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| RESEARCH ARTICLE

Vitamin D Status in North Batinah, Oman: Prevalence and Temporal Trends (2018-2022)

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| ABSTRACT
Background: Vitamin D plays a critical role in skeletal health and has important functions in immune regulation and chronic disease prevention. Despite abundant sunlight in the Middle East, vitamin D deficiency and insufficiency remain widely reported, with limited population-based data available from Oman. This study aimed to evaluate the prevalence and temporal trends of vitamin D status in North Batinah, Oman, and to identify demographic groups at increased risk of insufficiency and deficiency. Methods: A retrospective cross-sectional study was conducted using laboratory and clinical data from Suhar Hospital, the central referral laboratory in North Batinah. The study included 3,081 individuals of all ages who underwent serum 25-hydroxyvitamin D testing between January 2018 and November 2022. Vitamin D status was classified as deficient (<30 nmol/L), insufficient (30–50 nmol/L), or sufficient (>50 nmol/L). Demographic variables and vitamin D levels were analyzed, and temporal trends were assessed over the five-year period. Results: The overall mean vitamin D level was 82.5 ± 28.0 nmol/L. Vitamin D sufficiency was observed in 88.2% of adults and 89.0% of the pediatric population, while deficiency was rare (<1%). Insufficiency was more prevalent among females, particularly those aged 18–38 years (14.9%), and among adolescents aged 10–15 years (15.7%). Males had significantly higher vitamin D levels than females ($p < 0.001$). Temporal analysis demonstrated a significant decline in sufficiency from 93.1% in 2018 to 79.9% in 2021, followed by recovery to 91.0% in 2022 ($p < 0.001$), corresponding with reduced outdoor activity during the coronavirus pandemic period. Conclusion: Vitamin D sufficiency was high in this population, contrasting with commonly reported regional trends. However, insufficiency remains a clinically relevant concern, particularly among women and adolescents. These findings support a shift toward targeted, risk-based screening and highlight the importance of sustained public health strategies to maintain optimal vitamin D status.

| KEYWORDS
Vitamin D status, 25-hydroxyvitamin D, Temporal trends, Oman, Vitamin D insufficiency

| ARTICLE INFORMATION

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1.Introduction and Literature Review

Vitamin D in Human Health

Vitamin D, a lipid-soluble secosteroid hormone, is crucial for calcium and phosphorus homeostasis and plays a fundamental role in preserving skeletal health (Liu et al., 2025; Mendes et al., 2022). Beyond its established role in musculoskeletal health, vitamin D is recognized for its involvement in diverse physiological processes, encompassing immune modulation, insulin secretion, cardiovascular regulation, and neurocognitive function (Liu et al., 2025). Vitamin D deficiency is correlated with a heightened susceptibility to skeletal pathologies such as osteoporosis, rickets, and an elevated incidence of fractures (Charoenngam et al., 2019). Furthermore, it has been associated with the pathogenesis of various chronic conditions, including diabetes mellitus, hypertension, autoimmune disorders (Jeong & Vacanti, 2020), and an increased risk of all-cause mortality (Rebelos et al., 2023). Vitamin D, unlike most micronutrients, is predominantly synthesized endogenously through cutaneous exposure to ultraviolet B radiation (Domínguez et al., 2021; Fraser, 2022). Dietary contributions from natural sources typically provide only a modest fraction of the total vitamin D reserves, particularly in regions with limited supplementation and fortification initiatives (Jaruratanasirikul et al., 2023). As a result, geospatial, socio-cultural, and behavioral factors that dictate sun exposure are pivotal in influencing population-level vitamin D status (Khanna et al., 2022; Oliver et al., 2022).

Global Epidemiology of Vitamin D Deficiency

Vitamin D insufficiency and deficiency are widely acknowledged as a significant global public health concern, impacting more than one billion individuals across the globe (Cashman, 2021; Cui et al., 2023). Counterintuitively, some of the highest rates of hypovitaminosis D are reported in geographic areas with abundant sunlight, particularly in the Middle East(Cui et al., 2023; Patseadou & Haller, 2019). Within Europe, the prevalence of vitamin D deficiency exhibits variability, influenced by latitude and seasonal changes (Cashman, 2021; Cui et al., 2023). In Asian populations, especially across South and Southeast Asia, a high prevalence of vitamin D deficiency is observed, with reports indicating that up to 61–71% of adolescents and adults experience suboptimal vitamin D status (Patseadou & Haller, 2019; Siddiqee et al., 2022). Conversely, North America generally demonstrates a comparatively lower prevalence of vitamin D deficiency, largely attributable to extensive supplementation and food fortification strategies. Nevertheless, specific demographic cohorts, including older adults, individuals with darker skin tones, and institutionalised populations, continue to face an elevated risk of deficiency (Cashman, 2021; Lips et al., 2021).

Vitamin D Deficiency in the GCC Region

The Gulf Cooperation Council nations—comprising Oman, Saudi Arabia, the United Arab Emirates, Kuwait, Qatar, and Bahrain—are characterized by abundant year-round solar radiation(Singh et al., 2019). Despite this environmental advantage, a paradoxical high prevalence of vitamin D deficiency and insufficiency is observed across the region ("A Cross-Cultural Systematic Review of Vitamin D Deficiency in Women," 2022; Alshamsi et al., 2025; Grant et al., 2019). Singh et al. reviewed evidence across the GCC and reported deficiency rates ranging from 30% to over 80%, depending on age group and setting (Singh et al., 2019).

Vitamin D Deficiency in Oman

Comprehensive national surveillance data on vitamin D status in Oman remain limited. Several small-scale studies have highlighted a high prevalence of vitamin D insufficiency among women and children in Oman and the wider Middle East and North Africa region (Al-Kindi, 2011; Chakhtoura et al., 2018; Hussein et al., 2022). However, robust, population-level evaluations assessing biochemical vitamin D status across broader demographics are lacking.

To address this gap, the present study was designed as a five-year, retrospective, population-based analysis of vitamin D status in North Batinah. The primary objectives were to determine the prevalence of vitamin D deficiency and insufficiency among Omani and non-Omani residents, evaluate temporal trends from 2018 to 2022, and identify demographic groups at increased risk. By generating comprehensive, real-world data, this study aims to inform clinical practice, support evidence-based public health strategies, and contribute to the development of national guidelines for vitamin D management in Oman.

2. Methodology

Study Design, Setting, and Data Collection

This retrospective cross-sectional study used existing clinical and laboratory data from the North Batinah governorate in the Sultanate of Oman, a densely populated region with over 900,000 residents. The study was conducted at Suhar Hospital, the central referral institution and the sole laboratory providing vitamin D testing in the region. This centralized testing system ensured standardized laboratory procedures, minimized inter-laboratory variability, and enabled the generation of a robust and consistent dataset. The study period extended from January 2018 to November 2022, allowing for a comprehensive five-year assessment of vitamin D status across the population. The study population included all Omani and non-Omani residents of any age or gender who underwent serum vitamin D testing during the study period. Duplicate records and cases with incomplete demographic or biochemical data were excluded, resulting in a final sample of 3,081 individuals. Data were extracted from the Alshifa electronic medical records system and included demographic characteristics and serum vitamin D levels.

Laboratory Analysis and Vitamin D Definitions

Serum 25-hydroxyvitamin D (25D) levels were measured at Suhar Hospital using a chemiluminescent immunoassay on the Roche cobas e analyzer, consistent with standard practice across Oman. Analytical reliability was maintained through strict adherence to national calibration and quality control protocols. Vitamin D status was classified according to internationally recognized consensus definitions endorsed by the Institute of Medicine, the National Institutes of Health, and the National Centre for Statistics and Information (2022). Categories included deficiency (<30 nmol/L), insufficiency (30–50 nmol/L), and sufficiency (>50 nmol/L). These thresholds are widely used in clinical practice and research, allowing comparability with global studies and supporting local guideline implementation.

Statistical Analysis

Continuous variables, including age and serum 25-hydroxyvitamin D levels, were summarized as mean ± standard deviation (SD), while categorical variables (gender, nationality, age groups, and vitamin D status) were presented as frequencies and percentages. Comparisons between two groups were performed using the independent samples t-test, and multiple group comparisons were analyzed using one-way ANOVA. Associations between categorical variables were assessed using the Chi-square test. Temporal trends from 2018 to 2022 were evaluated using the Chi-square test for trend, with results illustrated through line graphs. A p-value <0.05 was considered statistically significant. All analyses were performed using IBM SPSS Statistics software.

Ethical Considerations

Ethical clearance for data acquisition and subsequent analysis was secured from the Regional Ethical Approval Research Committee, aligning with the mandates stipulated by the Ministry of Health, Oman. The committee undertook a rigorous review and sanctioned the study protocol prior to the start of data acquisition. Given the retrospective design of this study and its reliance on de-identified patient data, the requirement for individual informed consent was waived. The confidentiality and anonymity of all collected data were rigorously preserved, and access was exclusively restricted to authorized personnel.

3. Results

General Characteristics of the Study Population

The study included 3,081 participants, predominantly Omani (96%) and female (81.5%). Adults constituted the majority, particularly females aged ≥18 years. The overall mean serum vitamin D level was 82.5 ± 28.0 nmol/L. Males demonstrated significantly higher vitamin D levels compared to females (88.9 ± 30.8 vs 81.0 ± 27.2 nmol/L; $p < 0.001$). No significant difference was observed between Omani and non-Omani participants ($p = 0.28$). Vitamin D levels were comparable across age subgroups within each gender, with slightly higher levels observed in younger males. Overall, gender emerged as the primary determinant of variation in vitamin D levels in this cohort (Table 1).

Table 1. Demographic Characteristics of the Study Population (N = 3081)

Characteristic	N (% of total)	Mean ± SD (nmol/L)	p-value
Total population	3081 (100)	82.5 ± 28.0	—
Nationality			0.28
Omani	2959 (96.0)	82.5 ± 27.96	
Non-Omani	122 (4.0)	80.8 ± 29.63	
Gender			<0.001
Male	570 (18.5)	88.9 ± 30.78	
Female	2511 (81.5)	81.0 ± 27.15	
Age Group (by Gender)			0.37
≥18 yrs (Male)	461 (15.0)	88.5 ± 30.67	
<18 yrs (Male)	109 (3.5)	90.7 ± 31.28	
≥18 yrs (Female)	2365 (76.8)	80.9 ± 26.65	
<18 yrs (Female)	146 (4.7)	81.7 ± 34.32	

Vitamin D Status in Adults

Among 2,826 adults, vitamin D sufficiency was high overall (88.2%), while insufficiency (11.3%) was more common than deficiency (0.5%). Females constituted the majority of the cohort, particularly those aged 18–58 years. The highest prevalence of insufficiency was observed in females aged 18–38 years (14.9%), followed by those aged 38–58 years (11.0%). In contrast, males demonstrated lower insufficiency rates and a progressive increase in sufficiency with age, peaking at 97.4% in the 58–78-year group. Vitamin D deficiency was rare across all subgroups, indicating that insufficiency, especially among younger females, represents the primary concern in adults (Table 2).

Table 2. Distribution of Vitamin D Status in Adults by Age and Gender (N = 2826)

Gender	Age group	Total n (%)	Normal n (%)	Insufficient n (%)	Deficient n (%)
Male	18–38	173 (6.12%)	155 (89.60%)	16 (9.25%)	2 (1.16%)

Male	38–58	194 (6.87%)	175 (90.16%)	16 (8.29%)	3 (1.55%)
Male	58–78	78 (2.76%)	76 (97.44%)	2 (2.56%)	0 (0.00%)
Male	>78	16 (0.57%)	15 (93.75%)	1 (6.25%)	0 (0.00%)
Female	18–38	989 (35.00%)	838 (84.75%)	147 (14.85%)	4 (0.40%)
Female	38–58	1018 (36.03%)	901 (88.51%)	112 (11.01%)	5 (0.49%)
Female	58–78	322 (11.39%)	299 (92.86%)	22 (6.84%)	1 (0.31%)
Female	>78	36 (1.27%)	34 (94.44%)	2 (5.56%)	0 (0.00%)
Total	—	**2826 (100%)**	**2493 (88.22%)**	**318 (11.25%)**	**15 (0.53%)**

Vitamin D Status in the Pediatric Population

Among 255 pediatric participants, vitamin D sufficiency was high overall (89.0%), while insufficiency accounted for 10.2% and deficiency remained rare (0.8%). Younger children (<10 years) demonstrated the highest sufficiency rates, consistently exceeding 93%. In contrast, adolescents showed a relative decline in vitamin D status, with the highest insufficiency observed in the 10–15 year age group (15.7%), followed by those aged 15–18 years (13.5%). Vitamin D deficiency was minimal across all age groups. These findings indicate that, while overall vitamin D status is adequate in children, adolescence represents a vulnerable period for insufficiency and may warrant targeted preventive strategies (Table 3)

Table 3. Distribution of Vitamin D Status in Pediatric Population by Age Group (N = 255)

Age group (years)	Total n (%)	Normal n (%)	Insufficient n (%)	Deficient n (%)
0–2	16 (6.27%)	15 (93.75%)	1 (6.25%)	0 (0.00%)
2–6	72 (28.24%)	67 (93.06%)	4 (5.56%)	1 (1.39%)
6–10	41 (16.08%)	39 (95.12%)	2 (4.88%)	0 (0.00%)
10–15	89 (34.90%)	74 (83.15%)	14 (15.73%)	1 (1.12%)
15–18	37 (14.51%)	32 (86.49%)	5 (13.51%)	0 (0.00%)
Total	**255 (100%)**	**227 (89.02%)**	**26 (10.20%)**	**2 (0.78%)**

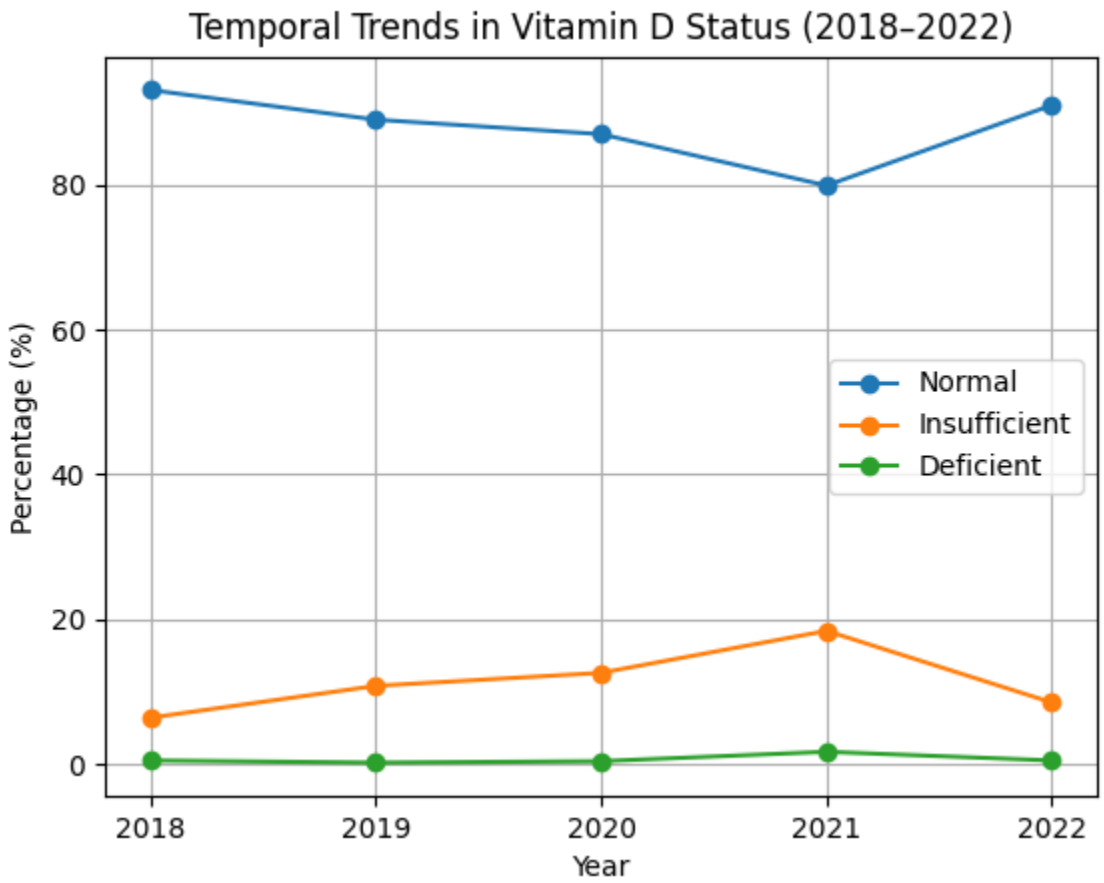
Temporal Trends in Vitamin D Levels (2018–2022)

Temporal analysis of 3,081 participants demonstrated significant variation in vitamin D status across 2018–2022 ($p < 0.001$). Vitamin D sufficiency declined from 93.1% in 2018 to a nadir of 79.9% in 2021, followed by recovery to 91.0% in 2022. Conversely, insufficiency increased from 6.4% in 2018 to a peak of 18.4% in 2021 before declining to 8.5% in 2022. Vitamin D deficiency remained consistently low, with a slight increase in 2021 (1.7%; $p = 0.02$) . These trends, illustrated in Figure 1, highlight a transient deterioration in vitamin D status during 2021 with subsequent recovery.

Table 4. Temporal Distribution of Vitamin D Status (2018–2022)

Year	Total n (%)	Normal n (%)	Insufficient n (%)	Deficient n (%)
2018	378 (12.26%)	352 (93.12%)	24 (6.35%)	2 (0.53%)
2019	635 (20.62%)	565 (88.98%)	69 (10.87%)	1 (0.16%)
2020	980 (31.81%)	853 (87.04%)	123 (12.55%)	4 (0.41%)
2021	358 (11.62%)	286 (79.89%)	66 (18.44%)	6 (1.68%)
2022	730 (23.69%)	664 (90.96%)	62 (8.49%)	4 (0.55%)
Total	**3081 (100%)**	**2720 (88.27%)**	**344 (11.17%)**	**17 (0.55%)**
p-value	—	**<0.001**	**<0.001**	**0.02**

Figure 1. Temporal trends in vitamin D levels observed from 2018 to 2022.



4. Discussion

High Prevalence of Sufficiency

These findings provide important insights into population-level vitamin D status in North Batinah, Oman. The most striking finding of this study is the high prevalence of vitamin D sufficiency, which contrasts with the widely recognized global burden of vitamin D deficiency, often described as a pandemic affecting more than one billion individuals worldwide (Alqahtani et al., 2022; Cui et al., 2023). In contrast to this global and regional burden, the present study demonstrated a notably high prevalence of vitamin D sufficiency, diverging from findings reported across several Gulf Cooperation Council (GCC) countries, where deficiency and insufficiency rates are typically significantly higher (Hussein et al., 2022). This discrepancy may be partly explained by methodological differences, particularly in study population selection (Brenner, 2023; Giustina et al., 2020). Many studies from the GCC region have focused on hospital-based or high-risk populations, including inpatients and individuals with chronic illnesses, who are inherently more prone to vitamin D deficiency (Bucurică et al., 2023; Chen et al., 2021; Düğeroğlu & Kaya, 2022). In contrast, this study was conducted within a large primary care cohort undergoing routine health assessments and supported by a centralized laboratory system. This approach likely captured a more representative and relatively healthier population, thereby explaining the higher observed rates of vitamin D sufficiency.

Gender and Age Disparities

Consistent with previous findings, males exhibited higher mean vitamin D concentrations compared to females. This disparity may be attributed to several factors, including greater sunlight exposure among men due to occupational and lifestyle differences (Joukar et al., 2022; Mendes et al., 2024; Veselka et al., 2017), while cultural clothing practices often limit sun exposure in women (Joukar et al., 2022; Sabico et al., 2025). Additionally, women of reproductive age have increased physiological demands for vitamin D, particularly during pregnancy and lactation, which may further contribute to insufficiency (Durá-Travé & Gallinas-Victoriano, 2023; Saraf et al., 2015). Supporting this, studies have reported that 67.1% of Emirati men and 73.5% of Emirati women had serum 25D levels <50 nmol/L, with female gender significantly associated with a higher risk of deficiency (Buckley et al., 2019) ("Prevalence, Predictors, and Gender-Based Risk Factors of Vitamin D Deficiency: A Retrospective Cross-Sectional Study," 2024).

Age-related patterns were also evident, particularly within the pediatric population, where adolescents demonstrated the highest rates of vitamin D insufficiency, a trend consistently observed worldwide (Al-Daghri et al., 2015; Lenz et al., 2023). This increased vulnerability during adolescence is likely multifactorial. It represents a critical developmental phase characterized by rapid skeletal growth and hormonal changes, leading to increased physiological requirements for vitamin D (Patseadou & Haller, 2019). Moreover, modern lifestyle factors, such as reduced outdoor activity and increased screen time, further limit sun exposure and contribute to insufficiency (Cavarzere et al., 2023). These findings highlight adolescence as a key target group for preventive interventions to improve vitamin D status.

Impact of COVID-19

A notable observation in this study was the temporary decline in vitamin D sufficiency during 2021, with levels decreasing to 79.9%. This period coincided with the peak of the COVID-19 pandemic in Oman, characterized by lockdowns, restricted mobility, school closures, and heightened public concern, all of which likely reduced outdoor exposure. Similar declines in vitamin D levels have been reported globally, with studies from Europe, Asia, and the Middle East demonstrating comparable trends during pandemic-related restrictions (Arayıcı et al., 2023; Benameur et al., 2023; Cavarzere et al., 2023; Chen & Kong, 2024). By 2022, vitamin D sufficiency rebounded, suggesting that the decline was primarily driven by environmental and behavioral changes rather than intrinsic biological factors. This highlights the sensitivity of vitamin D status to external disruptions and underscores the importance of maintaining preventive strategies, including supplementation and safe sun exposure, during public health crises (Harvey et al., 2024; Tanna et al., 2023). The post-pandemic recovery further supports the strong relationship between outdoor activity, sunlight exposure, and vitamin D synthesis, emphasizing the value of promoting safe outdoor engagement (Khudadad et al., 2024). Additionally, evidence from other studies indicates persistently lower vitamin D levels in early 2022 compared to 2023, suggesting a lingering impact of the pandemic on population vitamin D status (Chen & Kong, 2024).

Clinical and Public Health Implications

This study provides important insights for both clinical practice and public health policy. Its major strengths include a large sample size, inclusion of both adult and pediatric populations, and the use of a centralized laboratory system, which ensured methodological consistency and minimized inter-laboratory variability. The five-year study period further enabled robust assessment of temporal trends, including the impact of the COVID-19 pandemic. However, certain limitations should be acknowledged. The retrospective cross-sectional design relied on laboratory testing requests, which may introduce selection bias, although it reflects real-world clinical practice and has been supported by similar large-scale analyses (Benameur et al., 2023). Additionally, the lack of data on key confounders such as sun exposure, dietary intake, body mass index, and supplementation limits the ability to fully adjust for potential factors (Grant et al., 2022).

From a clinical and public health perspective, the findings highlight that despite overall high vitamin D sufficiency, specific subgroups—particularly women of childbearing age, younger adults, and adolescents—remain at increased risk of insufficiency (Abiaka et al., 2013; Al-Kindi, 2011; Hussein et al., 2022). These groups should be prioritized for targeted interventions, including awareness campaigns promoting safe sun exposure, dietary fortification, and supplementation strategies (Harvey et al., 2024; "Prevalence, Predictors, and Gender-Based Risk Factors of Vitamin D Deficiency: A Retrospective Cross-Sectional Study," 2024). The observed decline in vitamin D status during the COVID-19 pandemic further emphasizes the need for resilient healthcare systems capable of maintaining preventive services during periods of disruption (Arayıcı et al., 2022; Li et al., 2020). Ensuring continuity of supplementation programs and public health initiatives during such crises is essential (Arayıcı et al., 2023; Buttriss et al., 2021). Furthermore, the use of centralized laboratory data for systematic regional monitoring represents a cost-effective approach for real-time surveillance of population health trends(Arayıcı et al., 2022).

Overall, while vitamin D sufficiency was high, the disproportionate burden of insufficiency among adolescents and young women, together with the observed temporal fluctuations, underscores the importance of targeted, sustainable public health strategies to maintain optimal vitamin D status across the population.

4. Conclusion

This five-year population-based analysis demonstrates a high prevalence of vitamin D sufficiency in North Batinah, Oman, contrasting with commonly reported regional and global trends. Vitamin D deficiency was rare, while insufficiency emerged as the more clinically relevant concern. Significant gender and age disparities were identified, with women—particularly those of reproductive age—and adolescents exhibiting higher rates of insufficiency. The observed temporal decline in vitamin D status during 2021, followed by recovery in 2022, highlights the strong influence of environmental and behavioral factors, particularly during periods of public health disruption such as the COVID-19 pandemic.

From a clinical perspective, these findings support a shift from universal screening toward targeted, risk-based testing and management strategies, focusing on vulnerable groups. At the policy level, there is a need to optimize test utilization, strengthen public health initiatives promoting safe sun exposure and supplementation, and ensure continuity of preventive services during crises. Future research should focus on integrating laboratory data into national surveillance systems, evaluating the role of supplementation and fortification programs, and incorporating clinical risk factors to refine screening strategies.

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