



The Prevalence and Determinants of Vitamin D Deficiencies among Medical Students: A Review

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| KEYWORDS | ABSTRACT |
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| Vitamin D, College students, Deficiency, Sun protection factors | <p>Background: Vitamin D deficiency (VDD), characterized by serum levels of 25-hydroxy vitamin D (25(OH) D) below 20 ng/ml, is a significant global issue affecting an estimated one billion people worldwide. VDD undermines biological organ systems, playing a crucial role in both adaptive and innate immunity, and is linked to chronic musculoskeletal pain and autoimmune disorders. Despite abundant sunlight, VDD is paradoxically prevalent in India due to factors such as cultural dress codes, increasing urbanization, sedentary urban lifestyles, and Indian diets that are typically very low in Vitamin D and lack fortified foods.</p> <p>Methodology: This study conducted an extensive literature search across major databases, focusing on publications from 2000 to early 2025. The search employed specific terms including "vitamin D," "deficiency," "college students," and "sun protection factors."</p> <p>Findings: VDD is confirmed to be a widespread issue among college and medical students in India, with key contributing factors being academic demands that limit outdoor exposure, low physical activity, and inadequate nutrition. Notably, a significant lack of awareness regarding VDD prevalence and management was reported among medical undergraduates.</p> <p>Conclusion: Given the high prevalence of VDD and the evident knowledge gap among future health workers, urgent action is necessary to prevent adverse consequences. Recommendations emphasize implementing targeted training programs for health workers to address the knowledge deficit. Additionally, there is a need for fundamental changes in lifestyle and dietary habits, along with improved food fortification, and the consideration of routine screening for at-risk student populations.</p> |

1. Introduction

I. A. Vitamin D: Structure, Synthesis, and Metabolism

Vitamin D is a fat-soluble secosteroid [1] and a unique pro hormone, naturally obtained either through

endogenous synthesis in the skin via ultraviolet B (UVB) radiation or through dietary sources. It is often referred to as the 'sunshine vitamin' because its synthesis in the skin is triggered by sunlight [2].The two main forms are Vitamin D3 (Cholecalciferol) and vitamin D2 (Ergocalciferol) [1].Its primary traditional



role involves calcium and phosphorus regulation, which is essential for preserving healthy bones and teeth, preventing conditions such as rickets in children and osteomalacia in adults [3].

Vitamin D is found in foods like fatty fish, eggs, milk, and supplements [4]. However, the primary and most effective source of Vitamin D for humans is through the skin's exposure to ultraviolet B radiation from sunlight [4].

Vitamin D, acquired either through the diet or through sun-induced cutaneous synthesis, is initially stored in adipose tissue or processed in the liver [4, 5]. This activation begins in the liver, yielding the principal circulating form, 25-hydroxyvitamin D, which acts as the optimal biomarker of Vitamin D status. This form then undergoes a second conversion step in the kidneys, resulting in 1, 25-dihydroxyvitamin D. This active form works by binding to vitamin D receptors (which are transcription factors) found across various tissues, enabling its crucial roles in systemic homeostasis and gene expression. The production of the active form, 1, 25 dihydroxy vitamin D, is tightly regulated by parathyroid hormone (PTH), which stimulates its synthesis. The system includes crucial feedback mechanisms to maintain stable calcium levels. Furthermore, when the active metabolite 1, 25-dihydroxyvitamin D is sufficiently available, the kidney forms a different compound, 24, 25-dihydroxyvitamin D, which is intended for further breakdown and catabolism [2,5,6]. These complex regulatory mechanisms underscore the importance of maintaining adequate substrate (25-hydroxyvitamin D) levels.

Nutritional status significantly influences vitamin D levels, with both obesity and underweight conditions posing unique challenges. In cases of obesity, the presence of excess adipose tissue can sequester vitamin D, which subsequently reduces its bioavailability in the body. This mechanism results in a greater risk of deficiency, even for individuals whose dietary vitamin D intake is considered adequate [7]. Conversely, underweight individuals may face vitamin D deficiency due to insufficient dietary sources [8].

I. B. Global Burden and Definition of Vitamin D Deficiency (VDD)

Based on this widespread impact, vitamin D deficiency or insufficiency is a massive global problem, with one billion people worldwide estimated to have low levels. The biologically active circulating form, 25-hydroxy vitamin D, is widely considered the best indicator of an individual's Vitamin D status.

Deficiency is defined as a serum level of 25-hydroxy vitamin D less than

20 n g/ml [2, 4, 9]. A 25(OH) D level between 21 and 29 n g/ml (21-29 n g/ml) is considered insufficient. The goal for maintaining optimal status in both children and adults is to achieve a level greater than 30 n g/ml [10].

Table 1: Deficiency, Insufficiency and Sufficiency Definitions (Based on Endocrine Society Clinical Practice Guidelines [10])

| Criterion | Level | Units (n g/ml) |
|---------------------|--------------|------------------------------------|
| Deficiency | Less than | 20 ng/ml (50 nmol/liter) |
| Insufficiency | Range | 21–29 ng/ml (52.5–72.5 nmol/liter) |
| Optimal/Sufficiency | Greater than | 30 ng/ml (75 nmol/liter) |

Different factors contribute to risk of impaired vitamin D status [6, 10,11]. They include variation in sun exposure due to latitude, season, time of day, cultural dress codes and veiling or due to pigmented skin, less time spent outdoors because of hot weather, lower vitamin D intake, age, obesity, sunscreen use and the incidence of several chronic illnesses. In the specific context of India, modernization and increasing temperatures have led to reduced outdoor activities, with urban residents increasingly adopting sedentary lifestyles. Changes in lifestyle and dietary habits among the younger population may also result in insufficient Vitamin D intake [12].

Adolescents with severe VDD may present with vague manifestations including pain in weight-bearing joints, back, thighs or calves, difficulty in walking or climbing stairs or running and muscle cramps [13]. The occurrence of nutritional rickets and osteomalacia among adolescents across regions like the Middle East,



North Africa, and India, which are characterized by abundant sunlight, indicates that local practices and variables are limiting the benefits of ultraviolet irradiation [13, 14].

Historically, the main source of vitamin D for Indians has always been through synthesis in the skin from exposure to UVB light from the sun. Due to the high incidence of vegetarian dietary practices, oily fish are generally missing from the diet of a significant portion of the Indian population, resulting in a crucial gap in natural Vitamin D intake [2]. However; Indian diets are typically very low in Vitamin D, characterized by low intake of fortified foods. Meat, another source, is avoided by significant proportion of the Indian population due to personal choice, resulting in a dietary gap [2, 15], and is consumed only by a small proportion due to high costs [16].

Urbanization has led to large-scale migration to cities, resulting in cramped homes with minimal sunlight, and a lifestyle shift where the middle and affluent classes stay indoors in air-conditioned homes and offices, limiting direct sun exposure. A genetic predisposition to Vitamin D deficiency reported among Asian people and higher Body Mass Index (BMI) are also contributing factors [17].

Vitamin D Deficiency (VDD) impairs every biological organ system and is frequently implicated in degenerative, chronic, and pro-inflammatory health conditions. This widespread pathology impacts the neurological, cardiovascular, and musculoskeletal systems, as well as core processes like metabolism, sleep, and immune response [18]. This reliance on solar synthesis makes inadequate sun exposure a critical risk factor in this population.

Vitamin D enables immune cells to exert a specific effect on the immunological system, playing a key role in both adaptive and innate immunity. Researches strongly suggest that Vitamin D deficiency or insufficiency can increase the rate of autoimmune diseases. Specifically, low vitamin D levels are frequently found in patients with Autoimmune Thyroid Disorders such as Hashimoto's thyroiditis and Graves' disease [19]. Given these systemic implications, understanding VDD prevalence, particularly in future healthcare professionals, is critical.

I. C. Factors Restricting Vitamin D Synthesis in India

The benefit and duration of sun exposure required for adequate synthesis depend heavily on the time of day, geographic location, skin tone, and the amount of skin exposed. Exposure of the skin over the arms and face for 30 minutes daily is recommended [5]. For populations in India, local guidelines suggest 30 minutes of daily sun exposure to prevent deficiency [2]. Another specific recommendation suggests exposing the arms and legs to sunlight between 10 AM and 2 PM for 10 minutes to half an hour twice a week [20].

The actual duration required to receive sufficient Vitamin D is dramatically increased by several factors that restrict UVB absorption or availability.

Individuals with naturally darker skin tones require significantly longer exposure times (three to five times longer) to synthesize the same amount of Vitamin D₃ as those with lighter skin [4]. An Asian Indian may require approximately 30 minutes of exposure to receive one MED (Minimal Erythema Dose) [6].

Furthermore factors such as applying sunscreen, even with a Sun Protection Factor (SPF) of 30, reduces Vitamin D synthesis in the skin by more than 95% [10]. Clothing that covers the body also restricts production [2, 5]. Air pollution (e.g., particulate matter) reduces Vitamin D synthesis by dispersing and absorbing UVB rays, making adequate exposure difficult even in sunny urban environments [4]. Additionally, exposure to sunlight that passes through glass is not suitable for Vitamin D synthesis [20].

Methodology : The methodology outlined involved a focused literature search across major databases (e.g., PubMed, Scopus, Web of Science) to find studies detailing the role of Vitamin D and its deficiency. This search focused on publications from 2000 through early 2025 and utilized specific search terms such as vitamin D, deficiency, college students, sun protection factors etc. The articles were generally required to be published in English and within the specific timeframe.

iii. Discussion:

Multiple studies suggest that vitamin D deficiency is a major public health concern, [2, 5, 11, 20] affecting diverse populations, including college and medical



students in India. Though one study [21] questioned if it is a true 'pandemic'.

The high prevalence of VDD in geographically sunny regions, such as India, represents a paradoxical public health challenge. Studies found that students have limited outdoor exposure due to academic demands and a preference for indoor activities [2,12, 22]. Lack of knowledge about vitamin D's importance, its sources, and the role of sunlight contributes to practices that lead to deficiency [2, 10]. Addressing these behavioral factors and promoting vitamin D health awareness, if replicated across populations, could lead to positive health outcomes globally [20]. A recent study [22] among dental students highlighted poor knowledge of vitamin D levels and general lack of awareness regarding the role of vitamin D in maintaining physiological functions, as well as insufficient emphasis on periodic vitamin D screening as a reason for vitamin D insufficiency.

According to recent studies changes in lifestyle and dietary habits, along with improved food fortification must be implemented to avert any future negative consequences of hypovitaminosis D [2].

While individuals often show adequate fundamental knowledge concerning Vitamin D — including its main dietary sources, site of synthesis, positive effects on bone health, major deficiency effects on bones, identification of high-risk groups and the importance of supplements, critical knowledge deficits persist [23]. Vitamin D deficiency is highly prevalent in medical students and most of them were asymptomatic [24]. A lack of awareness of vitamin D deficiency, prevalence and its management among medical undergraduates was reported by a recent study [25] which emphasizes training programs among these future health workers to accomplish the knowledge deficit and provide awareness about adequate intake of vitamin D to improve overall health of society.

The current practice of wearing sunscreens reduces vitamin D synthesis. A few studies have taken into account of the impact of sunscreen on Vitamin D levels.

While some studies[26] provide evidence that the daily use of high SPF sunscreen over one year increases the risk of vitamin D deficiency , leading to recommendations for testing and supplementation for

regular users , other investigations[27] suggest that it is possible to use sunscreens effectively to prevent the adverse effects of UV radiation (UVR) without compromising vitamin D synthesis . This conflicting data underscores the need for clear guidelines for populations with high sun exposure restrictions.

Vitamin D deficiency is highly prevalent among medical students and is strongly associated with the presence of chronic musculoskeletal pain [28]. Even when low levels of vitamin D status have been shown to be associated with a large number of chronic diseases such as diabetes, metabolic syndrome, autoimmune disorders, cardiovascular diseases, depression, cognitive impairment, and Parkinson's disease , a study of medical students and doctors, reported a high proportion of vitamin D insufficiency [29].

An urgent action to prevent adverse consequences of low Vitamin D in young generation of this country has been reported by a study showing that 99% of young, educated female students in the medical field have low Vitamin D levels [30]. This extremely high rate highlights the severe risk faced by this demographic. A recent study explored the co-occurrence of other deficiencies, such as vitamin B12, alongside vitamin D deficiency in students, suggesting potential co-related factors [31].

Conclusion:

The current literature review confirms that Vitamin D Deficiency (VDD) is a widespread global public health crisis, significantly affecting students in India. This deficiency persists despite India's abundant sunlight, primarily due to factors such as sedentary academic lifestyles, limited outdoor exposure, and local diets critically low in Vitamin D. Alarmingly, there is a pervasive lack of awareness about VDD prevalence and management, even among medical undergraduates. Studies on medical students indicate that deficiency is prevalent even within a population trained in health sciences, underscoring the need for targeted educational interventions. To effectively address hypovitaminosis D, proactive public health measures must be implemented, including mandatory targeted training programs for future health professionals to bridge the existing knowledge gap. Additionally, policies should promote lifestyle modifications, improved food



fortification, and routine Vitamin D screening for all identified at-risk student populations.

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