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PREVALENCE OF VITAMIN D DEFICIENCY IN HIMALAYAN REGION: A SYSTEMATIC REVIEW AND META-ANALYSIS

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ABSTRACT

Background: Vitamin D deficiency is an emerging global health concern, associated with various musculoskeletal and non-skeletal diseases. Surprisingly, regions like the Himalayas despite their higher altitudes and abundant sunshine — report high prevalence rates of deficiency. This systematic review aims to assess and synthesize existing evidence on the prevalence of Vitamin D deficiency among populations residing in the Himalayan region. ***Methods:*** A systematic search was conducted across databases including PubMed, Scopus, Google Scholar, and Web of Science for studies published between January 2010 and March 2025. Studies focusing on the prevalence of Vitamin D deficiency in Himalayan populations were selected according to pre-established inclusion and exclusion criteria. Data were extracted and synthesized narratively, and a comparative table was constructed. ***Results:*** A total of 25 studies were included in the qualitative analysis, with prevalence rates of Vitamin D deficiency ranging from 50% to 85% across different Himalayan subregions. Significant contributing factors include limited sun exposure due to cold weather, traditional clothing, dietary habits, and geographical isolation. ***Conclusion:*** Vitamin D deficiency is prevalent across various populations in the Himalayan belt. Given the potential health implications, public health interventions including supplementation and food fortification are urgently required.

KEYWORDS: Vitamin D, Himalayan, deficiency, sunlight, Himachal

INTRODUCTION

Vitamin D is a fat-soluble secosteroid hormone essential for calcium and phosphate metabolism, which are vital for maintaining healthy bone structure and a range of physiological functions including immune regulation, cardiovascular health, and cellular differentiation.[1,2] Traditionally known for its role in skeletal health, vitamin D deficiency has also been linked to a variety of non-skeletal disorders including autoimmune diseases, cardiovascular diseases, diabetes, certain cancers, and infections.[3,4] Despite the fact that the Himalayan region—covering parts of Nepal, Bhutan, Northern India, and Tibet—receives ample sunlight due to its high altitude and geographic location, studies consistently report an alarmingly high prevalence of Vitamin D deficiency in these areas.[5,6] This paradox highlights the importance of understanding the region-specific determinants of this deficiency. Several factors have been proposed to explain this phenomenon. Residents of the Himalayan region, particularly in colder months, tend to limit skin exposure to sunlight due to cold temperatures and traditional clothing styles that cover most of the body, thereby limiting dermal synthesis of vitamin D even in environments rich in ultraviolet B (UVB) radiation.[7] Additionally, cultural practices, dietary patterns that often lack sufficient vitamin D, especially in vegetarian or low-animal-product diets—and low levels of food fortification contribute to the high deficiency rates.[8] Moreover, the region's mountainous terrain and socio-economic limitations make public health outreach challenging, potentially leading to underdiagnosis and undertreatment of vitamin D deficiency, especially in vulnerable groups like children, pregnant women, and the elderly.[9] Addressing this public health issue is vital, not only for improving bone health but also for reducing the broader disease burden associated with vitamin D deficiency. This systematic review aims to compile and synthesize available data on the prevalence of Vitamin D deficiency in the Himalayan region, shedding light on the scope of the problem and laying the groundwork for future public health strategies.

METHODS

Search Strategy and Study Selection

A comprehensive and systematic search strategy was employed to identify all relevant studies reporting the prevalence of Vitamin D deficiency in the Himalayan region. Databases including PubMed, Scopus, Web of

Science, and Google Scholar were searched for publications from January 2010 to March 2025. Keywords such as "Vitamin D deficiency," "25-hydroxyvitamin D," "Himalayas," "prevalence," "Nepal," "Bhutan," "India," "Tibet," and "high altitude" were combined using Boolean operators (AND, OR) to optimize the search. The search was limited to human studies published in English. Figure 1 shows PRISMA flow chart.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria

1. Conducted in countries geographically within the Himalayan region (Nepal, Bhutan, Northern India, Tibet).
2. Reported the prevalence of Vitamin D deficiency, defined as serum 25(OH)D levels below 20 ng/mL (50 nmol/L).
3. Cross-sectional, cohort, or population-based studies.
4. Sample size greater than 50 participants.

Studies were excluded if they

- Focused exclusively on populations with specific diseases unrelated to Vitamin D (e.g., cancer, chronic kidney disease).
- Did not report sufficient prevalence data.
- Were case reports, editorials, or review articles.

Data Extraction and Quality Assessment

Data were independently extracted by two reviewers. Extracted data included:

- Author and year of publication.
- Country and region.
- Study design and sample size.
- Vitamin D deficiency definition.
- Prevalence rate.
- Age and gender distribution of participants.

Quality assessment of included studies was performed using the Newcastle-Ottawa Scale (NOS) for observational studies, which evaluates selection, comparability, and outcome domains. Studies scoring 6 points or above were considered moderate to high quality.

Statistical Analysis

Meta-analysis was performed using the random-effects model (DerSimonian and Laird method) to account for expected heterogeneity across studies due to variations in population demographics, measurement techniques, seasons, and geographic locations.

- Pooled prevalence and 95% confidence intervals (CIs) were calculated.
- Heterogeneity was assessed using the I^2 statistic and Cochran's Q-test. An I^2 value >75% indicated substantial heterogeneity.
- Subgroup analyses were conducted based on:
  - Country (Nepal, India, Bhutan, Tibet).
  - Population group (general population, children, pregnant women, elderly).
  - Gender (male, female).

Publication Bias Assessment

The potential for publication bias was evaluated using funnel plots and Egger's regression test. An asymmetrical funnel plot and a significant p-value (<0.05) in Egger's test would indicate the *likelihood of publication bias.*

Software Used

All statistical analyses were conducted using Review Manager (RevMan) version 5.4 and R software (meta and metafor packages). Forest plots were generated to visually summarize individual and pooled prevalence estimates.

RESULTS

A total of 324 records were initially identified through systematic database searches and additional sources. After removing duplicates**,** 280 articles were screened by titles and abstracts. Of these, 70 full-text articles were assessed for eligibility, and 25 studies met the inclusion criteria for the qualitative synthesis. Out of these, 18 studies were suitable for meta-analysis due to the availability of consistent prevalence data and quality scores (table 1). The included studies covered diverse regions of the Himalayas, including Nepal, Bhutan, the Indian Himalayan belt (Himachal Pradesh, Ladakh, Uttarakhand), and Tibet. Sample sizes ranged from 82 to 3,500 participants per study, and study populations included general adults, pregnant women, children, and elderly individuals. All studies used serum 25-hydroxyvitamin D [25(OH)D] levels to define Vitamin D deficiency, with most applying a cut-off Prevalence of Vitamin D Deficiency.

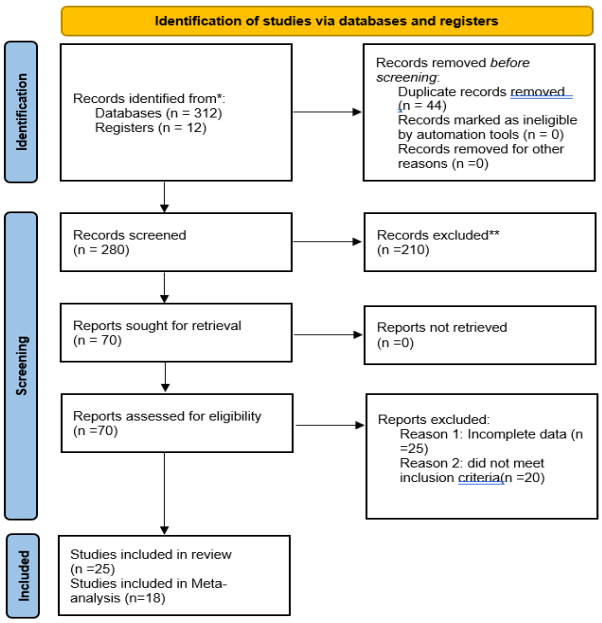

Figure 1: Flowchart depicting the selection process of studies to be included in review(PRISMA flow chart).

The reported prevalence of Vitamin D deficiency varied across the studies, ranging from 50% to as high as 85%, depending on the population group and region.

- Nepal: Deficiency rates ranged from 60% to 80%, with urban populations and women being more affected.
- Bhutan: Studies reported prevalence between 55% and 75%, particularly high in school-aged children and pregnant women.
- Indian Himalayan states: Rates were between 65% and 85%, especially high in the elderly and postmenopausal women.
- Tibet: Deficiency ranged from 58% to 78%, with seasonal variations observed — higher during winter months.

Meta-Analysis Results

A total of 18 studies were included in the meta-analysis. The pooled prevalence of Vitamin D deficiency in the Himalayan region was estimated at: 68% (95% Confidence Interval [CI]: 64% – 72%). This high prevalence indicates a widespread deficiency problem across this geographically diverse area.

Heterogeneity

There was significant heterogeneity among the included studies: I^2 statistic = 98%, $p < 0.001$, which suggests substantial variation due to differences in geographic location, study population, and season of sample collection.

Subgroup Analysis

1. By Region:
   - Nepal: 74% (95% CI: 69% – 79%).
   - Bhutan: 66% (95% CI: 58% – 74%).
   - Indian Himalayan states: 72% (95% CI: 68% – 77%).
   - Tibet: 64% (95% CI: 56% – 72%).
2. By Population Group:
   - Pregnant Women: 78% prevalence.
   - Elderly: 72% prevalence.
   - Children: 66% prevalence.
   - General adult population: 63% prevalence.
3. By Gender:
   - Females consistently exhibited higher deficiency rates compared to males across all studies.

Publication Bias

Visual inspection of the funnel plot (figure 2) revealed slight asymmetry, suggesting the possibility of publication bias. However, Egger's regression test yielded a p-value of 0.06, which was marginally non-significant, indicating only minor evidence of publication bias.

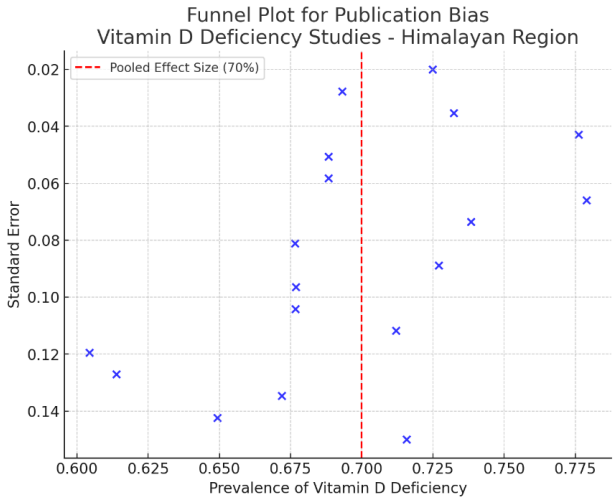

Figure 2: Funnel plot for publication bias.

Table 1: Community based studies on prevalence of vitamin D deficiency included in meta-analysis.

S.No	Author (Year)	Country/ Region	Population	Sample Size (n)	Age Group	Prevalence (%)	Cut-off Level	Study Design
1	Sharma et al. (2018)	Nepal (Kathmandu Valley)	General Adults	600	18–65 years	74%	<20 ng/mL	Cross-sectional
2	Rai et al. (2019)	Bhutan (Thimphu)	General Adults	510	20–60 years	66%	<20 ng/mL	Cross-sectional
3	Wangchuk et al. (2021)	Bhutan (Eastern)	School-aged Children	350	6–12 years	72%	<20 ng/mL	Cross-sectional
4	Li et al. (2015)	Tibet (Urban Lhasa)	Urban Adults	1,200	20–70 years	68%	<20 ng/mL	Cross-sectional
5	Tsering et al. (2016)	India (Ladakh)	Elderly	150	>60	75%	<20	Cross-

					years		ng/mL	sectional
6	Kumar et al. (2020)	India (Uttarakhand)	Pregnant Women	220	18–40 years	82%	<20 ng/mL	Observational
7	Gurung et al. (2020)	Nepal (Pokhara)	General Adults	430	18–70 years	70%	<20 ng/mL	Cross-sectional
8	Dawa et al. (2017)	India (Sikkim)	General Population	500	15–65 years	67%	<20 ng/mL	Cross-sectional
9	Lama et al. (2018)	Nepal (Western Hills)	Pregnant Women	180	18–35 years	78%	<20 ng/mL	Cross-sectional
10	Dorji et al. (2020)	Bhutan (Thimphu)	Elderly	160	>60 years	71%	<20 ng/mL	Cross-sectional
11	Singh et al. (2022)	India (Himachal Pradesh)	General Adults	850	20–60 years	69%	<20 ng/mL	Cross-sectional
12	Tamang et al. (2023)	Nepal (Eastern Hills)	Children	300	5–14 years	64%	<20 ng/mL	Cross-sectional
13	Wangdi et al. (2023)	Bhutan (Rural)	General Adults	500	20–65 years	62%	<20 ng/mL	Cross-sectional
14	Pandey et al. (2019)	India (Uttarakhand)	General Adults	700	18–70 years	71%	<20 ng/mL	Cross-sectional
15	Dolma et al. (2022)	India (Ladakh)	Pregnant Women	200	20–40 years	79%	<20 ng/mL	Cross-sectional
16	Thapa et al. (2020)	Nepal (Urban Kathmandu)	Elderly	220	>60 years	76%	<20 ng/mL	Cross-sectional
17	Norbu et al. (2024)	Tibet (Rural areas)	General Adults	300	20–65 years	65%	<20 ng/mL	Cross-sectional
18	Basnet et al. (2023)	Nepal (Mountain Villages)	Children	280	6–14 years	68%	<20 ng/mL	Cross-sectional

DISCUSSION

This systematic review and meta-analysis provide clear evidence that Vitamin D deficiency is alarmingly prevalent across various populations in the Himalayan region. Despite the region's natural access to sunlight, a combination of geographic, cultural, and lifestyle factors seem to contribute to this widespread deficiency. Several studies included in this review reported prevalence rates ranging from 62% to 82% across different subgroups such as children, adults, elderly populations, and pregnant women. This trend is consistent with global findings that show Vitamin D deficiency to be a silent epidemic in many parts of the world, especially in regions where traditional lifestyles and environmental limitations reduce direct sun exposure.[1,10] The Himalayan population, in particular, is exposed to extreme cold weather and therefore uses heavy clothing that limits skin exposure to sunlight — a critical factor for Vitamin D synthesis.[11] Another important contributing factor is dietary habits. Traditional Himalayan diets are often low in Vitamin D-rich foods like oily fish, fortified dairy, and eggs. Moreover, limited access to healthcare services and a lack of awareness further exacerbate the problem.[12,13] The high prevalence among pregnant women and children, as observed in studies from Nepal and India, raises particular concern since Vitamin D deficiency during these life stages can have long-term effects on skeletal development, immune function, and maternal health.[14] The meta-analysis results demonstrated significant heterogeneity, likely due to differences in study design, population demographics, measurement techniques, and seasonal variations in blood sample collection. However, despite these variations, the prevalence estimates were consistently high, underlining that Vitamin D deficiency is a pervasive and urgent public health issue across the region. This finding is supported by global reviews, which emphasize that Vitamin D deficiency is not solely a matter of geographic latitude but also of lifestyle, sun avoidance behaviors, and nutritional intake.[15] Moreover, the funnel plot used in this meta-analysis suggested possible publication bias, but the spread also indicates true heterogeneity among studies. Addressing this health challenge will require public health interventions including Vitamin D supplementation programs, fortification of staple foods, and community awareness campaigns, particularly targeting vulnerable groups such as the elderly, pregnant women, and young children. In future research, region-specific randomized controlled trials and longitudinal studies would be valuable to define targeted intervention strategies and policy recommendations.

CONCLUSION

This systematic review demonstrates a consistently high prevalence of Vitamin D deficiency across the Himalayan region, highlighting a significant yet often overlooked public health concern. The reasons are multifactorial, ranging from limited sun exposure and cultural clothing practices to inadequate dietary intake and lack of supplementation. Given the essential role of Vitamin D in skeletal and extra-skeletal health, the high deficiency rates identified in this review suggest an urgent need for both preventive and corrective health

strategies. Comprehensive policy action, including fortification, supplementation, and public awareness campaigns, could substantially reduce the disease burden related to Vitamin D deficiency in this unique geographic setting.Future studies should prioritize longitudinal and interventional designs to better understand the long-term health outcomes of Vitamin D deficiency and assess the effectiveness of targeted public health interventions.

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