# Prevalence, Predictors, and Gender-Based Risk Factors of Vitamin D Deficiency: A Retrospective Cross-Sectional Study

Mohammed a.m.y. Al-Hetar[1,2,4], Husni al-Goshae[3], Norasyikin a. Wahab[1], Mahfoudh A.M. abdulghani[3], Abdullah y. Al-Mahdi[3], Mohamad Faez Baobaid[3], Abdullah Mohammed al-matary[4], Qais m. Al-hetar[2], Mohammed e. Alezzy[2], Dya'a alhaq senan[2], Sakina Ruhi[3]

## Abstract

Background: Vitamin D deficiency, a widespread global health issue, significantly impacts bone health and overall physiological well-being. Despite its prevalence, the deficiency often remains underdiagnosed and untreated, particularly in regions such as South Asia, the Middle East and North Africa (MENA), Europe, and the United States, where unique cultural, environmental, and lifestyle factors exacerbate its occurrence. Methods: This retrospective cross-sectional study, conducted at the Medical City Complex in Ibb, Yemen, analyzed data from 5,407 participants over six years (2018–2024). Serum 25-hydroxyvitamin D levels were measured to classify vitamin D status as deficient (<20 ng/mL), insufficient (20–29.9 ng/mL), or sufficient (≥30 ng/mL). Demographic and clinical characteristics were evaluated using descriptive statistics, independent t-tests, and multiple linear regression to assess age- and gender-based differences in vitamin D levels. Results: Among the study population, 77.1% were vitamin D deficient, with females showing a significantly higher prevalence (62.1%) than males (15.0%). Insufficiency was observed in 11.5%, and only 11.3% had sufficient levels. Males exhibited higher mean log-transformed vitamin D levels compared to females across all age groups. Deficiency rates peaked among adults aged 19–50 years, particularly females (45.24%). Regression analysis identified age and gender as significant predictors of deficiency, with older age and female gender increasing the likelihood of deficiency. Conclusion: Vitamin D deficiency remains alarmingly high in Yemen, particularly among females and adults aged 19–50 years. These findings emphasize the need for targeted public health interventions, including supplementation, dietary modifications, and strategies to increase safe sun exposure. Gender-specific approaches are crucial to mitigating the burden of vitamin D deficiency, particularly in populations at higher risk.

**Keywords:** Vitamin D deficiency, gender differences, prevalence, Yemen, public health

***Significance*** | This study determined critical gender and age disparities in vitamin D deficiency, emphasizing targeted interventions for public health improvement.

*Correspondence. Sakina Ruhi, Management and Science University (MSU), Section 13, 40100, Shah Alam, Selangor, Malaysia.

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## Introduction

Vitamin D, a fat-soluble prohormone, plays a vital role in regulating calcium and phosphorus homeostasis, thereby maintaining bone health and overall physiological balance (Norman, 2008). Deficiency in vitamin D, or hypovitaminosis D, is recognized as a global public health issue with severe consequences such as rickets

**Author Affiliation.**
[1] Department of Medicine, Faculty of Medicine, Universiti Kebangsaan Malaysia, Jalan Yaacob Latiff, 56000, Cheras, Kuala Lumpur, Malaysia.
[2] Medical City Complex, The Specialized Clinic for Endocrinology and Diabetes, Ibb, Yemen.
[3] Management and Science University (MSU), Section 13, 40100, Shah Alam, Selangor, Malaysia.
[4] Jiblah University for Medical and Health Sciences, Jiblah city, Ibb, Yemen.

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in children and osteomalacia or osteoporosis in adults (Holick, 2007). Despite the widespread occurrence, vitamin D deficiency remains among the most underdiagnosed and untreated nutritional deficiencies worldwide (Darling, 2020).

The prevalence of vitamin D deficiency is particularly alarming in South Asia. Studies indicate severe deficiencies (<12.5 nmol/L) affect 27–60% of individuals in this region, attributed to cultural, dietary, and environmental factors (Darling, 2020). For instance, hospital-based research in India reports a prevalence ranging from 37% to 99% (Basu et al., 2015). Similarly, in Malaysia, despite the country's equatorial position, over half of the population exhibits suboptimal vitamin D levels (Saffian et al., 2022).

In the Middle East and North Africa (MENA) region, including Gulf countries like Saudi Arabia, UAE, and Kuwait, deficiency rates range from 60% to 90% (Neela et al., 2019). Factors such as limited sun exposure, traditional clothing practices, and urban indoor lifestyles contribute to this epidemic (Alzaheb, 2018). In Egypt, nearly 90% of individuals across various demographic groups have insufficient vitamin D levels, driven by similar cultural and lifestyle determinants (Abdelmonem et al., 2021). Likewise, in Yemen, 87.2% of participants in a recent study showed hypovitaminosis D, with 23.4% having severe deficiencies (<10 ng/mL) (Alwabr & Al-Wadhaf, 2020).

In Europe, vitamin D deficiency is highly prevalent, particularly during winter and spring when sunlight exposure diminishes (Lips & de Jongh, 2018). Even in sun-rich Southern European countries, deficiency rates remain high due to urbanization and lifestyle shifts (Manios et al., 2018). A comprehensive study involving over 55,000 participants revealed a 13% deficiency prevalence across Europe, underscoring the need for public health interventions (Cashman et al., 2016).

The United States also faces significant challenges related to vitamin D deficiency, particularly among non-Hispanic Black Americans, women, and individuals aged 20–29 years (Cui et al., 2022). The interplay of reduced sun exposure, higher obesity rates, and darker skin pigmentation contributes to these disparities. Estimates suggest that 20% to over 40% of Americans may have insufficient vitamin D levels (Cui et al., 2022).

Given the global prevalence and multifaceted causes of vitamin D deficiency, effective strategies are essential. These include enhancing public awareness, increasing dietary intake of vitamin D-rich foods, promoting safe sun exposure, and ensuring appropriate supplementation under medical guidance (Sizar et al., 2024).

## 2. Materials and Methods

### *2.1 Study Design and Setting*

This was a retrospective cross-sectional study conducted at the Medical City Complex, one of the largest private healthcare facilities in Ibb, Yemen. The facility, particularly its Endocrinology and Diabetes Clinic, plays a central role in diagnosing and managing endocrine-related disorders, including vitamin D deficiency. The study spanned from 2018 to 2024, with data collected from 5,407 participants.

### *2.2 Study Design and Reference*

Tables 4 and 5 were designed by me based on the descriptions provided in the studies from Milne & Delander, 2007; Holick, 2007), respectively. Table 5 uses the description from the study from Milne & Delander, 2007, while Table 6 is based on the description from the study Holick, 2007.

### *2.3 Ethics Statement*

This study adhered to the ethical principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the institutional review board of the Medical City Complex in Ibb, Yemen. Given the retrospective nature of the study, written informed consent was waived. Anonymization techniques were employed to ensure that patient confidentiality was maintained throughout the research.

### *2.4 Study Population*

Data were retrospectively collected from the medical records of individuals who visited the clinic during the study period. These individuals included Visitors who came for routine tests and patients seeking care for various health concerns, including those who presented with symptoms such as general malaise, myalgia, arthralgia, hyposexuality, or infertility. Individuals were diagnosed with or monitored for chronic conditions like diabetes, hypertension, dyslipidemia, and coronary artery disease (CAD). Still, all were included regardless of the presence or absence of these conditions. This inclusive approach allowed for the examination of the relationship between vitamin D levels and various health conditions across the general population. Inclusion Criteria: Yemeni ethnicity, Both genders, and All age groups.

### *2.5 Data Collection*

Data were collected from medical records of patients visiting the Endocrinology and Diabetes Clinic between 2018 and 2024. The data collection process involved the following stages: Clinical Records Evaluation: Patient clinical records were reviewed to extract detailed medical histories, laboratory results, and any relevant diagnostic information, ensuring a comprehensive dataset for analysis. Serum 25-Hydroxyvitamin D Quantification: Blood samples were obtained from participants to measure their serum 25-hydroxyvitamin D levels, which were used to assess vitamin D status. The serum vitamin D levels were categorized as follows: Deficient: <20 ng/ml, Insufficient: 20-29.9 ng/ml, Sufficient: ≥30 ng/ml.

### *2.6 Statistical Analysis*

Data from 5,407 participants were analyzed. The mean age of the study population was 37.55 years (SD = 16.22), with a gender distribution of 79.84% females (n = 4,317) and 20.16% males (n = 1,090).Descriptive statistics were used to summarize the demographic and clinical characteristics of the study population. Continuous variables (such as age and log-transformed vitamin D levels) were presented as means ± standard deviations (SD). Categorical variables (such as vitamin D deficiency status) were presented as frequencies and percentages.

Independent t-tests compared log-transformed vitamin D levels between males and females. Multiple linear regression analyses were performed to identify factors associated with vitamin D levels, adjusting for potential confounders such as age, gender, and other health-related factors. A p-value of <0.05 was considered statistically significant. All statistical analyses were carried out using SPSS version 24.

## 3. Results

A total of 5,407 participants were included in the analysis, with a mean age of 37.55 ± 16.22 years. The study cohort comprised a predominance of females (79.84%, n = 4,317), while males represented 20.16% (n = 1,090) of the population. The overall prevalence of vitamin D deficiency (<20 ng/ml) in the study population was 77.1% (n = 4,154), with significantly higher rates among females (62.1%, n = 3,355) compared to males (15.0%, n = 811). Vitamin D insufficiency (20–29.9 ng/ml) was observed in 11.5% (n = 632) of participants, with higher rates in females (8.7%, n = 376) compared to males (2.8%, n = 161). The remaining 11.3% (n = 611) of participants had sufficient vitamin D levels (≥30 ng/ml), with 9.0% (n = 389) of females and 2.3% (n = 118) of males meeting the sufficient threshold.

### *3.1 Gender-Based Differences in Vitamin D Status*

The analysis of gender differences revealed that males consistently had higher mean log-transformed vitamin D levels across all deficiency, insufficiency, and sufficiency categories. The mean log vitamin D level for males was 1.24 ± 0.006, significantly higher than that of females (1.12 ± 0.003). For the deficiency category, males had a mean log vitamin D level of 1.15 ± 0.003, while females had 1.10 ± 0.002. In the insufficiency category, males showed a mean log level of 1.37 ± 0.004, compared to 1.38 ± 0.003 in females. The sufficiency category revealed similar trends, with males having a mean log level of 1.66 ± 0.010 and females 1.65 ± 0.005. A statistically significant difference in vitamin D levels between males and females was noted within the adult age group (19-50 years) (p < 0.001) (Table 1).

### *3.2 Age-Based Distribution of Vitamin D Deficiency*

The prevalence of vitamin D deficiency varied significantly across different age groups.

#### *3.2.1 Children (1-12 years)*

In the children's cohort, males represented 1.35% (n = 73) of the total population, with 0.83% (n = 45) deficient, 0.37% (n = 20) insufficient, and 0.15% (n = 8) having sufficient levels. Females made up 1.65% (n = 89) of the cohort, with 1.44% (n = 78) deficient, 0.13% (n = 7) insufficient, and 0.07% (n = 4) sufficient (Table 2).

#### *3.2.2 Adolescents (13-18 years)*

Among adolescents, males comprised 2.07% (n = 112) of the total population, with 1.59% (n = 86) deficient, 0.28% (n = 15) insufficient, and 0.20% (n = 11) with sufficient levels. Females in this group represented 5.29% (n = 286), with 4.72% (n = 255) deficient, 0.28% (n = 15) insufficient, and 0.30% (n = 16) sufficient (Table 3 and Figure 1).

#### *3.2.3 Adults (19-50 years)*

The adult age group (19–50 years) had the highest number of participants. Males made up 12.00% (n = 649), with 9.30% (n = 503) deficient, 1.50% (n = 81) insufficient, and 1.20% (n = 65) with sufficient levels. Females in this group represented 57.96% (n = 3,134), with 45.24% (n = 2,446) deficient, 6.10% (n = 330) insufficient, and 6.62% (n = 358) with sufficient levels (Table 3 and Figure 2).

#### *3.2.4 Elderly (>50 years)*

In the elderly group (>50 years), males represented 4.73% (n = 256), with 3.27% (n = 177) deficient, 0.70% (n = 38) insufficient, and 2.05% (n = 111) with sufficient levels. Females in this age group comprised 14.94% (n = 808), with 10.67% (n = 577) deficient, 2.22% (n = 120) insufficient, and 0.76% (n = 41) sufficient (Table 3 and Figure 2).

### *3.3 Statistical Analysis and Key Findings*

The analysis of vitamin D levels revealed statistically significant gender-based differences in mean log-transformed vitamin D levels across all age groups, with males consistently exhibiting higher levels than females. This difference was most pronounced in the adult group (19-50 years), where females showed significantly lower levels of vitamin D than their male counterparts (p < 0.001).

A multiple linear regression analysis identified age and gender as significant predictors of vitamin D deficiency. Both older age and female gender were associated with higher risks of vitamin D deficiency, particularly in adults (19-50 years) and elderly individuals (>50 years). These results suggest that gender-specific interventions may be required to address vitamin D deficiency, with special attention needed for females in childbearing years and elderly populations.

### *3.4 Summary of Vitamin D Deficiency Across Age and Gender*

The overall prevalence of vitamin D deficiency in the study population was 77.1% (n = 4,154), with significantly higher rates in females (62.1%, n = 3,355) compared to males (15.0%, n = 811). The adult group (19-50 years) demonstrated the highest rates of deficiency, particularly among females (45.24%, n = 2,446). Males consistently had higher average log vitamin D levels than females across all deficiency categories. Age and gender were identified as significant predictors of vitamin D deficiency, with older age and female gender linked to a higher likelihood of deficiency.

**Table 1.** General Descriptive Statistics of Demographic Variables and Serum Vitamin D Levels

| Baseline Characteristics | Total Number of Individuals (%) | Mean Log Serum Vitamin D Levels (ng/ml) |
|---|---|---|
| **Age (mean ± SD)** | 37.55 ± 16.22 years | N/A |
| **Gender (Both)** | 5407 (100%) | N/A |
| **Gender: Male** | 1090 (20.16%) | **< 1.30** |
| **Gender: Female** | 4317 (79.84%) | **< 1.30** |
| **Vitamin D Deficiency (< 20 ng/ml)** | 4167 (77.1%) | **< 1.30** |
| Male: | 811 (15.0%) | **< 1.30** |
| Female: | 3356 (62.1%) | **< 1.30** |
| **Vitamin D Insufficiency (20–29.9 ng/ml)** | 626 (11.5%) | **1.30 – 1.48** |
| Male: | 154 (2.8%) | **1.30 – 1.48** |
| Female: | 472 (8.7%) | **1.30 – 1.48** |
| **Vitamin D Sufficiency (> 30 ng/ml)** | 614 (11.3%) | **> 1.48** |
| Male: | 125 (2.3%) | **> 1.48** |
| Female: | 489 (9.0%) | **> 1.48** |

**Table 2.** Serum Vitamin D levels and percentage between the different age groups of males and females.

| Age groups (years) | Gender | Total | | Deficiency | | Insufficiency | | Sufficiency | |
|---|---|---|---|---|---|---|---|---|---|
| | | n | % | n | % | n | % | n | % |
| **Overall** | **Male** | 1090 | 20.16 | 811 | 15.00 | 161 | 2.98 | 471 | 8.71 |
| | **Female** | 4317 | 79.84 | 3355 | 62.05 | 491 | 9.08 | 118 | 2.18 |
| **Children (1-12)** | **Male** | 73 | 1.35 | 45 | 0.83 | 20 | 0.37 | 8 | 0.15 |
| | **Female** | 89 | 1.65 | 78 | 1.44 | 7 | 0.13 | 4 | 0.07 |
| **Adolescent (13-18)** | **Male** | 112 | 2.07 | 86 | 1.59 | 15 | 0.28 | 11 | 0.20 |
| | **Female** | 286 | 5.29 | 255 | 4.72 | 15 | 0.28 | 16 | 0.30 |
| **Adults (19-50)** | **Male** | 649 | 12.00 | 503 | 9.30 | 81 | 1.50 | 65 | 1.20 |
| | **Female** | 3134 | 57.96 | 2446 | 45.24 | 330 | 6.10 | 358 | 6.62 |
| **Elders (>50)** | **Male** | 256 | 4.73 | 177 | 3.27 | 38 | 0.70 | 111 | 2.05 |
| | **Female** | 808 | 14.94 | 577 | 10.67 | 120 | 2.22 | 41 | 0.76 |

**Table 3.** Average serum Vitamin D levels and frequency between the different age groups of males and females.

| Age groups (years) | Gender | n= 5407 | Average log Vit. D | Deficiency | Insufficiency | Sufficiency |
|---|---|---|---|---|---|---|
| Overall | Male | 1090 | 1.24 ± 0.006** | 1.15 ± 0.003* | 1.37 ± 0.004 | 1.66 ± 0.010 |
| | Female | 4317 | 1.12 ± 0.003 | 1.10 ± 0.002 | 1.38 ± 0.003 | 1.65 ± 0.005 |
| Children | Male | 73 | 1.27 ± 0.018* | 1.17 ± 0.011 | 1.37 ± 0.011 | 1.58 ± 0.28* |
| | Female | 89 | 1.19 ± 0.016 | 1.15 ± 0.010 | 1.33 ± 0.008 | 1.74 ± 0.071 |
| Adolescent | Male | 112 | 1.22 ± 0.016** | 1.15 ± 0.010 | 1.36 ± 0.011 | 1.61 ± 0.031 |
| | Female | 286 | 1.13 ± 0.011 | 1.08 ± 0.007 | 1.37 ± 0.060 | 1.68 ± 0.026 |
| Adults | Male | 649 | 1.23 ± 0.007** | 1.16 ± 0.004* | 1.36 ± 0.005 | 1.67 ± 0.015 |
| | Female | 3134 | 1.19 ± 0.004 | 1.10 ± 0.002 | 1.37 ± 0.003 | 1.65 ± 0.006 |
| Elders | Male | 256 | 1.24 ± 0.014 | 1.12 ± 0.008 | 1.36 ± 0.008 | 1.64 ± 0.017 |
| | Female | 808 | 1.20 ± 0.008 | 1.08 ± 0.005 | 1.39 ± 0.005 | 1.65 ± 0.012 |

Average ± SEM p-value **<0.001; * <0.05

**Table 4.** General descriptive statistics of demographic variables and serum vitamin D levels.

| Baseline Characteristics | Total number of individuals (%) | Mean log serum vitamin D levels (ng/ml) |
|---|---|---|
| Age in years (mean ± SD) | 37.55 ± 16.22 | N |
| Gender (Both) | 5407 (100) | - |
| Gender: Male | 1090 (20.16) | |
| Gender: Female | 4317 (79.84) | - |
| Vitamin D deficiency (< 20ng/ml) | Male: 811 (15.0)<br>Female: 3356 (62.1)<br>**Total: 4167 (77.1)** | <1.30 |
| Vitamin D insufficiency (20 – 29.9 ng/ml) | Male: 154 (2.8)<br>Female: 472 (8.7)<br>**Total: 626 (11.5)** | 1.30 – 1.48 |
| Vitamin D sufficiency (> 30 ng/ml) | Male: 125 (2.3)<br>Female: 489 (9.0)<br>**Total: 614 (11.3)** | > 1.48 |

**Table 5.** Shows several distinct forms of Vitamin D's chemical composition and its sources

| **Form** | **Composition** | **Source** | **Chemical Structure Description** |
|---|---|---|---|
| **Vitamin D1** | Ergocalciferol-Lumisterol Mixture (1:1) | Ergosterol from fungi and yeast | Secosteroid with double bonds (Ergocalciferol); isomer (Lumisterol) |
| **Vitamin D2** | Pure Ergocalciferol | Fortified cereals, supplements, fungi exposed to ultraviolet light | Secosteroids with a broken ring system, multiple double bonds |
| **Vitamin D3** | Cholecalciferol | Sunlight exposure (UVB rays), fatty fish, egg yolks, fortified dairy | Secosteroids with three intact rings and one broken ring |
| **Vitamin D4** | 22-Dihydroergocalciferol | Some plant-based foods | Like D2, hydrogenated at 22nd carbon |
| **Vitamin D5** | Sitocalciferol | Plant oils, grains | Like D3, different side chain |

**Table 6.** Shows the vitamin D level and its effects.

| **Vitamin D Level (ng/ml)** | **Status** | **Effects/Recommendations** |
|---|---|---|
| **Below 20** | Deficient | Weakened bones, muscle pain, increased fracture risk |
| **20-30** | Insufficient | Higher than severe deficiency; needs addressing to prevent complications |
| **30-40** | Sufficient (for bone health) | Adequate for bone health, but not optimal for immune function |
| **40-60** | Ideal Therapeutic Range | Optimal for bone health, immune function, and overall well-being |
| **Above 60** | High Normal | Monitor closely; risk of affecting calcium homeostasis (potential kidney stones) |
| **Above 100** | Toxicity | Risk of hypercalcemia, which can harm kidneys, bones, and other organs |

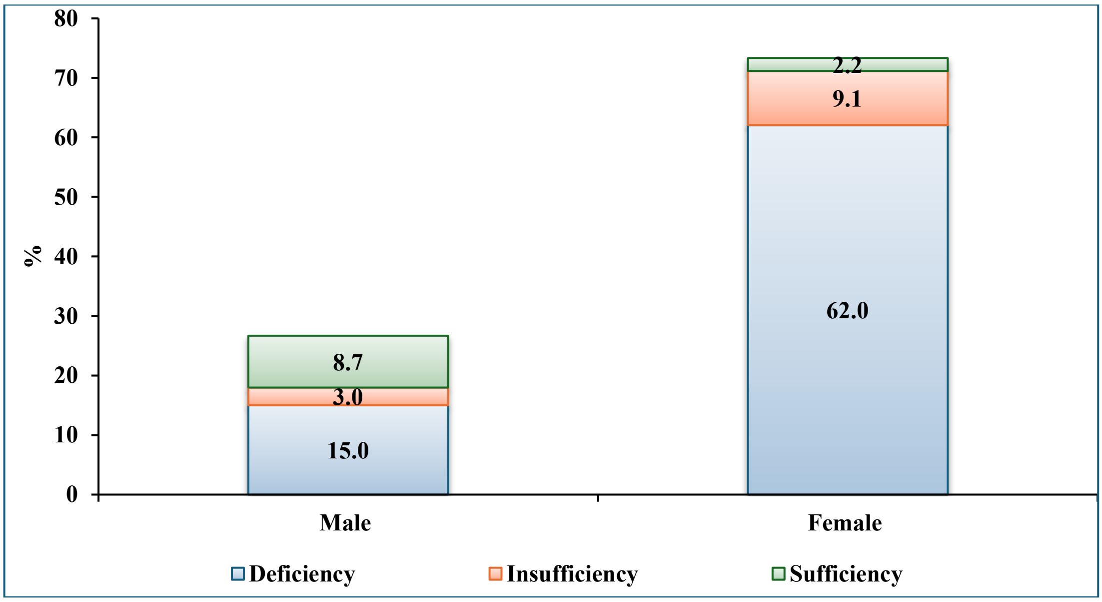


**Figure 1**. Vitamin D status among male and female. Legend: This figure presents the nutritional status of 5,407 participants, categorized by deficiency, insufficiency, and sufficiency, across different age groups and genders. The analysis reveals that male participants, who accounted for 20.16% (n=1,090) of the sample, had 15.00% (n=811) showing deficiency, 2.98% (n=161) insufficiency, and 8.71% (n=471) sufficiency. Female participants made up 79.84% (n=4,317) of the sample, with 62.05% (n=3,355) showing deficiency, 9.08% (n=491) insufficiency, and 2.18% (n=118) sufficiency.

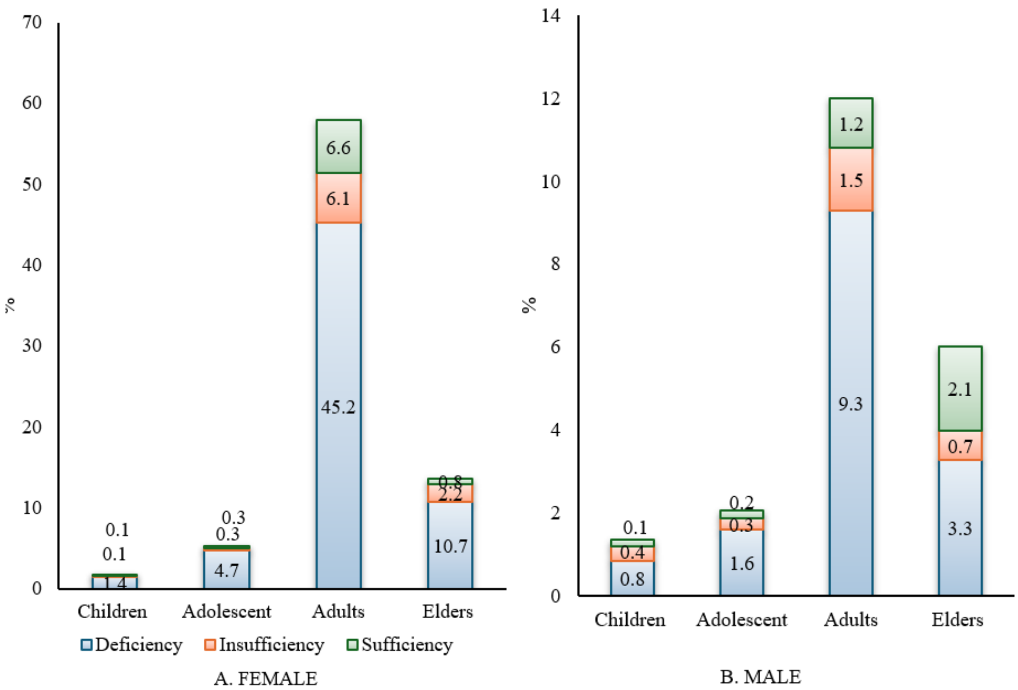


**Figure 2.** Vitamin D status among different studied groups in both male and female. Legend: This figure illustrates the prevalence of vitamin D deficiency, insufficiency, and sufficiency across different age groups for females A, and Males B. In the children's group (1-12 years), males represented 1.35% (n=73) of the total population, with 0.83% (n=45) displaying deficiency, 0.37% (n=20) insufficiency, and 0.15% (n=8) sufficiency. Female children made up 1.65% (n=89), with 1.44% (n=78) showing deficiency, 0.13% (n=7) insufficiency, and 0.07% (n=4) sufficiency. Among adolescents (13-18 years), males constituted 2.07% (n=112) of the total population, with 1.59% (n=86) displaying deficiency, 0.28% (n=15) insufficiency, and 0.20% (n=11) sufficiency. Female adolescents represented 5.29% (n=286), with 4.72% (n=255) showing deficiency, 0.28% (n=15) insufficiency, and 0.30% (n=16) sufficiency.

A total of 5,407 participants were analyzed to assess nutritional deficiency, insufficiency, and sufficiency across different age groups and genders. Overall, male participants accounted for 20.16% (n=1,090) of the sample, with 15.00% (n=811) showing deficiency, 2.98% (n=161) insufficiency, and 8.71% (n=471) sufficiency. Female participants made up 79.84% (n=4,317) of the sample, with 62.05% (n=3,355) showing deficiency, 9.08% (n=491) insufficiency, and 2.18% (n=118) sufficiency **(Table 1 and Figure 1).**

In the children's group (1-12 years), males represented 1.35% (n=73) of the total population, with 0.83% (n=45) displaying deficiency, 0.37% (n=20) insufficiency, and 0.15% (n=8) sufficiency. Female children made up 1.65% (n=89), with 1.44% (n=78) showing deficiency, 0.13% (n=7) insufficiency, and 0.07% (n=4) sufficiency **(Table 2, Figure 1).**

Among adolescents (13-18 years), males constituted 2.07% (n=112) of the total population, with 1.59% (n=86) displaying deficiency, 0.28% (n=15) insufficiency, and 0.20% (n=11) sufficiency. Female adolescents represented 5.29% (n=286), with 4.72% (n=255) showing deficiency, 0.28% (n=15) insufficiency, and 0.30% (n=16) sufficiency **(Table 3, Figure 2).**

The adult group (19-50 years) represented the largest segment of the population. Male adults made up 12.00% (n=649) of the population, with 9.30% (n=503) displaying deficiency, 1.50% (n=81) insufficiency, and 1.20% (n=65) sufficiency. Female adults accounted for 57.96% (n=3,134) of the sample, with 45.24% (n=2,446) displaying deficiency, 6.10% (n=330) insufficiency, and 6.62% (n=358) sufficiency **(Table 3, Figure 2).**

In the elderly group (>50 years), males represented 4.73% (n=256), with 3.27% (n=177) displaying deficiency, 0.70% (n=38) insufficiency, and 2.05% (n=111) sufficiency. Female elders comprised 14.94% (n=808) of the sample, with 10.67% (n=577) displaying deficiency, 2.22% (n=120) insufficiency, and 0.76% (n=41) sufficiency **(Table 3, Figure 2).**

The study shows that males (n=1,090) had an average log Vitamin D level of 1.24 ± 0.006, with levels of 1.15 ± 0.003 for deficiency, 1.37 ± 0.004 for insufficiency, and 1.66 ± 0.010 for sufficiency. In comparison, females (n=4,317) had a lower average Vitamin D level of 1.12 ± 0.003, with 1.10 ± 0.002 for deficiency, 1.38 ± 0.003 for insufficiency, and 1.65 ± 0.005 for sufficiency. Among children aged 1-12 years, male children (n=73) had an average Vitamin D level of 1.27 ± 0.018, while female children (n=89) had an average of 1.19 ± 0.016. For adolescents (13-18 years), males (n=112) averaged 1.22 ± 0.016, whereas females (n=286) averaged 1.13 ± 0.011. In the adult group (19-50 years), male adults (n=649) exhibited an average of 1.23 ± 0.007, while female adults (n=3,134) had an average of 1.19 ± 0.004. In elders aged over 50 years, male elders (n=256) had an average Vitamin D level of 1.24 ± 0.014, while female elders (n=808) averaged 1.20 ± 0.008. Overall, males consistently had higher Vitamin D levels than females across all age groups, with significant differences noted in the adult group ($p < 0.001$) **(Table 3).**

## 4. Discussion

Vitamin D, a crucial nutrient for numerous physiological functions, including bone health, immune modulation, cardiovascular function, insulin sensitivity, and mental well-being, is also vital for calcium and phosphorus homeostasis (Bellavia et al., 2016; Holick, 2007; Lagoeiro et al., 2018). Deficiency in vitamin D has become a pressing global health issue, with Yemen being no exception (Suryanarayana et al., 2018; Saffian et al., 2022). This study analyzed vitamin D levels in 5,407 individuals from Ibb City, Yemen, uncovering a high prevalence of hypovitaminosis D and identifying key demographic and lifestyle factors contributing to the condition.

### *4.1 Prevalence of Hypovitaminosis D*

The prevalence of hypovitaminosis D observed in this study (77.1%) is consistent with findings across the Middle East and South Asia, regions often characterized by similar cultural and environmental conditions. Studies in Saudi Arabia reported prevalence rates of 77.4% in the general population and 80.6% among female university students (Alzaheb, 2018; Alzaheb & Al-Amer, 2017). Similarly, in Egypt, the prevalence ranged from 72% to 90% across various cohorts (Botros et al., 2015; Abdelmonem et al., 2021). Factors such as high temperatures, cultural clothing practices that limit sun exposure, and predominantly indoor lifestyles significantly contribute to these high rates (Neela et al., 2019; Bassil et al., 2013). In comparison, regions with proactive food fortification programs, such as the United States and Europe, report lower deficiency rates. In the U.S., the prevalence is around 24.6%, while in Europe, it is approximately 13% (Cashman et al., 2016; Cui et al., 2022). The stark difference highlights the impact of dietary interventions and ultraviolet (UV) exposure in mitigating deficiency.

### *4.2 Gender Disparities*

A significant gender disparity was noted, with females accounting for 79.84% of the study population and exhibiting higher deficiency rates (62.1%) compared to males (15%). Women of childbearing age demonstrated the highest deficiency levels, similar to findings in India and the Gulf region (Sofi et al., 2017; Alzaheb, 2018). This disparity may stem from cultural clothing practices, dietary inadequacies, and increased physiological demands during pregnancy and lactation, which exacerbate deficiency risks. Vitamin D insufficiency in women is associated with adverse health outcomes, including gestational diabetes, pre-eclampsia, and low birth weight in infants (Alamoudi et al., 2019; Anouti et al., 2022).

### *4.3 Age and Lifestyle Influences*

Age-related trends in vitamin D status were evident, with children showing significantly lower deficiency rates (1.44%) compared to adults. This may be attributed to better outdoor activity patterns among children. However, urbanization, sedentary lifestyles, and limited dietary sources of vitamin D, particularly in Yemen, contribute to deficiency in older populations (Alwabr & Al-Wadhaf, 2020; Sakra et al., 2021). In Gulf countries, widespread use of fortified foods and supplements has improved serum vitamin D levels to over 25 ng/ml, underscoring the importance of public health interventions (Neela et al., 2019).

***4.4 Implications of Vitamin D Deficiency***

Vitamin D levels below 20 ng/ml are classified as deficient and are linked to weakened bones, muscle pain, and increased fracture risks (Norman, 2008). Levels between 30 and 40 ng/ml are sufficient for bone health but may not optimize immune function, while levels of 40–60 ng/ml are considered ideal for comprehensive health benefits (Holick, 2007). This study's mean serum vitamin D level of 25 ng/ml indicates a substantial portion of the population remains at risk of both skeletal and nonskeletal health issues, such as impaired immunity and chronic diseases (Cui et al., 2023).

***4.5 Public Health Recommendations***

Addressing vitamin D deficiency in Yemen requires a multifaceted approach. Interventions such as food fortification, awareness campaigns promoting safe sun exposure, and supplementation programs could significantly mitigate deficiency rates. Lessons can be drawn from successful models in countries like the U.S. and Europe, where public health policies emphasize fortified foods and routine vitamin D screening (Cashman et al., 2016; Cui et al., 2023). Additionally, gender-specific strategies should target women of reproductive age, considering their heightened vulnerability. Healthcare providers must integrate vitamin D status evaluations into routine health checkups, particularly for pregnant women, to prevent associated complications (Alamoudi et al., 2019; Anouti et al., 2022).

***4.6 Vitamin D Forms and Toxicity***

Vitamin D exists in several forms, each with unique sources and roles. Common forms include vitamin D2 (ergocalciferol) from plants and fungi, and D3 (cholecalciferol), synthesized in human skin via UV exposure (Milne & Delander, 2007). Toxicity, though rare, can occur at levels exceeding 100 ng/ml, leading to hypercalcemia and associated complications such as kidney stones (Holick, 2007).

This retrospective study of 5,407 participants from Ibb City, Yemen, revealed a strikingly high prevalence of vitamin D deficiency, with 77.1% (n=4,154) of the population affected. Females demonstrated a significantly higher deficiency rate (62.1%, n=3,355) compared to males (15.0%, n=811), with the adult age group (19–50 years) exhibiting the highest deficiency among females (45.24%, n=2,446). Age and gender emerged as key predictors of deficiency, highlighting older age and female gender as major risk factors.

***4.7 Study Strengths and Limitations***

This study is among the largest in Yemen to investigate vitamin D deficiency, providing robust data on prevalence and contributing factors. However, its retrospective design and reliance on medical records limit the ability to establish causation. Future research should employ prospective methodologies to explore the long-term health impacts of vitamin D deficiency in Yemen.

This study has several strengths, including the large sample size and data collected across multiple seasons, which strengthens the generalizability of the findings within Ibb City, Yemen. However, there are a few limitations that should be considered. First, while the sample was drawn from a single healthcare facility, the diversity of the population in terms of age and gender, as well as the testing conducted over multiple years, helps enhance the external validity of the results. Nevertheless, the results may not fully represent populations outside of Ibb City or regions with differing healthcare access. Furthermore, this was a retrospective analysis based on clinical records, which limits the ability to control certain confounding variables. The lack of long-term data on vitamin D status and the absence of seasonal variation analysis limit the ability to determine the impact of seasonal fluctuations on vitamin D deficiency. Lastly, a randomized controlled trial (RCT) design would be necessary to more conclusively assess the causal relationship between vitamin D deficiency and its associated health outcomes in this population.

## 5. Conclusion

The findings emphasize the urgent need for targeted public health strategies in Yemen. Priority actions include the promotion of dietary improvements, implementation of vitamin D supplementation programs, and awareness campaigns on safe sun exposure practices, especially for high-risk groups such as women of childbearing age and the elderly.

Given the broader implications of vitamin D deficiency for skeletal and nonskeletal health, national-level interventions should adopt a multifaceted approach to address both immediate and long-term health challenges. This holistic effort is vital not only for improving individual and community health outcomes but also for alleviating the economic burden associated with deficiency-related diseases. Future research should prioritize evaluating the impact of these interventions and exploring sustainable solutions tailored to the region's unique cultural and environmental context.

## Author contributions

All authors contributed to this work. M.A.M.Y.A.-H. led conceptualization and supervision. H.A.-G. managed data analysis, and N.A.W. prepared the draft. M.A.M.A., A.Y.A.-M., and M.F.B. supported investigation and editing. A.M.A.-M. oversaw funding, while Q.M.A.-H. and M.E.A. handled technical and analytical tasks.

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**Competing financial interests**

The authors have no conflict of interest.

## References

Abdelmonem, M., Elhusseny, A., Wasim, H., Shedid, M., & Boraik, S. (2021). Vitamin D deficiency crisis in Egypt. American Journal of Clinical Pathology, 156, 36. https://doi.org/10.1093/ajcp/aqab191.071

Alamoudi, H. L., Almuteeri, Z. R., & Al-Otaibi, E. M. (2019). Awareness of vitamin D deficiency among the general population in Jeddah, Saudi Arabia. Journal of Nutrition and Metabolism, 2019, 4138187. https://doi.org/10.1155/2019/4138187

Alwabr, M. G. A., & Al-Wadhaf, A. Y. A. (2020). Risk factors and prevalence of vitamin D deficiency among Yemeni women attending Al-Zahrawi Medical Center in Sana'a City. Journal of Micro Medicine, 8(1). https://doi.org/10.5281/zenodo.3744221

Alzaheb, R. A. (2018). The prevalence of hypovitaminosis D and its associated risk factors among women of reproductive age in Saudi Arabia: A systematic review and meta-analysis. Saudi Journal of Health Sciences, 7(2), 105–114. https://doi.org/10.1177/1179562X18767884

Anouti, F. A., Ahmed, L. A., & Riaz, A. (2022). Vitamin D deficiency and its associated factors among female migrants in the United Arab Emirates. Nutrients, 14(5), 1074. https://doi.org/10.3390/nu14051074

Bassil, D., Rahme, M., Hoteit, M., & Fuleihan, G. H. (2013). Hypovitaminosis D in the Middle East and North Africa: Prevalence, risk factors, and impact on outcomes. Dermatoendocrinology, 5(2), 274–298. https://doi.org/10.4161/derm.25111

Basu, S., Gupta, R., Mitra, M., & Ghosh, A. (2015). Prevalence of vitamin D deficiency in a pediatric hospital of eastern India. Indian Journal of Clinical Biochemistry, 30(2), 167–173. https://doi.org/10.1007/s12291-014-0428-2

Bellavia, D., Costa, V., De Luca, A., Maglio, M., Pagani, S., Fini, M., & Giavaresi, G. (2016). Vitamin D level between calcium-phosphorus homeostasis and the immune system: New perspectives in osteoporosis. Current Osteoporosis Reports, 14(5), 371–380. https://doi.org/10.1007/s11914-016-0331-2

Botros, R. M., Sabry, I. M., & Abdelbaky, R. S. (2015). Vitamin D deficiency among healthy Egyptian females. Endocrinology and Nutrition, 62(6), 314–321. https://doi.org/10.1016/j.endonu.2015.03.010

Cashman, K. D., Dowling, K. G., Škrabáková, Z., et al. (2016). Vitamin D deficiency in Europe: Pandemic? American Journal of Clinical Nutrition, 103, 1033–1044. https://doi.org/10.3945/ajcn.115.120873

Cui, A., Xiao, P., Ma, Y., Fan, Z., Zhou, F., Zheng, J., & Zhang, L. (2022). Prevalence, trend, and predictor analyses of vitamin D deficiency in the US population, 2001–2018. Frontiers in Nutrition, 9, 965376. https://doi.org/10.3389/fnut.2022.965376

Cui, A., Zhang, T., Xiao, P., Fan, Z., Wang, H., & Zhuang, Y. (2023). Global and regional prevalence of vitamin D deficiency in population-based studies from 2000 to 2022: A pooled analysis of 7.9 million participants. Frontiers in Nutrition, 10, 1070808. https://doi.org/10.3389/fnut.2023.1070808

Darling, A. L. (2020). Vitamin D deficiency in Western dwelling South Asian populations: An unrecognized epidemic. Proceedings of the Nutrition Society, 2020, 1–13. https://doi.org/10.1017/S0029665120000063

Holick, M. F. (2007). Vitamin D deficiency. New England Journal of Medicine, 357, 266–281. https://doi.org/10.1056/NEJMra070553

Lagoeiro, A. J., Cordeiro, J. R., Rosa, M. L., & Bianchi, D. B. C. (2018). Vitamin D deficiency and cardiovascular diseases. International Journal of Cardiovascular Sciences, 31(5), 490–495. https://doi.org/10.5935/2359-4802.20180025

Lips, P., & de Jongh, R. T. (2018). Vitamin D deficiency in immigrants. Bone Reports, 8, 37–41. https://doi.org/10.1016/j.bonr.2018.06.001

Manios, Y., Moschonis, G., & Lambrinou, C. P. (2018). A systematic review of vitamin D status in Southern European countries. European Journal of Nutrition, 57, 2001–2036. https://doi.org/10.1007/s00394-017-1564-2

Milne, G. W. A., & Delander, M. (2007). Vitamin D handbook: Structures, synonyms, and properties. John Wiley & Sons. https://doi.org/10.1002/9780470238165

Neela, S., Buthainah, A. B., Lyutha, A. S., Samir, A. A., Mohamed, E. M., & Qoronfleh, M. W. (2019). Vitamin D public health status in the Gulf region. International Journal of Nutrition, Pharmacology, Neurological Diseases, 9, 117–135. https://doi.org/10.4103/ijnpnd.ijnpnd_68_19

Norman, A. W. (2008). From vitamin D to hormone D: Fundamentals of the vitamin D endocrine system essential for good health. American Journal of Clinical Nutrition, 88(1), 491S-9S. https://doi.org/10.1093/ajcn/88.2.491S

Saffian, S. M., Jamil, N. A., Tahir, N. A. M., & Hatah, E. (2022). Vitamin D insufficiency is high in Malaysia: A systematic review and meta-analysis of studies on vitamin D status in Malaysia. Frontiers in Nutrition, 9. https://doi.org/10.3389/fnut.2022.1050745

Sakra, B. R., Al-Ashmory, N. M., Hassan, S. Z., Al-Akwa, A. A., & Shaker, O. G. (2021). Vitamin D deficiency in Egyptian and Yemeni primary knee osteoarthritis patients: Relation to physical function and radiographic severity. Egyptian Rheumatology, 43, 47–52. https://doi.org/10.1016/j.ejr.2020.06.005

Sizar, O., Khare, S., & Goyal, A. (2024). Vitamin D deficiency. In StatPearls. Treasure Island, FL: StatPearls Publishing.

Sofi, N. Y., Jain, M., Kapil, U., Seenu, V., Ramakrishnan, L., & Yadav, C. P. (2017). Status of serum vitamin D and calcium levels in women of reproductive age in the National Capital Territory of India. Indian Journal of Endocrinology and Metabolism, 21, 731–733. https://doi.org/10.4103/ijem.IJEM_134_17

Suryanarayana, P., Arlappa, N., Sai Santhosh, V., Balakrishna, N., Lakshmi Rajkumar, P., & Prasad, U. (2018). Prevalence of vitamin D deficiency and its associated factors among the urban elderly population in Hyderabad metropolitan city, South India. Annals of Human Biology, 45(2), 133–139. https://doi.org/10.1080/03014460.2017.1412239

Zhang, R., Zhang, Y., Liu, Z., Pei, Y., Xu, P., Chong, W., ... Peng, X. (2022). Association. Chemical Science, 14(15), 3717. https://doi.org/10.1039/C7SC02967E