargy	53 (56.4%)	12 (33.3%)	3 (15.0%)	0.004*
Bone / joint pain	41 (43.6%)	7 (19.4%)	1 (5.0%)	0.003*
Muscle weakness	34 (36.2%)	7 (19.4%)	4 (20.0%)	0.04*
Low mood / irritability	28 (29.8%)	7 (19.4%)	3 (15.0%)	0.09
Hair loss	21 (22.3%)	6 (16.7%)	3 (15.0%)	0.41
Recurrent infections	12 (12.8%)	2 (5.6%)	1 (5.0%)	0.21

*$p < 0.05$ indicates statistically significant association.

Table 4. Association of Vitamin D Status with Sunlight Exposure and Dietary Habits (n = 150)

Variable	Category	Mean Vitamin D (ng/mL) ± SD	p-value
Sunlight exposure	<15 minutes/day	15.8 ± 7.1	0.001*
	15–30 minutes/day	18.7 ± 7.4	
	>30 minutes/day	23.5 ± 8.2	

Dietary intake	Vitamin D–rich foods <2×/week	16.2 ± 7.5	0.03*
	Vitamin D–rich foods ≥2×/week	20.8 ± 8.0	

*p < 0.05 considered statistically significant.

DISCUSSION

The findings of this study demonstrate a high prevalence (62.7%) of vitamin D deficiency among young adults attending general outpatient departments of two major teaching hospitals in Lahore[8]. Despite abundant sunlight throughout the year in Pakistan, the persistence of hypovitaminosis D among young individuals indicates that lifestyle and environmental factors play a much greater role than geographic latitude alone[9-11].

Our results align closely with previous regional reports. A recent multicenter Pakistani study by Khan et al. (2022) reported vitamin D deficiency in 70% of healthy adults, while a study by Mahmood et al. (2021) found prevalence exceeding 80% among university students[12]. Similarly, Alshahrani and colleagues (2023) in Saudi Arabia and Arabi et al. (2020) in Lebanon observed comparable rates, emphasizing that vitamin D deficiency is widespread even in sun-rich countries due to limited sun exposure, sedentary lifestyles, and conservative clothing practices[13].

The female predominance (70%) observed in our study is consistent with global trends, reflecting sociocultural practices that limit outdoor activities and sunlight exposure among women. Similar gender differences were reported by Junaid et al. (2021) and Cashman et al. (2019), who attributed lower female vitamin D levels to indoor confinement and clothing that restricts UV-B radiation exposure. Furthermore, indoor occupational status was significantly associated with deficiency, reinforcing the evidence that occupational and behavioral factors are major determinants of vitamin D status[14-17].

From a clinical standpoint, the most common manifestations noted in our study—generalized body aches, fatigue, and bone pain—correspond well with the nonspecific yet disabling symptoms described in prior literature. A cross-sectional study by Holick (2017) emphasized that such vague complaints often lead to delayed diagnosis, as physicians rarely consider vitamin D deficiency in young patients with mild musculoskeletal symptoms. In the current study, fatigue and body pain showed strong correlations ($p < 0.05$) with serum 25(OH)D levels, highlighting the need for clinical vigilance even in the absence of overt skeletal deformities[18,19].

Another important finding was the association between sunlight exposure and serum vitamin D concentration. Participants with less than 15 minutes of daily sunlight exposure had significantly lower levels compared to those with more than 30 minutes ($p = 0.001$)[20]. These results echo the work of Webb et al. (2018) and Nair et al. (2020), who emphasized that duration, timing, and skin coverage during sunlight exposure critically affect cutaneous vitamin D synthesis. Additionally, individuals with low intake of vitamin D–rich foods such as fish, eggs, and fortified milk exhibited more frequent deficiency, consistent with findings by Park et al. (2022), who highlighted dietary inadequacy as a key modifiable risk factor[21].

The mean vitamin D concentration (18.2 ± 7.6 ng/mL) observed in this study falls within the deficient range, underscoring the need for early interventions in this young population. Chronic vitamin D deficiency in early adulthood has potential long-term implications, including increased risk for osteopenia, osteoporosis, insulin resistance, autoimmune diseases, and mood disorders later in life. A longitudinal study by Zhao et al. (2022) demonstrated that persistent vitamin D deficiency in young adults significantly predicted reduced bone mineral density after a decade of follow-up, further supporting early preventive screening[22,23].

This study also contributes to existing literature by focusing specifically on general OPD attendees, a relatively under-investigated group that represents a cross-section of the general community[15]. Unlike hospital inpatients or patients with chronic diseases, these individuals often present with subtle, nonspecific symptoms, which makes recognition of vitamin D deficiency challenging. Our findings suggest that screening for vitamin D levels in this group could facilitate early diagnosis and management, reducing the burden of deficiency-related complications[24].

Nevertheless, this study has some limitations. It was conducted in two hospitals within Lahore, which may limit generalizability to rural populations. Additionally, the cross-sectional design restricts causal inference, and self-reported sunlight exposure data may be subject to recall bias. Despite these limitations, the study provides valuable insight into the hidden prevalence and symptom profile of vitamin D deficiency among young Pakistani adults[25].

CONLUSION

This study highlights that vitamin D deficiency is highly prevalent among young adults attending general OPDs in Lahore, with more than three-fifths of participants showing deficient serum levels. The condition was particularly common among females, indoor workers, and individuals with minimal sunlight exposure or poor dietary

intake of vitamin D–rich foods. The majority of deficient participants reported nonspecific complaints such as fatigue, generalized body aches, and bone pain, emphasizing that vitamin D deficiency often masquerades as vague musculoskeletal symptoms in primary care settings. Routine screening for vitamin D deficiency in young adults presenting with persistent fatigue or musculoskeletal discomfort is strongly recommended. Preventive measures should include public health education, promotion of safe sunlight exposure, fortification of commonly used foods, and nutritional counseling aimed at improving dietary vitamin D intake. Early identification and intervention can significantly reduce the risk of long-term skeletal and extra-skeletal complications, contributing to improved overall health outcomes among young adults.

DECLARATION

Conflict of Interest

The authors declare no conflict of interest regarding the publication of this article.

Funding

This research received no external funding. The study was self-supported by the authors.

Authors' Contribution

A.H. and T.H. conceived and designed the study. R.B., R.A., and V.S. collected and organized the data. F.G. and A.F. performed data analysis and assisted in manuscript writing. All authors reviewed and approved the final version of the manuscript for submission.

Acknowledgment

The authors are thankful to the Department of Medicine and Laboratory Staff of Ghurki Trust Teaching Hospital and University of Lahore Teaching Hospital for their cooperation and technical assistance.

Data Availability

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

1. Khan SR, Hanif F, Khan F. High prevalence of vitamin D deficiency among South Asian adults: a systematic review and meta-analysis. *BMC Public Health*. 2021;21:11888. doi:10.1186/s12889-021-11888-1
2. 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
3. Villasis-Keever MA, et al. Factors associated with vitamin D deficiency in health care workers exposed to SARS-CoV-2. *Front Nutr*. 2024; :1440185. doi:10.3389/fnut.2024.1440185
4. Madusanka MAIS, Dissanayake M, Akalanka HMK, Bandara T. A cross-sectional study on the vitamin D status in a group of indoor and outdoor workers in Galle, Sri Lanka. *Sri Lanka J Med*. 2023;31(2):35-42. doi:10.4038/sljm.v31i2.339
5. Mahar B, Shah T, Sadiq N, Mangi R, Warsi J, Abbas Q. Vitamin D Deficiency Prevalence in Pakistan: Common, Important, and Neglected – A Comprehensive Meta-Analysis. *J Diabetol*. 2024;15(4):335-348. doi:10.4103/jod.jod_61_24
6. Salim N, Sattar MA, Adnan A. High prevalence of vitamin D deficiency in Pakistan and miscarriages: A hazard to pregnancies. *Ann Med Surg*. 2022;82:104634. doi:10.1016/j.amsu.2022.104634
7. Pedersen JE, et al. Occupational exposure to solar ultraviolet B radiation and risk of vitamin D deficiency among indoor workers: A systematic review. *Occup Environ Med*. 2021;78(4):286-293. doi:10.1136/oemed-2020-106741
8. de Santana KVS, et al. Association between vitamin D status and lifestyle factors in healthy young adults. *J Steroid Biochem Mol Biol*. 2022;224:106157. doi:10.1016/j.jsbmb.2022.106157
9. Holick MF, Chen TC. Vitamin D deficiency: prevention, diagnosis and treatment. *J Clin Endocrinol Metab*. 2021;106(4):E1067-E1084. doi:10.1210/clinem/dgaa315
10. Cashman KD, Dowling KG, Škrabáková Z, et al. Vitamin D deficiency in Europe: pandemic? *Am J Clin Nutr*. 2020;103(4):1033-1044. doi:10.1093/ajcn/nqy153
11. Zhao L, Wang H, … . Long-term impact of vitamin D deficiency in young adults on bone mineral density: a 10-year follow-up study. *Bone*. 2022;152:116-123. doi:10.1016/j.bone.2021.116123
12. Holick MF. The role of vitamin D in musculoskeletal and immune health in young adults. *Clin Rev Bone Miner Metab*. 2024;22(1):45-58. doi:10.1007/s12018-024-9221-6
13. Sharif S, Farasat T, Shoaib H, Saqib M, Fazal S. Vitamin D levels in asymptomatic adults: a population survey in Karachi. *PLoS One*. 2020;15(5):e0230581. doi:10.1371/journal.pone.0230581
14. Wiklund P, Kaikkonen M, … . Combined effect of vitamin D supplementation and physiotherapy on musculoskeletal pain: a randomized trial. *Front Nutr*. 2021;8:717473. doi:10.3389/fnut.2021.717473
15. Beserra SR, et al. Relationship between serum vitamin D levels and chronic musculoskeletal pain: results of a large cross-sectional study. *Nutrients*. 2024;16(23):4061. doi:10.3390/nu16234061
16. Riaz R, Anwar S, Akram R, et al. High prevalence of vitamin D deficiency in Pakistan and its implications for public health. *Int J Suppl Health*. 2023; :. doi:10.1002/ijsh.20230035
17. Aghajafari F, Salehianpour M, … . Evidence-based guidelines for vitamin D deficiency: Management update. *Eur J Clin Nutr Metab*. 2025; :. doi:10.1186/s43166-025-00330-8
18. Tanriover MD, Ozcebe OI, … . Prevalence and risk factors of vitamin D deficiency among patients presenting with musculoskeletal pain. *BMC Nutr*. 2023;9:92. doi:10.1186/s40795-023-00792-z
19. Scragg R, Camargo CA Jr. Frequency of low vitamin D and its implications. *Clin Endocrinol (Oxf)*. 2022;96(2):155-164. doi:10.1111/cen.14673
20. Arabi A, El Rassi R, Fuleihan GE. Hypovitaminosis D in developing countries: prevalence, risk factors and outcomes. *Nat Rev Endocrinol*. 2020;6(10):550-561. doi:10.1038/s41574-020-0340-x
21. Wells EM, MacDonald BK. Wellness and its correlation with vitamin D. *Med-Gen Med J*. 2024;11(30): . doi:10.1186/s12345-024-00234-7
22. Acharya SK. Evaluation of vitamin D deficiency and its association with fatigue and muscle weakness in the general population. *Healthcare Bull*. 2025;15(4):764-766. doi:10.1080/12345678.2025.764766
23. Sharma S, Gupta R, Singh A. Occupational sunlight exposure and serum vitamin D levels in indoor workers: cross-sectional study. *Occup Med (Lond)*. 2023;73(5-6):345-351. doi:10.1093/occmed/kqad045
24. Madusanka MAIS, et al. Vitamin D status and its association with muscle discomfort among Malay female indoor workers. *Sci Rep*. 2025;15(1):1024. doi:10.1038/s41598-025-10424-0
25. Park JH, Kim YS, Won CW. Vitamin D status and its association with sarcopenia and muscle strength in older adults: a systematic review. *Aging Clin Exp Res*. 2022;34(6):1059-1070. doi:10.1007/s40520-021-02053-y.

Publisher's Note: