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Original Research Article

Assessment of Serum Vitamin D Levels in the Indian Population: A Clinical and Epidemiological Study

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Abstract

Background: Vitamin D plays a crucial role in calcium homeostasis, bone metabolism, and immune function. Despite India's abundant sunlight, several studies have highlighted a surprisingly high prevalence of vitamin D deficiency among different age groups and regions. Factors such as urbanization, increased indoor lifestyles, dietary habits, skin pigmentation, and cultural clothing practices contribute to this widespread deficiency.

Aims: This study aimed to assess serum vitamin D levels in a representative sample of the Indian population and analyze their association with demographic and clinical variables.

Methods: This cross-sectional clinical and epidemiological study was conducted over a period of six months in the Department of Biochemistry at BGS Medical College and Hospital, Bangalore. A total of 150 participants were enrolled to assess serum vitamin D levels across diverse demographic and lifestyle factors, providing a snapshot of vitamin D status within this population.

Results: The study assessed serum vitamin D levels across various demographic and lifestyle factors. Mean vitamin D levels increased with age, while deficiency (<30 ng/mL) was highest among participants aged 18–30 years (80%) and lowest in those over 50 years (48%; p=0.001). Males showed higher mean vitamin D levels (28.9 ± 10.1 ng/mL) and lower deficiency rates (53.8%) compared to females (25.3 ± 9.2 ng/mL; 74.3% deficiency; p=0.038). Rural residents had significantly higher mean levels (30.9 ± 10.5 ng/mL) and lower deficiency prevalence (43.3%) than urban residents (24.8 ± 9.0 ng/mL; 76.7% deficiency; p=0.0002). Seasonal variation was marked, with the highest mean levels and lowest deficiency in summer (31.2 ± 9.7 ng/mL; 35% deficiency) and the lowest levels and highest deficiency in winter (24.5 ± 8.8 ng/mL; 78.2% deficiency; p < 0.0001).

Conclusion: The study revealed a high prevalence of vitamin D deficiency in the Indian population, influenced by multiple demographic and lifestyle factors. Younger age, female gender, urban residence, winter season, and higher BMI were significantly associated with lower mean serum vitamin D levels and greater deficiency rates. These findings highlight the need for targeted public health interventions and awareness to improve vitamin D status, especially among vulnerable groups.

Keywords: Vitamin D, Deficiency, India, Prevalence, Serum 25(OH)D, Epidemiology.

Introduction

Vitamin D, a secosteroid hormone traditionally known for its pivotal role in calcium-phosphorus metabolism and bone mineralization, has garnered extensive attention over the past two decades for its pleiotropic effects on immunity, cardiovascular health, diabetes, cancer prevention, and even mood regulation.

The major circulating form, 25-hydroxyvitamin D [25(OH)D], is considered the best indicator of vitamin D status in humans due to its longer half-life and reflection of both cutaneous synthesis and dietary intake [1]. Globally, vitamin D insufficiency and deficiency have emerged as significant public health concerns, affecting over one billion people across all age groups [2]. Despite India being a tropical country with abundant sunshine, a paradoxical high prevalence of vitamin D deficiency is reported consistently in diverse Indian cohorts [3].

In the Indian context, the prevalence of hypovitaminosis D ranges broadly from 50% to over 90%, depending on population subgroup, geography, seasonality, age, gender, and lifestyle [4]. This paradox is attributed to multiple interplaying factors. First, the melanin-rich skin typical of the Indian population inherently reduces the cutaneous production of vitamin D by absorbing ultraviolet B (UVB) radiation, which is critical for the photochemical conversion of 7-dehydrocholesterol to pre-vitamin D3 [5]. Second, urbanization, indoor-centric occupations, traditional clothing, and cultural practices limit direct sun exposure [6]. Third, dietary habits in India are predominantly vegetarian with low natural dietary sources of vitamin D, such as fatty fish and fortified dairy products, further compounding the risk [7].

Clinically, the deficiency of vitamin D has been implicated not only in rickets and osteomalacia but also in osteoporosis, increased fracture risk, and various extraskeletal disorders including insulin resistance, metabolic syndrome, autoimmune conditions, cardiovascular disease, and certain malignancies [8]. Recent studies have highlighted associations between low serum 25(OH)D levels and higher prevalence of type 2 diabetes mellitus, hypertension, and dyslipidemia in Indian adults [9].

Furthermore, hypovitaminosis D during pregnancy has been linked to adverse maternal and neonatal outcomes, including gestational diabetes, preeclampsia, low birth weight, and impaired skeletal development of the fetus [10]. The assessment of serum vitamin D status in the Indian population becomes particularly pertinent due to the sheer diversity in geography and lifestyle. India spans latitudes from approximately 8°N to 37°N, encompassing varied UVB exposure potential.

Northern regions experience pronounced seasonal variations and colder climates, leading to reduced UVB exposure during winter months, whereas southern regions are relatively UVB-rich throughout the year [11]. Additionally, rapid urbanization and industrialization in Indian metropolitan cities have altered traditional lifestyles, with limited outdoor activities and increased pollution, which further attenuates UVB penetration [12].

Recent multicentric and community-based studies in India reveal strikingly similar patterns of deficiency across age groups, from children and adolescents to pregnant women, adults, and the elderly [13]. Notably, even among healthcare professionals and medical students, who presumably have better awareness, vitamin D deficiency prevalence remains alarmingly high [14]. These observations underline the fact that awareness alone may be insufficient to overcome environmental, cultural, and dietary barriers inherent to the Indian context. Despite mounting evidence, large-scale population-based data on serum vitamin D levels in India remain limited. Most studies are cross-sectional, region-specific, and heterogeneous in methodology, making it difficult to draw robust nationwide prevalence estimates or compare subgroups effectively. Additionally, variations in assay methods and differing cut-off values used to define deficiency and insufficiency further complicate interpretation [15].

The primary aim of this study is to evaluate and analyze the serum vitamin D levels across diverse demographic groups within the Indian population. The objectives include determining the prevalence of vitamin D deficiency and insufficiency, assessing variations based on age, sex, geographic location, and socioeconomic status, and identifying potential risk factors contributing to hypovitaminosis D. This study also seeks to generate data that can inform public health strategies and guidelines for improving vitamin D status in India.

Materials and Methods

Study Design: Cross-sectional clinical and epidemiological study.

Study Duration: Conducted over a period of 6 months.

Study Setting: Department of Biochemistry, BGS Medical College and Hospital, Bangalore.

Sample Size: Total of 150 participants.

Inclusion Criteria

- Individuals aged ≥18 years.
- Both males and females.
- Individuals attending outpatient or inpatient departments who consented to participate.

Exclusion Criteria

- Individuals on vitamin D supplementation.
- Patients with chronic liver disease, chronic kidney disease, or malabsorption syndromes.
- Pregnant and lactating women.

Data Collection

- Detailed demographic data recorded: age, sex, BMI, residential area (urban/rural), and sun exposure habits.
- Relevant clinical history obtained.

Sample Collection

- 3–5 mL of venous blood collected under aseptic precautions.
- Serum separated by centrifugation and stored at –20°C until analysis.

Laboratory Analysis

Serum 25-hydroxyvitamin D [25(OH)D] levels measured using chemiluminescence immunoassay (CLIA) method.

Reference Ranges and Classification

- Vitamin D deficiency: <30 ng/mL
- Sufficient/normal: 30–100 ng/mL

Statistical Analysis: For statistical analysis, data were initially entered into a Microsoft Excel spreadsheet and then analyzed using SPSS (version 27.0; SPSS Inc., Chicago, IL, USA) and GraphPad Prism (version 5). Numerical variables were summarized using means and standard deviations, while Data were entered into Excel and analyzed using SPSS and GraphPad Prism. Numerical variables were summarized using means and standard deviations, while categorical variables were described with counts and percentages. Two-sample t-tests were used to compare independent groups, while paired t-tests accounted for correlations in paired data. Chi-square tests (including Fisher's exact test for small sample sizes) were used for categorical data comparisons. P-values ≤ 0.05 were considered statistically significant.

Result

Table 1: Comparison of Vitamin D Status Across Age, Gender, and Residence in the Study Population

Demographic Parameters		n	Mean Vit D (ng/mL) ± SD	Deficient (<30) n (%)	Normal (30–100) n (%)	p-value*
Age group (years)	18–30	40	22.6 ± 8.1	32 (80%)	8 (20%)	0.001
	31–50	60	27.4 ± 9.5	39 (65%)	21 (35%)	
	>50	50	30.2 ± 10.3	24 (48%)	26 (52%)	
Gender	Male	80	28.9 ± 10.1	43 (53.8%)	37 (46.2%)	0.038
	Female	70	25.3 ± 9.2	52 (74.3%)	18 (25.7%)	
Residence	Urban	90	24.8 ± 9.0	69 (76.7%)	21 (23.3%)	0.0002
	Rural	60	30.9 ± 10.5	26 (43.3%)	34 (56.7%)	

Table 2: Comparison of Vitamin D Status Across Seasons in the Study Population

Season	n	Mean Vit D (ng/mL) ± SD	Deficient (<30) n (%)	Normal (30–100) n (%)	p-value*
Summer	40	31.2 ± 9.7	14 (35%)	26 (65%)	<0.0001
Monsoon	55	26.1 ± 9.4	38 (69.1%)	17 (30.9%)	
Winter	55	24.5 ± 8.8	43 (78.2%)	12 (21.8%)	

Table 3: Comparison of Vitamin D Status Across BMI Categories in the Study Population

BMI category (kg/m²)	n	Mean Vit D (ng/mL) ± SD	Deficient (<30) n (%)	Normal (30–100) n (%)	p-value*
<25 (normal)	70	30.1 ± 10.4	33 (47.1%)	37 (52.9%)	0.004
≥25 (overweight/obese)	80	25.4 ± 8.9	62 (77.5%)	18 (22.5%)	

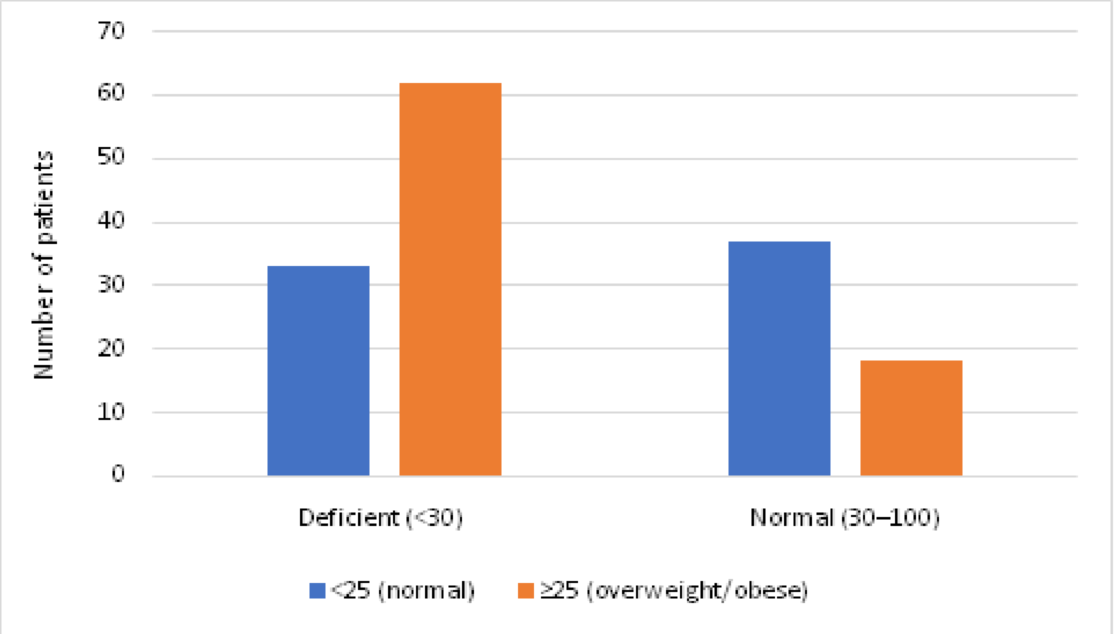

Figure 1: Comparison of Vitamin D Status Across BMI Categories in the Study Population

The study evaluated serum vitamin D levels across different demographic parameters, including age, gender, and residence. The mean vitamin D level increased with age, being lowest in the 18–30 years group (22.6 ± 8.1 ng/mL), intermediate in the 31–50 years group (27.4 ± 9.5 ng/mL), and highest in participants aged >50 years (30.2 ± 10.3 ng/mL). Vitamin D deficiency (<30 ng/mL) was most prevalent among the youngest age group (80%), compared to 65% in the 31–50 years group and 48% in those over 50 years; this difference was statistically significant (p=0.001).

Regarding gender, males had a higher mean vitamin D level (28.9 ± 10.1 ng/mL) than females (25.3 ± 9.2 ng/mL). Vitamin D deficiency was observed in 53.8% of males and 74.3% of females, with the difference being significant (p=0.038).

Analysis by residence showed significantly higher mean vitamin D levels among rural residents (30.9 ± 10.5 ng/mL) compared to urban residents (24.8 ± 9.0 ng/mL). Vitamin D deficiency was markedly more common in the urban population (76.7%) than in the rural population (43.3%), with this difference also reaching statistical significance (p=0.0002).

The mean serum vitamin D levels varied significantly across different seasons (p < 0.0001). The highest mean level was observed in summer (31.2 ± 9.7 ng/mL), followed by the monsoon (26.1 ± 9.4 ng/mL), and the lowest in winter (24.5 ± 8.8 ng/mL). Correspondingly, the prevalence of vitamin D deficiency (<30 ng/mL) was lowest during summer (35%), while it increased notably during the monsoon (69.1%) and peaked in winter (78.2%). Conversely, the proportion of participants with normal vitamin D status (30–100 ng/mL) was highest in summer (65%) and declined during the monsoon (30.9%) and winter (21.8%). Vitamin D status differed significantly by BMI category (p=0.004). Participants with a normal BMI (<25 kg/m²) had a higher mean serum vitamin D level (30.1 ± 10.4 ng/mL) compared to those who were overweight or obese (≥25 kg/m²) with a mean level of 25.4 ± 8.9 ng/mL. Vitamin D deficiency (<30 ng/mL) was observed in 47.1% of individuals with normal BMI, whereas it was significantly more common among overweight/obese participants (77.5%). Conversely, 52.9% of the normal BMI group had sufficient vitamin D levels, compared to only 22.5% in the overweight/obese group.

Discussion

In the present study, serum vitamin D levels were found to be significantly associated with age, gender, residence, season, and BMI. The mean vitamin D concentration increased progressively with age, being lowest among participants aged 18–30 years and highest in those over 50 years. Similar trends have been documented in previous research; for instance, Sahu et al. reported lower vitamin D levels among younger adults, attributing it to lifestyle factors such as increased indoor activity and sunscreen use among this age group [16]. Likewise, Goswami et al. noted higher deficiency rates in younger populations in North India [17].

Gender differences were evident, with males exhibiting significantly higher mean vitamin D levels and a lower prevalence of deficiency compared to females. This aligns with findings from Marwaha et al., who observed that cultural practices, clothing habits, and reduced sun exposure among women contribute to higher deficiency rates [18]. Another study by Bhatia et al. similarly reported significantly lower vitamin D levels in women, highlighting the impact of limited outdoor activity [19].

Urban residents in our cohort had significantly lower mean vitamin D levels compared to rural residents, and a correspondingly higher prevalence of deficiency. This is consistent with the study by Agarwal et al., which demonstrated better vitamin D status among rural dwellers due to greater sun exposure associated with outdoor occupations [20]. Furthermore, Harinarayan et al. reported urban–rural disparities in vitamin D levels, emphasizing urban lifestyle factors such as indoor working environments and air pollution [21].

Seasonal variation was also marked in our findings, with the highest mean vitamin D level observed during summer and the lowest in winter. This pattern mirrors results from Mithal et al., who found substantial seasonal fluctuation in serum vitamin D, driven by differences in UVB availability [22]. Similarly, Arya et al. highlighted significantly lower levels during winter months, especially in northern India where winter sunlight is less intense [23].

Body mass index showed a significant association, with overweight and obese participants having lower mean vitamin D levels and higher deficiency prevalence. Comparable observations were reported by Kaur et al., suggesting increased sequestration of vitamin D in adipose tissue as a plausible mechanism [24]. Finally, Puri et al. found significantly lower vitamin D levels among obese individuals, supporting the hypothesis of volumetric dilution and altered metabolism [25].

Overall, the present study corroborates the multifactorial influences on vitamin D status seen in the Indian population, emphasizing the role of demographic, lifestyle, and environmental determinants. These findings highlight the need for targeted public health strategies, including awareness, supplementation, and lifestyle modification, especially for younger adults, females, urban residents, and individuals with higher BMI, to address widespread vitamin D deficiency.

Conclusion

We conclude that, the study highlights significant demographic variations in serum vitamin D status among the population studied. Younger adults, females, urban residents, individuals with higher BMI, and the winter season were all associated with lower mean vitamin D levels and a higher prevalence of deficiency. Conversely, older age groups, males, rural residents, normal BMI, and the summer season were linked to comparatively better vitamin D status. These findings underscore the multifactorial nature of vitamin D deficiency and emphasize the need for targeted public health strategies, especially for vulnerable subgroups, to improve overall vitamin D sufficiency and related health outcomes.

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