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*RESEARCH ARTICLE*

# ESTIMATION OF SERUM VITAMIN D LEVELS AMONG COLLEGE STUDENTS IN KUPWARA, JAMMU AND KASHMIR: A CROSS-SECTIONAL STUDY

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## *Abstract*

**Background:** Vitamin D plays a fundamental role in bone mineralization, calcium–phosphate homeostasis, immune regulation, and various metabolic processes. Despite abundant sunlight in India, deficiency remains common because of lifestyle, dietary insufficiency, geographical constraints, and adiposity.

**Objective:** This study aimed to estimate serum vitamin D levels among college students in Kupwara district, Jammu and Kashmir, and to evaluate gender-based and BMI-based differences and contributing lifestyle factors.

**Methods:** A cross-sectional study was carried out at Government Degree College Handwara, involving 120 students (80 females and 40 males). Data were collected via structured questionnaires assessing sunlight exposure, diet, clothing, supplementation, and anthropometry (BMI). Serum 25(OH)D levels were determined using a Vitamin D FIA-200 (SD Biosensor) fluorescence immunoassay. Descriptive statistics, independent t-tests, chi-square tests, and correlation analyses were performed, with statistical significance assessed at $p<0.05$.

**Results:** Approximately 69% of participants had vitamin D deficiency (<30 ng/mL), based on the gender-wise breakdown in Table 1. Females had significantly lower levels (18.6 ± 5.3 ng/mL) than males (36.7 ± 6.2 ng/mL; $p<0.0001$). Supplement users (12% of the cohort, primarily male) had optimal levels (55 ± 7.2 ng/mL). Students who were overweight or obese (BMI ≥25 kg/m²) showed the lowest mean levels (17.6 ± 6.2 ng/mL) and the highest prevalence of deficiency. An inverse correlation between BMI and serum vitamin D was observed ($r = −0.32$, $p<0.05$).

**Conclusion:** Vitamin D deficiency is highly prevalent in this cohort, particularly among females and overweight/obese students. Public health interventions such as dietary fortification, supplementation, safe sun exposure, weight management, and awareness campaigns are warranted.



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## Introduction:-

Vitamin D, a fat-soluble prohormone, is synthesized primarily in the skin upon exposure to ultraviolet B (UVB) radiation. Following cutaneous synthesis, it undergoes hydroxylation in the liver to form 25-hydroxyvitamin D [25(OH)D] — the most reliable biomarker of vitamin D status — and further hydroxylation in the kidneys to yield 1,25-dihydroxyvitamin D (calcitriol), its biologically active form (Holick, 2007). Acting through vitamin D receptors, which are widely expressed across human tissues, calcitriol regulates calcium and phosphorus homeostasis and exerts pleiotropic effects on bone health, immune regulation, insulin secretion, cardiovascular function, and neurocognitive processes (Bouillon et al., 2019; Christakos et al., 2016).

Vitamin D deficiency is a recognized global public health problem, affecting more than one billion people across age groups (Mithal et al., 2009). Its prevalence is shaped by geographical, environmental, cultural, and lifestyle factors: limited UVB availability during winter contributes to seasonal deficiency in Europe and North America (Cashman et al., 2016), while in the Middle East and South Asia, conservative clothing practices, atmospheric pollution, indoor-oriented lifestyles, and darker skin pigmentation are major risk factors despite year-round sunlight (Palacios & Gonzalez, 2014). India illustrates this paradox particularly clearly: 50–90% of adolescents and young adults are vitamin D deficient despite abundant sunshine, largely due to poor dietary intake, limited food fortification, and changing lifestyle patterns (Nair & Maseeh, 2012; Aparna et al., 2018).

The Indian Council of Medical Research (ICMR) recommends a daily intake of 600–800 IU of vitamin D for adults; compliance is nonetheless low, and national fortification programs remain limited (ICMR-NIN, 2020). Regional variation in prevalence and risk is also evident. Northern states such as Jammu and Kashmir, and Kupwara district in particular, lie at higher latitudes with prolonged winters, reduced UVB penetration, and greater seasonal restriction of cutaneous synthesis. Traditional clothing practices, predominantly indoor academic routines, limited dietary diversity, and minimal availability of fortified foods or supplements further compound this risk — a pattern corroborated by earlier biochemical surveys of the Kashmir Valley, which found vitamin D deficiency in 66–83% of otherwise healthy adults (Zargar et al., 2007; Bhat et al., 2023).

College students are a particularly vulnerable group in this context. Academic schedules that involve prolonged indoor activity, sedentary routines, and limited dietary awareness heighten the likelihood of hypovitaminosis D. Despite the wide recognition of vitamin D deficiency in India generally, few studies have systematically examined its prevalence and determinants specifically among college-aged students in Jammu and Kashmir, leaving a gap in both epidemiological understanding and public health policy for this age group.

### Rationale and Aim:-

The present study was undertaken to estimate serum vitamin D levels among college students in Kupwara district, Jammu and Kashmir, and to identify associated sociodemographic, lifestyle, and dietary risk factors. The findings are intended to generate region-specific evidence to inform preventive strategies, guide public health interventions, and support policy initiatives such as supplementation and food fortification programs.

## Materials and Methods:-

**Study design and population.** This cross-sectional study was conducted at Government Degree College Handwara, Kupwara district. A total of 120 students (80 females, 40 males) aged 18–25 years were enrolled.

**Sampling method and sample size.** Participants were recruited by random sampling. The target sample size of 120 was based on the expected availability of eligible students during the study period and the logistical feasibility of recruitment, while ensuring adequate representation of both sexes and sufficient statistical power for descriptive and comparative analyses. Inclusion criteria: healthy college students who provided consent to participate. Exclusion criteria: chronic illness, corticosteroid therapy, metabolic bone disease.

**Data collection.** Data were collected using a structured, pre-tested questionnaire administered by trained investigators to obtain information on demographic characteristics (age, sex, and place of residence), lifestyle factors, sunlight exposure, clothing habits, dietary intake, and vitamin D supplement use. The questionnaire was developed based on previously published epidemiological studies on vitamin D status and reviewed by experts for content validity before use. Sunlight exposure was assessed by recording the average duration of direct sun exposure per day during the preceding month and categorized as <30 min/day, 30–60 min/day, and >60 min/day. Participants were also asked about their usual time of sun exposure and the extent of body surface area exposed, based on their clothing habits, as these factors influence cutaneous vitamin D synthesis. Dietary intake was assessed using a semiquantitative food frequency questionnaire (FFQ) that recorded the frequency of consumption of vitamin D-rich foods, including fish, eggs, fortified milk and dairy products, and vitamin D supplements. A dietary vitamin D score was calculated by assigning one point for regular consumption (≥3 times/week) of each vitamin D-rich food, resulting in a total score ranging from 0 to 4, with higher scores indicating greater dietary vitamin D intake. Height was measured to the nearest 0.1 cm using a portable stadiometer, and body weight was measured to the nearest 0.1 kg using a calibrated digital weighing scale, with participants wearing light clothing and no shoes. Body mass index (BMI) was calculated as weight (kg) divided by height squared ($m^2$) and classified according to the World Health Organization criteria as underweight (<18.5 kg/$m^2$), normal weight (18.5–24.9 kg/$m^2$), overweight (25.0–29.9 kg/$m^2$), and obese (≥30.0 kg/$m^2$).

**Laboratory methods.** Approximately 5 mL of venous blood was collected from each participant under aseptic conditions by a trained phlebotomist. Blood samples were allowed to clot at room temperature and were then centrifuged at 3,000 rpm for 10 minutes to separate the serum. Serum samples were analyzed immediately or stored at −20°C until analysis. Serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using the Vitamin D FIA-200 (SD Biosensor, Republic of Korea), a fluorescence immunoassay (FIA) with an analytical measurement range of 4–150 ng/mL, according to the manufacturer's instructions. The instrument was calibrated before sample analysis, and internal quality-control procedures were performed using low- and high-level control materials supplied by the manufacturer. All samples and quality-control materials were analyzed in accordance with standard operating procedures, and quality-control results were required to fall within the manufacturer's acceptable ranges before participant samples were accepted.

**Classification of vitamin D status.** Serum 25(OH)D concentrations were classified according to Endocrine Society criteria into four non-overlapping bands: severe deficiency (<10 ng/mL), deficiency (10–20 ng/mL), insufficiency (21–29 ng/mL), and sufficiency (≥30 ng/mL).

**Ethical considerations.** The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment after explaining the purpose, procedures, potential benefits, and minimal risks associated with the study. Participation was entirely voluntary, and participants were informed that they could withdraw from the study at any time without any consequences. Participant confidentiality and anonymity were maintained by assigning unique identification codes, and all collected data were used solely for research purposes

**Statistical analysis.** Data were entered and analyzed in GraphPad Prism. Continuous variables are reported as mean ± standard deviation (SD) and were compared using independent-samples t-tests; categorical variables are reported as frequencies and percentages and were compared using chi-square tests. Pearson correlation was used to examine the association between sunlight exposure, BMI, and serum 25(OH)D. Statistical significance was set at $p<0.05$.

## Results:-

Overall, the mean serum 25(OH)D level was 24.6 ± 10.2 ng/mL (weighted from the gender subgroups in Table 1). Female students had significantly lower serum 25(OH)D concentrations than male students (independent-samples t-test, $p<0.0001$).

**Table 1. Gender-wise distribution of serum 25(OH) D status**

| **Gender** | **n** | **Mean ± SD (ng/mL)** | **Severe deficiency (<10 ng/mL)** | **Deficiency (10–20 ng/mL)** | **Insufficiency (21–29 ng/mL)** | **Sufficiency (≥30 ng/mL)** |
|---|---|---|---|---|---|---|
| Female | 80 | 18.6 ± 5.3 | 12% | 22% | 48% | 18% |
| Male | 40 | 36.7 ± 6.2 | 5% | 10% | 27% | 58% |

SD, standard deviation. Classification per Endocrine Society criteria (severe deficiency <10 ng/mL; deficiency 10–20 ng/mL; insufficiency 21–29 ng/mL; sufficiency ≥30 ng/mL). Between-group comparison by independent t-test (mean levels) and chi-square test (categorical distribution).

Supplement users (12% of the cohort, primarily male) had significantly higher serum 25(OH)D levels (55 ± 7.2 ng/mL) than non-users (19 ± 10.5 ng/mL). A positive correlation was observed between daily sunlight exposure and serum 25(OH)D ($r = 0.46$, $p<0.05$).

**Table 2. Distribution of serum 25(OH)D status by BMI category**

| BMI category | n | Mean ± SD (ng/mL) | Severe deficiency (<10) | Deficiency (10–20) | Insufficiency (21–29) | Sufficiency (≥30) |
|---|---|---|---|---|---|---|
| Underweight (<18.5) | 20 | 29.4 ± 8.6 | 5% | 15% | 35% | 45% |
| Normal (18.5–24.9) | 70 | 25.7 ± 9.8 | 6% | 18% | 44% | 32% |
| Overweight (25–29.9) | 20 | 18.8 ± 6.2 | 10% | 30% | 45% | 15% |
| Obese (≥30) | 10 | 15.2 ± 5.4 | 20% | 30% | 40% | 10% |

SD, standard deviation; BMI, body mass index. Classification per Endocrine Society criteria as in Table 1.
Students with a higher BMI (≥25 kg/m²) had significantly lower mean serum 25(OH)D levels than those with a normal BMI, and the prevalence of deficiency was highest among overweight and obese students. Students with a normal BMI showed comparatively better vitamin D status, although more than half remained below the sufficiency threshold. A significant inverse correlation was observed between BMI and serum vitamin D level ($r = -0.32$, $p<0.05$).

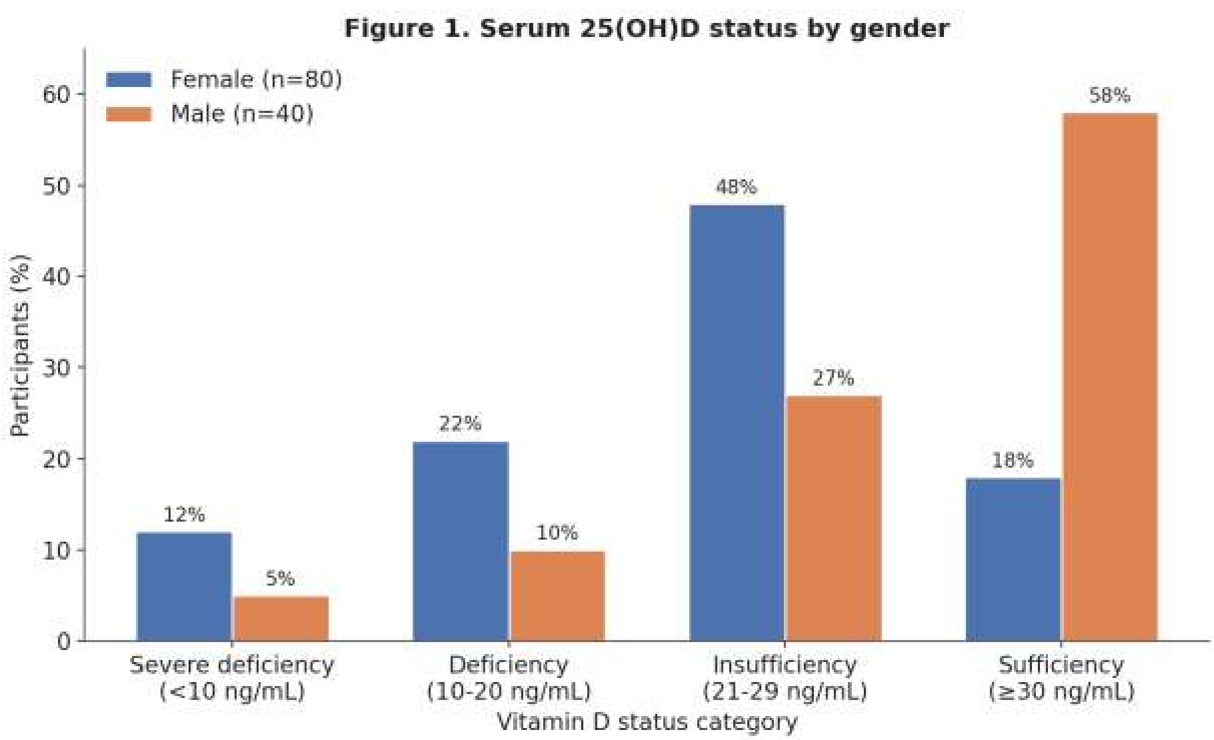


**Figure 1. Serum 25(OH)D status by gender. A higher proportion of females fell in the lower vitamin D categories, while a higher proportion of males were in the sufficiency range.**

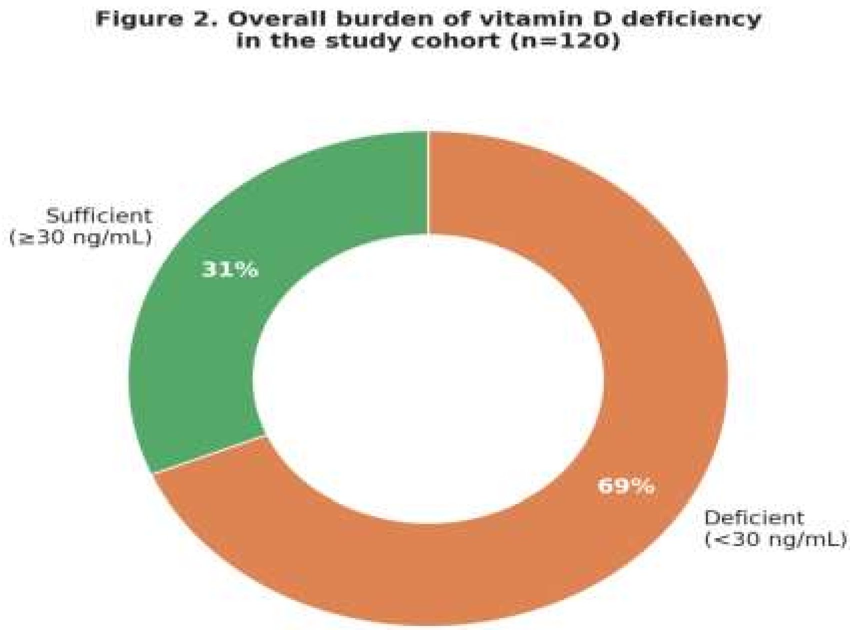


**Figure 2. Overall burden of vitamin D deficiency in the study cohort. Approximately two-thirds of participants had levels below 30 ng/mL.**

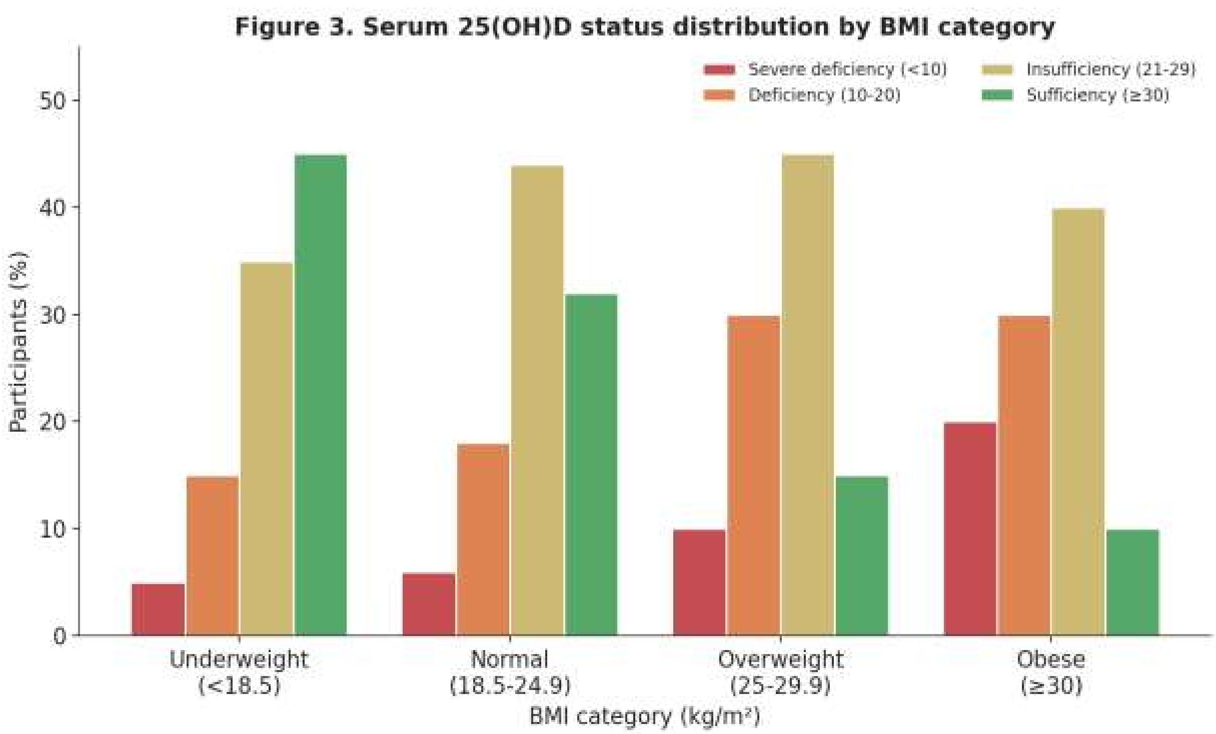


**Figure 3. Serum 25(OH)D status distribution by BMI category.**

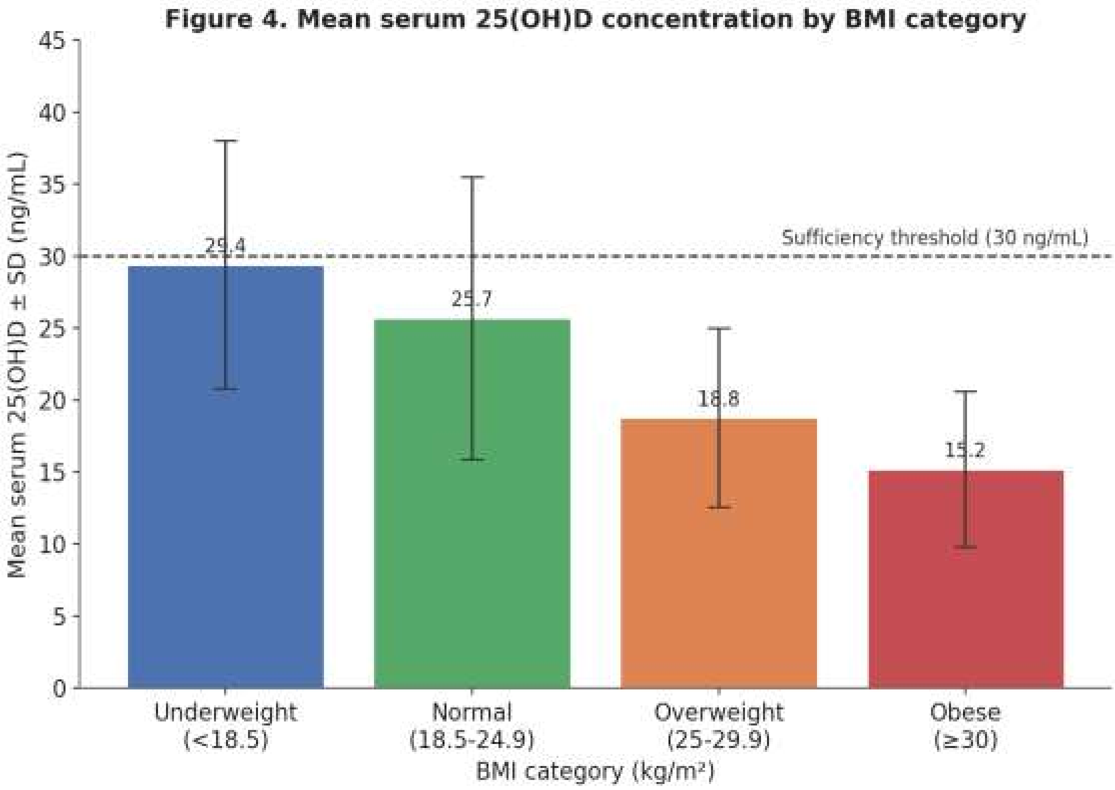


**Figure 4. Mean serum 25(OH)D concentration (± SD) by BMI category, showing a graded decline with increasing BMI relative to the 30 ng/mL sufficiency threshold.**

## Discussion:-

This study found a high prevalence of vitamin D deficiency (≈69%) among college students in Kupwara district, Jammu and Kashmir, consistent with earlier Indian reports of 50–90% deficiency among adolescents and young adults (Goswami et al., 2000; Agarwal et al., 2019; Aparna et al., 2018), and with regional biochemical surveys from the Kashmir Valley reporting deficiency in 66–83% of apparently healthy adults (Zargar et al., 2007; Bhat et al., 2023). Even at these very different sample sizes and settings, the persistence of a substantial deficit despite ample regional sunlight reflects what has been termed the “sunshine paradox,” whereby environmental, cultural, and behavioral factors limit effective cutaneous synthesis and dietary intake.

Body mass index emerged as an important correlate of vitamin D status in this cohort: students who were overweight or obese had lower serum concentrations than their normal-weight peers, consistent with the hypothesis that adipose tissue sequesters vitamin D and reduces its bioavailability (Wortsman et al., 2000). Because this is a cross-sectional association, it cannot establish that adiposity independently causes lower vitamin D status; a multivariable model adjusting for the other measured covariates would be required to support an independence claim.

Gender disparities were also evident, with female students disproportionately affected — a pattern reported elsewhere in India and the Middle East/North Africa, where conservative clothing, limited outdoor activity, and lower intake of vitamin D–rich foods contribute to lower status among women (Ritu & Gupta, 2014; Bassil et al., 2013), and which may be compounded by physiological differences such as higher adiposity in females.

Kupwara's higher latitude and prolonged winters restrict UVB penetration and dermal synthesis of cholecalciferol (Webb et al., 1988; Holick, 2007), while predominantly indoor academic routines and limited midday sun exposure add to the risk. These patterns mirror those seen across South Asia and the Middle East and parallel the seasonal nadirs reported in Europe and North America during winter (Mithal et al., 2009; Cashman et al., 2016).

These findings carry clinical relevance: adolescence and early adulthood are critical windows for achieving peak bone mass, and vitamin D deficiency during this period raises the lifetime risk of osteopenia, osteoporosis, and fracture (Arabi et al., 2010; Weaver et al., 2016). Low 25(OH)D has also been linked to cardiometabolic risk, immune dysregulation, and neurocognitive outcomes (Demay et al., 2024; Nejabat et al., 2024; Zhang et al., 2024), and meta-analyses suggest supplementation may reduce acute respiratory infection risk, particularly among individuals with low baseline levels, although trial evidence for other non-skeletal outcomes remains mixed (Martineau et al., 2017; Bouillon et al., 2019).

The better vitamin D status observed among supplement users in this cohort is consistent with dose–response data showing that oral cholecalciferol reliably raises serum 25(OH)D (Heaney et al., 2003; Vieth, 1999). At a population level, fortification of widely consumed foods such as milk, wheat flour, and edible oils has proven both effective and cost-efficient elsewhere (Calvo & Whiting, 2013). For Kupwara specifically, a combined approach — structured outdoor breaks within college schedules, awareness programs on sun exposure and diet, routine screening with supplementation protocols, and district-level fortification aligned with national policy — appears warranted (Ross et al., 2011).

This study has several limitations. It was conducted at a single institution with a modest sample size, which limits generalizability to students elsewhere in Jammu and Kashmir. Diet and sun-exposure data were self-reported and are subject to recall and social-desirability bias. The absence of seasonal sampling precludes assessment of intra-annual variability, and the lack of parathyroid hormone, calcium, or vitamin D–binding protein measurements limits insight into secondary metabolic adaptation.

**Future research** should adopt multicentric, longitudinal designs incorporating seasonal variation, objective exposure metrics (e.g., wearable light sensors), and expanded biochemical profiling (25(OH)D, PTH, calcium, and binding proteins). Stratification by sex, BMI, skin phototype, clothing practice, and physical activity would provide more granular insight, and implementation research is needed to evaluate the acceptability, adherence, and cost-effectiveness of fortification, supplementation, and behavioral interventions on college campuses.

## Conclusion:-

Vitamin D deficiency was highly prevalent among the college students studied, with females and those in higher BMI categories disproportionately affected. Overweight and obese students had the lowest mean serum vitamin D concentrations; BMI was inversely associated with vitamin D concentrations, though the cross-sectional design means this association should not be interpreted as evidence of an independent causal effect without further (e.g., regression-adjusted) analysis. Limited sun exposure, conservative clothing practices, and inadequate dietary intake were additional contributors to deficiency alongside adiposity.

These findings support the case for multifaceted public health strategies — awareness campaigns, promotion of safe sun exposure, dietary diversification, targeted supplementation, and large-scale food fortification — together with weight-management initiatives for young adults, to help optimize vitamin D status during this critical period of bone and metabolic development.

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