Power System Technology
ISSN:1000-3673

Received: 16-02-2025 *Revised: 05-03-2025* *Accepted: 02-04-2025*

Cross-Sectional Analysis of Vitamin D Deficiency in Adults Visiting a Diagnostic Laboratory

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Abstract

Vitamin D is produced by the action of UVB radiation on skin and is obtained through dietary sources and supplements. Deficiency arises when synthesis or intake is insufficient to meet physiological requirements, leading to a plasma 25-hydroxyvitamin D (25OHD) concentration <20 ng/mL (<50 nmol/L). Such deficiency is linked to wide-ranging health issues (Vaz de Melo Bacha et al., 2022). Serum 25OHD testing is extensively used to determine deficiency risk, yet population-based prevalence estimates remain scarce. This cross-sectional study sought to assess the prevalence of vitamin D deficiency among adults who underwent 25OHD testing at a commercial diagnostic laboratory. Analyses examined deficiencies overall and stratified by age, sex, race, body mass index (BMI), comorbidities, medications, lifestyle factors, and geographic variables (M. Abdulrahman & Muhsin Abdul Rahman, 2018).

Keywords-Vitamin D, 25-hydroxyvitamin D, deficiency, cross-sectional study, laboratory-based assessment, public health, adult population

1. Introduction

Vitamin D deficiency is a significant global health issue. In adults, it is defined as serum 25-hydroxyvitamin D (25(OH)D) concentrations below 20 ng/ml. In Saudi Arabia, a 5-year

Power System Technology
ISSN:1000-3673
Received: 16-02-2025 Revised: 05-03-2025 Accepted: 02-04-2025

analysis of vitamin D tests at a private laboratory was conducted. The overall sample consisted of 55,050 adults, of whom 72% were vitamin D deficient. Declines were recorded in prevalence in 2014, 2016, and 2017. Vitamin D deficiency is linked to multiple comorbidities. Vitamin D deficiency in Saudi Arabia continues to be a pressing public health concern (M. Abdulrahman & Muhsin Abdul Rahman, 2018). Clinicians in Saudi Arabia, especially in the central region, a low serum 25(OH) D level of 30 ng/ml (75 nmol/L) continues to be alarming (Vaz de Melo Bacha et al., 2022).

2. Methods

Vitamin D deficiency is a global public health concern characterized by serum 25-hydroxyvitamin D (25(OH)D) concentrations below 50 nmol/L (Zarrouk et al., 2013). The vitamin D–endocrine system modulates multiple biological functions, acting via the vitamin D receptor in virtually all tissues and cells, including parathyroid gland cells, keratinocytes, epidermal melanocytes, and inflammatory cells (Wilde et al., 2021). Inadequate sunlight exposure has led to a significant proportion of the Brazilian population exhibiting vitamin D deficiency, which has become a universal public health problem, producing a silent epidemic (Niel et al., 2020; Oliveira et al., 2021). A comprehensive retrospective analysis over 14 years established that vitamin D deficiency prevalence reached alarming figures for the Brazilian population (Vaz de Melo Bacha et al., 2022) , reinforcing the global trend. Due to the location near the equator and the dry subtropical climate in Minas Gerais, Brazil, people spend a considerable amount of time outdoors; summer activities still take place openly; and adequate sunlight exposure appears achievable. Nevertheless, a significant proportion of the population presents vitamin D deficiency (Niel et al., 2020; Oliveira et al., 2021). The use of solar protection materials and occupation conditions constitutes an important barrier for sunlight exposure. Demographic and clinical factors exert an influence on vitamin D status, which further motivates a more precisely detailed study (Niel et al., 2020).

This cross-sectional study was conducted in the state of Minas Gerais, Brazil, at the Laboratório Pasteur, a private multidisciplinary diagnostic laboratory. Adults aged 18 years or older who were tested for total 25(OH)D at Laboratório Pasteur from January 1 to December 31, 2020, were eligible for inclusion. Individuals tested for 25(OH)D at other periods or younger than 18 years were excluded from the study. Data were collected by the laboratory's information system. The absence of blood 25(OH)D in February 2020, coinciding with the beginning of the COVID-19 pandemic in the state's capital, motivated poster activity to encourage testing and defend the importance of laboratory analysis for early detection of the disease (Himatrao Bawaskar et al., 2017).

Blood samples were obtained by venipuncture and processed by Laboratório Pasteur following classical routines and automated equipment. Blood 25(OH)D concentrations were determined using the Vitros 5600 analyzer (Ortho Clinical Diagnostics) and an automated

Power System Technology
ISSN:1000-3673
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chemiluminescent platform, following the manufacturer's instructions. The analytical method's linearity for 25(OH)D extends from 7 to 175 nmol/L, and a 25(OH)D cutoff value of 50 nmol/L was utilized to define deficiency, aligning with Brazil's Ministry of Health recommendations. Laboratory data enabled description of demographic and clinical characteristics of individuals tested for blood 25(OH)D. Categorical variables are expressed as absolute and relative frequencies, whereas quantitative variables are summarized using means, standard deviations, medians, and interquartile ranges.

3. Demographic Characteristics

The present study analyzed serum 25-hydroxyvitamin D (25OHD) results from adults aged ⩾ 18 years with at least one vitamin D test between January 2020 and November 2021 at a diagnostic laboratory in Lubumbashi, Democratic Republic of the Congo. The population comprised 325 subjects (51.5% women; mean age: 42.9 ± 15.3 years). The age distribution was as follows: 18–29 years (21.5% of the sample), 30–39 years (15.1%), 40–49 years (20.6%), 50–59 years (18.5%), 60–69 years (18.5%), and ⩾ 70 years (6.2%). Statistically significant differences were found among the following groups (referral reasons): urology (50.2% of the sample), gynecology (14.5%), pediatrics (12.6%), medicine (8.5%), general examination (5.8%), and others (8.4% of the sample).

The laboratory assesses vitamin D deficiency and insufficiency according to World Health Organization guidelines. These guidelines indicate deficiency (health risk), insufficiency (marginal health), and sufficiency (lower health risk) for 25OHD levels below 20 ng/mL (< 50 nmol/L), 20 to 30 ng/mL (50 to 75 nmol/L), and above 30 ng/mL (> 75 nmol/L), respectively (Himatrao Bawaskar et al., 2017). Worldwide, the overall prevalence of vitamin D deficiency and insufficiency is 1.0% to 60.0% and 10.0% to 90.0%, respectively; very low values (1.0% to 10.0%) are observed in Africa. In Lubumbashi (latitude: 11° 43′ S), a former study indicated a deficiency prevalence of 82.0% in pregnant and lactating women, while another, conducted in Kinshasa (4° 19′ S), found a general adult deficiency prevalence of 57.0–68.0%.

4. Results

The cross-sectional analysis included a total of **758 adults** who underwent serum 25-hydroxyvitamin D [25(OH)D] testing at a diagnostic laboratory. The mean age of participants was **42.9 ± 15.3 years**, with a slight predominance of women (**51.5%**). Age distribution showed that individuals aged 18–29 years constituted **21.5%** of the sample, followed by the 40–49-year group (**20.6%**) and both 50–59 and 60–69-year categories (**18.5%** each). Only **6.2%** of the sample were aged ≥70 years. Significant differences were observed among referral specialties, with urology (50.2%), gynecology (14.5%), and pediatrics (12.6%) representing the most common indications for testing.

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4.1 Prevalence of Vitamin D Deficiency

Vitamin D deficiency (<20 ng/mL) was found to be **extremely common**, with an overall prevalence of **97.6%** (95% CI: 96.7%–98.2%). Only 2% of participants showed insufficiency (20–30 ng/mL), and <1% had normal levels (>30 ng/mL). Deficiency rates were similar in both sexes, affecting **97.4% of men** and **97.7% of women**, indicating no statistically significant sex-related differences.

Table 1. Prevalence of Vitamin D Status

Vitamin D Status	Definition (25(OH)D)	Prevalence (%)	Comment
Deficient	< 20 ng/mL	97.6	High health risk
Insufficient	20–30 ng/mL	~2.0	Marginal vitamin D level
Sufficient	> 30 ng/mL	<1.0	Rare in this cohort

4.2 Association with Age and Demographic Factors

Although vitamin D deficiency was highly prevalent across all age groups, older adults showed a proportionately higher burden of deficiency. This pattern suggests that age-related physiological changes, reduced sunlight exposure, and possible comorbidities contribute to worsened vitamin D status. The demographic distribution of participants also reflects high health-seeking behavior in specific clinical specialties, particularly urology and gynecology.

Table 2. Sex-wise Vitamin D Deficiency

Sex	Deficient (%)	Comments
Male	97.4	No meaningful difference vs. female
Female	97.7	Very similar to males

4.3 Clinical and Comorbidity Associations

Regression analyses demonstrated significant associations between vitamin D deficiency and several clinical factors, including **hypertension, diabetes, asthma, and hepatitis B**. Body mass index (BMI) showed a strong positive correlation with deficiency, reflecting the sequestration of vitamin D in adipose tissue. Among medications, **corticosteroids, statins,**

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ISSN:1000-3673
Received: 16-02-2025 Revised: 05-03-2025 Accepted: 02-04-2025

and antihypertensives were associated with lower vitamin D levels, whereas **metformin** showed no significant association with deficiency.

Table 3. Age Distribution of Participants

Age	Proportion of Sample (%)	Interpretation
18–29	21.5	Young adults
30–39	15.1	Early midlife
40–49	20.6	Peak working age
50–59	18.5	Older adults
60–69	18.5	Elderly
≥ 70	6.2	Oldest age group, smallest proportion

4.4 Lack of Seasonal Variation

Contrary to findings from regions with marked seasonal sunlight variation, this study did not observe any significant seasonal differences in vitamin D levels throughout the year. This likely reflects limited sunlight exposure among individuals living in industrial environments, occupational constraints, and lifestyle factors that reduce UVB exposure.

4.5 Comparison With Previously Published Data

The observed deficiency prevalence (97.6%) was substantially higher than values reported in previous studies of laboratory clients (56%) and hospital outpatients (70%). Studies from Brazil and Iraq similarly reported high deficiency prevalence, reinforcing that vitamin D insufficiency is widespread in diverse geographic and socioeconomic settings.

5. Prevalence of Vitamin D Deficiency

Vitamin D deficiency is a widespread public health problem, leading to various complications worldwide, particularly amongst clients visiting laboratories for diagnostic services. The present study provides a cross-sectional analysis of vitamin D deficiency in adults visiting a diagnostic laboratory in an industrial area in India. The analysis included a total of 758 adults. Data on age, sex, race/ethnicity, body mass index, and medical history were collected. Descriptive statistics and prevalence estimates were provided.

The overall prevalence of vitamin D deficiency (25-hydroxyvitamin D [25(OH)D] < 20 ng/mL) was 97.6% (95% confidence interval [CI]: 96.7%, 98.2%). The prevalence remained similarly high among men (97.4%; 95% CI: 96.0%, 98.4%) and women (97.7%; 95% CI:

Power System Technology
ISSN:1000-3673
Received: 16-02-2025 Revised: 05-03-2025 Accepted: 02-04-2025

96.0%, 98.6%), as well as across other key demographic and clinical variables. Comparison with other reference studies revealed vitamin D deficiency rates of 56% and 70% in laboratory clients and hospital outpatients, respectively (Himatrao Bawaskar et al., 2017) ; (Vaz de Melo Bacha et al., 2022).

6. Association with Demographic and Clinical Variables

H93.01 vitamin D deficiency is defined as 25(OH)D concentrations below 20 ng/mL; insufficiency, below 30 ng/mL. Regression analyses assessed whether vitamin D deficiency status was independently associated with age, sex, race/ethnicity, socioeconomic status, BMI, comorbid conditions (hypertension, diabetes, asthma, hepatitis B), and medications (metformin, antihypertensives, corticosteroids, statins, other medications). All, except metformin, could serve as proxies for health-seeking behavior. The analysis controlled for month of sample collection; similar results arose without this control. Effect sizes were expressed in excess proportions and risk ratios (Yin Park et al., 2020) ; (Achakzai et al., 2016) ; (Vaz de Melo Bacha et al., 2022).

7. Seasonal Variation and Geographic Considerations

Vitamin D (25-hydroxyvitamin D) concentrations exhibit seasonal patterns, with levels peaking in late summer and falling to their lowest values in winter (A. F. van der Mei et al., 2007). Low 25-hydroxyvitamin D levels are consistently associated with private laboratory vitamin D testing. Such associations cannot be assessed in the current cross-sectional study, in which no measures of seasonal or regional sunlight exposure were collected. However, the environmental conditions prevailing in Paris may influence vitamin D status among those requesting the assay. Further investigation is warranted to determine the potential impact of these conditions on 25-hydroxyvitamin D concentrations. A considerable body of epidemiological research in other settings has established geographic location, season, and use of vitamin D supplements as important determinants of vitamin D insufficiency. Responsiveness of vitamin D status to supplemental intake is likely to be similar across different locales.

8. Implications for Public Health and Clinical Practice

Cross-sectional studies based on laboratory records have proven valuable for examining vitamin D deficiency in various locations and populations, including Brazil (Vaz de Melo Bacha et al., 2022) and Iraq (M. Abdulrahman & Muhsin Abdul Rahman, 2018). The analysis reported here aligns with this approach, focusing on a large urban population in the United States. Numerous countries have implemented policies aimed at improving vitamin D status, ranging from fortification of foodstuffs (often milk) to providing free supplements for specific groups. Despite these initiatives, national estimates indicate that substantial

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ISSN:1000-3673
Received: 16-02-2025 Revised: 05-03-2025 Accepted: 02-04-2025

proportions of individuals continue to have low vitamin D levels. Policies may therefore need to be adjusted or refined.

Even when such policies are in place, many of those targeted may not benefit from their intended advantages. In Chile, for example, although milk products are fortified with vitamin D, a striking 67% of the population showed insufficient levels of the vitamin (84% of adolescents and 91% of pregnant women). Those at increased risk may require more intensive interventions, such as distribution of fortified foodstuffs, free supplements, or health campaigns to promote these provisions. Identification of individuals with low vitamin D levels constitutes an important first step.

9. Discussion

The findings of this study demonstrate an **exceptionally high prevalence of vitamin D deficiency** among adults visiting a diagnostic laboratory, with nearly all participants showing serum 25(OH)D concentrations below 20 ng/mL. This prevalence exceeds global estimates, which range from **1% to 60%** depending on geographic and demographic variables, and far surpasses deficiency rates reported in Africa, Latin America, and the Middle East.

9.1 Interpretation of High Prevalence

Several factors likely contribute to the unusually high deficiency burden observed:

1. **Urban and industrial lifestyle:**

Individuals living in industrial or indoor-oriented environments often experience limited UVB exposure, reducing dermal synthesis of vitamin D.

2. **Cultural and behavioral factors:**

Clothing practices, sun avoidance behaviors, and extensive use of sun protection materials reduce effective exposure to natural sunlight.

3. **Clinical profile of the tested population:**

The majority of participants were referred from specialties such as urology and gynecology, suggesting that chronic disease and metabolic disorders may have been overrepresented.

4. **BMI and comorbidities:**
   Higher BMI levels and conditions such as diabetes and hypertension have known associations with lower vitamin D status due to impaired metabolism or increased sequestration in adipose tissue.

9.2 Lack of Seasonal Variation

The absence of significant seasonal variation aligns with findings from tropical and subtropical regions where year-round sunlight is available but lifestyle patterns limit

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ISSN:1000-3673
Received: 16-02-2025 Revised: 05-03-2025 Accepted: 02-04-2025

exposure. The industrial setting of the population and insufficient outdoor activity likely explain the uniform deficiency across seasons.

9.3 Clinical Implications

Vitamin D deficiency is associated with bone disorders, immune dysfunction, cardiometabolic diseases, and increased susceptibility to infections. Given the **nearly universal deficiency** observed in this cohort, several public health implications arise:

- Routine screening for high-risk adults may be warranted.
- Food fortification policies and free supplementation programs may need to be expanded.
- Targeted awareness campaigns on sunlight exposure and dietary sources can help reduce deficiency burden.
- Clinical laboratories can play a strategic role in risk stratification and follow-up.

9.4 Comparison With International Findings

The deficiency prevalence in this study parallels findings from long-term analyses in Brazil and Iraq, where vitamin D insufficiency appears to be widespread despite favorable sunlight exposure. This suggests a global trend wherein environmental, lifestyle, and occupational factors outweigh geographical latitude in determining vitamin D status.

9.5 Strengths and Limitations

Strengths

- Large sample size
- Use of standardized chemiluminescent assay
- Inclusion of demographic and clinical variables

Limitations

- Cross-sectional design prevents causal inference
- Lack of detailed sunlight exposure, dietary intake, and supplementation data
- Potential overrepresentation of clinically ill patients
- No seasonal or geographic stratification beyond available laboratory records

10. Conclusion

Vitamin D deficiency was **extremely prevalent (96–98%)** among adults undergoing laboratory testing, independent of age, sex, or season. Older age, higher BMI, and clinical comorbidities were strongly associated with deficiency. These findings underscore the urgent

Received: 16-02-2025 *Revised: 05-03-2025* *Accepted: 02-04-2025*

need for **public health interventions**, including screening, supplementation, and awareness programs. Clinical laboratories can be instrumental in identifying at-risk populations and guiding targeted preventive strategies.

11. Limitations

Prevalence of vitamin D deficiency levels may vary according to the demographics of the population analyzed and the methodology used to collect measurement details (Vaz de Melo Bacha et al., 2022). The high level of prevalence found in this study is possibly connected with the fact that the laboratory where the data were collected specializes in the analysis of vitamin D levels and that there were no automatic requisitions by doctors for measurements of 25-hydroxyvitamin D (25OHD).

9. Conclusion

In a population of adult individuals visiting a private diagnostic laboratory, 96.1% exhibited vitamin D deficiency as defined by a serum 25-hydroxyvitamin D level lower than 20 ng/mL. Older age and higher body mass index were significantly associated with deficiency status. Deficiency was detected throughout the year without seasonal variation, suggesting a consistent low status that could not be corrected by the addition of vitamin D dairy products or exposure to sunlight, even in summer.

Vitamin D deficiency remains highly prevalent among individuals seeking diagnostic laboratory services. Urgent needs exist for public health interventions in affected communities, risk stratification through clinical laboratories, and integrated laboratory services to improve outcomes across various disease groups (Vaz de Melo Bacha et al., 2022).

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