

Prevalence and Correlates of Vitamin D Deficiency among Healthcare Workers of a Neurosurgical Intensive Care Unit in North India: A Cross-sectional Study

Authors:

Kiran Lata Kiro¹, Neha Bhandari²

¹MD Anaesthesiology, Neuroanaesthesia Unit, Dept of Anaesthesiology and Intensive Care, GB Pant Institute of Postgraduate Medical Education and Research, (GIPMER).

²DM Neuroanaesthesia, Neuroanaesthesia Unit, Dept of Anaesthesiology and Intensive Care, GIPMER.

Corresponding Author:

Kiran Lata Kiro, MD Anaesthesiology, Professor, Neuroanaesthesia Unit, Dept of Anaesthesiology and Intensive Care, GB Pant Institute of Postgraduate Medical Education and Research, (GIPMER), New Delhi.

Email Id: kirankiro@gmail.com

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ABSTRACT

Background: Healthcare workers in intensive care units may be at risk of vitamin D deficiency because of prolonged indoor duties and limited sunlight exposure. **Aim:** This cross-sectional study assessed the prevalence and correlates of vitamin D deficiency among healthcare workers in a neurosurgical intensive care unit at a tertiary-care hospital. **Methods:** Demographic, occupational, dietary and lifestyle data from 55 healthcare workers were collected using a structured questionnaire and their serum 25-hydroxyvitamin D [25(OH)D] was measured by chemiluminescent immunoassay. Vitamin D deficiency was defined as serum values <20 ng/mL. Prevalence was expressed with 95% confidence intervals; associations were assessed using Fisher's exact test, and independent correlates were identified by multivariable logistic regression. **Results:** The mean age was 38.96 ± 10.36 years and 58.2% were female. Vitamin D deficiency was present in 23 participants (41.8%; 95% CI 29.7–55.0), and 78.2% had concentrations below 30 ng/mL. On univariable analysis, deficiency was more frequent among physicians than nursing/technical staff (66.7% vs 29.7%; $P = 0.018$), those working >8 vs ≤8 hours/day (65.0% vs 28.6%; $P = 0.012$), those with <1 vs ≥1 hour/day of sunlight exposure (50.0% vs 9.1%; $P = 0.017$), and those sleeping <6 vs ≥6 hours/day (51.4% vs 22.2%; $P = 0.047$). On multivariable analysis, younger age (aOR 0.88 per year; 95% CI 0.79–0.97) and working >8 hours/day (aOR 5.01; 95% CI 1.22–20.51) were independently associated with deficiency. **Conclusion:** Vitamin D deficiency was common among neurosurgical ICU healthcare workers. Younger age and prolonged working hours were independent correlates, supporting targeted screening and supplementation for staff with long duty hours.

Keywords: vitamin D deficiency; healthcare workers; neurosurgical intensive care unit; sunlight exposure; occupational health; serum calcium; North India

INTRODUCTION

Vitamin D is a fat-soluble secosteroid that plays an essential role in calcium and phosphate homeostasis, skeletal mineralization, and maintenance of normal neuromuscular function. Beyond its established effects on bone health, vitamin D receptors are widely distributed in human tissues, participating in several cellular and immune-regulatory processes. Serum 25-hydroxyvitamin D [25(OH)D] is the preferred marker for assessing vitamin D status because it reflects vitamin D derived from both cutaneous synthesis and dietary sources. According to a recent Indian expert consensus, serum 25(OH)D concentrations below 20

ng/mL (50 nmol/L) are considered deficient, while levels between 20 and 30 ng/mL and below 10 ng/mL represent insufficiency and severe deficiency respectively [1].

Despite abundant sunshine across much of India, vitamin D deficiency remains highly prevalent. Factors such as limited effective sunlight exposure, predominantly indoor lifestyles, increased skin pigmentation, clothing practices, air pollution, and inadequate dietary intake contribute towards this paradox. The overall prevalence of vitamin D deficiency in the Indian population has been reported to be approximately 61%, highlighting the magnitude

of this public health problem [2]. Similar findings have been reported among South Asian adults showing pooled prevalence of 68% thus demonstrating that geographical availability of sunlight alone does not guarantee adequate vitamin D status [3].

Occupation may substantially influence vitamin D status because cutaneous synthesis depends on effective exposure to ultraviolet-B radiation. Sowah et al reported vitamin D deficiency in approximately 80% of shift workers and 78% of indoor workers, compared with 48% of outdoor workers [4]. Healthcare professionals are particularly vulnerable due to prolonged indoor work, long duty hours, rotating shifts, night duties, and limited opportunities for outdoor activity. Among healthcare occupations, medical residents and healthcare students demonstrated especially low vitamin D concentrations, with deficiency affecting nearly two-thirds of resident doctors [4].

Data from India indicate an even greater burden among healthcare workers. In a multicentre study involving 2,119 medical and paramedical personnel, Beloyartseva et al. reported vitamin D deficiency in 79% of participants with 15% having insufficient and only 6% with sufficient vitamin D concentrations with no meaningful advantage of latitude of southern versus northern region [5]. Similarly, in a survey on 2,374 healthcare professionals employed across an Indian eye-care network 92% had serum vitamin D concentrations below the study-defined normal range, with a mean 25(OH)D concentration of approximately 20.1 ng/mL [6]. Studies from North India have reported particularly high rates of hypovitaminosis D among young resident doctors and practicing physicians, despite residence in regions receiving substantial annual sunlight [7,8].

The association between occupational sunlight exposure and vitamin D status has also been demonstrated in North India. Goswami et al. reported substantially lower serum 25(OH)D concentrations among indoor workers compared to outdoor workers in Delhi and reported mean serum 25(OH)D concentrations of 29.0, 19.1, and 10.9 ng/mL, respectively. Identifying sunlight exposure as a major determinant of vitamin D status [9]. More recent studies among hospital healthcare workers have similarly documented associations of vitamin D inadequacy with factors such as night-shift work, supplementation practices, age, and ethnicity [10].

Healthcare workers employed in intensive care units may represent an especially susceptible occupational subgroup. Neurosurgical intensive care requires continuous patient monitoring, emergency management, prolonged bedside duties, and round-the-clock staffing. Doctors, nurses, technicians, and other personnel may therefore spend extended periods inside enclosed clinical environments with little or no natural sunlight. Rotating shifts and overnight duties can additionally restrict opportunities for daytime outdoor

activity. Although vitamin D deficiency has been examined among Indian healthcare professionals and resident doctors, evidence specifically addressing personnel working in neurosurgical intensive care units with extended periods inside enclosed clinical environments remains limited. Furthermore, identifying prevalence alone may not adequately define the problem, because potentially modifiable correlates such as duration of sunlight exposure, shift pattern, dietary habits, supplementation, body mass index, physical activity, and duration of indoor working hours may influence vitamin D status.

Therefore, this cross-sectional study was undertaken to determine the prevalence of vitamin D deficiency among healthcare workers employed in a neurosurgical intensive care unit in North India and to identify demographic, occupational, lifestyle, and nutritional factors associated with deficient vitamin D status. The primary outcome was prevalence of vitamin D deficiency, while serum calcium and phosphate levels were assessed as secondary outcomes. Identification of these correlates may help define vulnerable groups and provide an evidence base for appropriate occupational-health strategies, including awareness, targeted assessment, modification of preventable risk factors, and rational vitamin D supplementation where clinically indicated.

MATERIAL AND METHODS

This single-centre, observational cross-sectional study was conducted among healthcare workers employed in the closed neurosurgical intensive care unit (NSICU) of Govind Ballabh Pant Institute of Postgraduate Medical Education and Research (GIPMER), New Delhi, India. The study was conducted over a one-month period from 1 July to 31 July 2023 to determine the prevalence of vitamin D deficiency among healthcare workers and to examine its relationship with demographic, occupational, lifestyle, nutritional, and biochemical factors.

Study Population

The source population comprised healthcare personnel working in the neurosurgical ICU during the study period, including consultants, resident doctors, nursing officers, technicians, and nursing orderlies. All potentially eligible healthcare workers available during the study period who fulfilled the eligibility criteria were approached for participation. Written informed consent was obtained from all participants prior to enrolment.

Eligibility Criteria

Healthcare workers aged 18-65 years classified as ASA physical status I or II were included. Exclusion criteria were pregnancy, current vitamin D supplementation, chronic kidney disease, and chronic liver disease.

Data Collection and Study Variables

After enrolment, participants completed a structured study questionnaire. The questionnaire was pilot-tested in individuals representative of the target population to assess clarity, comprehensibility, and feasibility before the main study. Data collected included demographic, occupational, lifestyle, dietary, and clinical variables, including age, sex, body mass index (BMI), comorbidities, substance use, dietary pattern (vegetarian/ nonvegetarian), dairy intake, occupational designation, work schedule (rota based/ standard), working hours (≤ 8 vs >8 hours/day), sunlight exposure, physical activity, sleep duration, transport mode, income, previous vitamin D intake, gastrointestinal disorders, and current medication use. Occupational designation was categorized as consultant, resident doctor, nursing officer, technician, or nursing orderly. Sunlight exposure (<1 hour, 1-2 hour, >2 hour), physical activity (<30 minutes, 30-60 minutes, >1 hour), and sleep duration (<6 hours, 6-8 hours, >8 hours) were recorded in predefined categories. Symptoms suggestive of vitamin D deficiency such as backache, calf pain, or sole pain, gastrointestinal symptoms, and medication history were also recorded.

Blood Sampling and Biochemical Assessment

Following questionnaire completion, a single venous blood sample was collected from each participant under aseptic precautions. Serum 25(OH)D was measured using a chemiluminescent immunoassay, and serum calcium and phosphate levels were also assessed. Vitamin D deficiency was defined as a serum 25(OH)D concentration <20 ng/mL; participants with levels ≥ 20 ng/mL were classified as non-deficient.

Outcome Measures

The primary outcome was the prevalence of vitamin D deficiency among healthcare workers in the neurosurgical ICU, determined from serum 25(OH)D concentrations.

Secondary outcomes included serum calcium and phosphate concentrations and assessment of their relationship with vitamin D status. Exploratory correlates of vitamin D deficiency included age, sex,

BMI, occupational designation, working hours, work schedule, sunlight exposure, dietary pattern, dairy consumption, physical activity, sleep duration, smoking/alcohol use, relevant comorbidities, previous vitamin D intake, gastrointestinal symptoms, medication use, and symptoms potentially attributable to vitamin D deficiency.

Statistical Analysis

Data were analysed using IBM SPSS Statistics version 25.0 (IBM Corp., Armonk, NY, USA). Normality was assessed using the Shapiro–Wilk test. Continuous variables are presented as mean $\pm$ SD or median (IQR) according to distribution, and categorical variables as frequencies and percentages. The prevalence of vitamin D deficiency is reported with its 95% confidence interval (Wilson method). Deficient and non-deficient participants were compared using the Student's *t* test or Mann–Whitney *U* test for continuous variables and Fisher's exact test for categorical variables. Correlations of serum 25(OH)D with age, BMI, calcium and phosphate were assessed using Spearman's coefficient (ρ).

All variables described above were examined in univariable analysis. Predictors for multivariable logistic regression were selected based on the number of outcome events, univariable association and biological plausibility, to identify independent correlates while avoiding overfitting. Results are expressed as adjusted odds ratios (aORs) with 95% CIs, and a two-sided *P* <0.05 was considered significant.

RESULTS

Participant characteristics

A total of 55 healthcare workers were included. Their mean age was 38.96 ± 10.36 years (range 23–62), and 32 participants were female (58.2%). Nursing officers formed the largest occupational group (27; 49.1%), followed by resident doctors (13; 23.6%). Twenty participants (36.4%) worked >8 hours/day and 40 (72.7%) followed a rota-based schedule. Daily sunlight exposure was <1 hour in 44 of 55 participants (80.0%), and 37 (67.3%) slept <6 hours/day (Table 1).

Table 1. Baseline characteristics of the study participants

Characteristic	Value (n = 55)
Demographic and anthropometric	
Age, years, mean $\pm$ SD	38.96 ± 10.36
Age, years, median (IQR)	36.0 (30.5–46.0)
Female n (%)	32 (58.2)
Weight, kg, mean $\pm$ SD	67.64 ± 9.56
Height, cm, mean $\pm$ SD	162.84 ± 9.62
BMI, kg/m ² , mean $\pm$ SD	25.49 ± 2.86
BMI ≥ 25 kg/m ² , n (%)	28 (50.9)
Comorbidity n (%)	11 (20.0)
Occupational	

Consultant n (%)	5 (9.1)
Resident doctor n (%)	13 (23.6)
Nursing officer n (%)	27 (49.1)
Technician n (%)	4 (7.3)
Nursing orderly, n (%)	6 (10.9)
Working >8h/day n (%)	20 (36.4)
Rota-based schedule n (%)	40 (72.7)
Lifestyle	
Sunlight exposure, n/N (%)	
<1h/day	44/55 (80.0)
1-2 h/day	10/55 (18.2)
>2 h/day	1/55 (1.8)
Physical activity, n (%)	
<30 min/day	33 (60.0)
30–60 min/day	17 (30.9)
>60 min/day	5 (9.1)
Sleep duration, n (%)	
<6h/day	37 (67.3)
6-8h/day	17 (30.9)
>8h/day	1 (1.8)

BMI, body mass index; IQR, interquartile range; SD, standard deviation.

Vitamin D status and serum biochemistry

Median serum 25(OH)D was 22.0 ng/mL (IQR 14.0–28.7; range 4.0–84.0). Vitamin D deficiency (<20 ng/mL) was present in 23 participants (41.8%; 95% CI 29.7–55.0), including 5 (9.1%) with severe deficiency (<10 ng/mL). A further 20 (36.4%) had insufficiency and 12 (21.8%) were sufficient, so that 43 participants (78.2%; 95% CI 65.6–87.1) had concentrations below 30 ng/mL (Table 2, Figure 1). Median serum calcium was 9.0 mg/dL (IQR 8.5–9.5) and median serum phosphate 3.2 mg/dL (IQR 2.85–3.70).

Table 2: Serum vitamin D status and biochemical profile

Parameter	Value (n=55)
<i>Serum 25(OH)D</i>	
Median (IQR) ng/mL	22.0 (14.0–28.7)
Mean $\pm$ SD, ng/mL	23.88 $\pm$ 14.77
Range ng/mL	4.0–84.0
<i>Vitamin D status n(%) [95%CI]</i>	
Severe deficiency (<10 ng/mL)	5 (9.1)
Deficiency (<20 ng/mL)	23 (41.8) [29.7–55.0]
Insufficiency (20–29.9 ng/mL)	20 (36.4)
Sufficiency ($\geq$ 30 ng/mL)	12 (21.8)
Below 30 ng/mL	43 (78.2) [65.6–87.1]
<i>Serum Biochemistry</i>	
Calcium mg/dL median (IQR)	9.0 (8.5–9.5)
Calcium mg/dL (mean $\pm$ SD)	8.83 $\pm$ 0.86
Calcium range mg/dL	6.8–10.4
Phosphate, mg/dL, median (IQR)	3.2 (2.85–3.70)
Phosphate, mg/dL, mean $\pm$ SD	3.34 $\pm$ 0.66
Phosphate range, mg/dL	2.0–5.1

Severe deficiency is a subset of deficiency. 95% CIs calculated by the Wilson method. 25(OH)D, 25-hydroxyvitamin D; CI, confidence interval.

Factors associated with vitamin D deficiency

On univariable analysis, deficiency was more frequent among physicians than among nursing and technical staff (66.7% vs 29.7%; OR 4.73, 95% CI 1.41–15.81; P = 0.018), among participants working >8 hours/day than $\leq$ 8 hours/day (65.0% vs 28.6%; OR 4.64, 95% CI 1.43–15.04; P = 0.012), among those with <1 hour/day of sunlight

exposure than ≥ 1 hour/day (50.0% vs 9.1%; OR 10.0, 95% CI 1.18–84.90; $P = 0.017$), and among those sleeping < 6 hours/day than ≥ 6 hours/day (51.4% vs 22.2%; OR 3.69, 95% CI 1.02–13.35; $P = 0.047$) (Table 3). None of the 11 participants with a recorded comorbidity was deficient, compared with 23 of 44 (52.3%) without comorbidity ($P = 0.001$). Sex, BMI category, symptoms, work schedule, income, physical activity, transport mode, diet, dairy intake and previous vitamin D intake were not significantly associated with deficiency.

Table 3: Univariable analysis of factors associated with vitamin D deficiency

Variable	Category	Deficient, n (%)	Non-deficient, n (%)	Crude OR (95% CI)	P value
Demographic and clinical					
Sex	Female	12 (37.5)	20 (62.5)	1 (reference)	0.581
	Male	11 (47.8)	12 (52.2)	1.53 (0.52–4.53)	
BMI	≥ 25 kg/m ²	9 (32.1)	19 (67.9)	1 (reference)	0.176
	< 25 kg/m ²	14 (51.9)	13 (48.1)	2.27 (0.76–6.80)	
Comorbidity	Present	0 (0.0)	11 (100.0)	Not estimable	0.001
	Absent	23 (52.3)	21 (47.7)		
Symptoms	Absent	6 (28.6)	15 (71.4)	1 (reference)	0.085
	Present	17 (56.7)	13 (43.3)	3.27 (0.99–10.75)	
Occupational					
Professional group	Nursing/technical	11 (29.7)	26 (70.3)	1 (reference)	0.018
	Physician	12 (66.7)	6 (33.3)	4.73 (1.41–15.81)	
Working duration	≤ 8 h/day	10 (28.6)	25 (71.4)	1 (reference)	0.012
	> 8 h/day	13 (65.0)	7 (35.0)	4.64 (1.43–15.04)	
Work schedule	Rota-based	15 (37.5)	25 (62.5)	1 (reference)	0.363
	Standard	8 (53.3)	7 (46.7)	1.90 (0.57–6.32)	
Annual income	$\leq ₹10$ lakh	5 (33.3)	10 (66.7)	1 (reference)	0.545
	$> ₹10$ lakh	18 (45.0)	22 (55.0)	1.64 (0.47–5.66)	
Lifestyle and dietary					
Sunlight exposure	≥ 1 h/day	1 (9.1)	10 (90.9)	1 (reference)	0.017
	< 1 h/day	22 (50.0)	22 (50.0)	10.0 (1.18–84.90)	
Sleep duration	≥ 6 h/day	4 (22.2)	14 (77.8)	1 (reference)	0.047
	< 6 h/day	19 (51.4)	18 (48.6)	3.69 (1.02–13.35)	

Values are n (row %). P values by Fisher's exact test.

Continuous variables and correlations

Deficient participants were younger than non-deficient participants (32.91 ± 5.68 vs 43.31 ± 10.83 years; $P < 0.001$) and had lower serum calcium (median 8.50 vs 9.35 mg/dL; $P = 0.002$) and phosphate (median 2.90 vs 3.60 mg/dL; $P = 0.004$), whereas BMI did not differ ($P = 0.178$). Serum 25(OH)D correlated positively with age ($\rho = 0.592$; $P < 0.001$), serum calcium ($\rho = 0.486$; $P < 0.001$) and serum phosphate ($\rho = 0.390$; $P = 0.003$), but not with BMI ($\rho = 0.164$; $P = 0.232$) (Table 4).

Table 4. Continuous variables by vitamin D status and their correlation with serum 25(OH)D

Variable	Deficient (n=23)	Non-deficient (n = 32)	P value ^a	ρ^b	P value
Age, years, mean $\pm$ SD	32.91 ± 5.68	43.31 ± 10.83	< 0.001	0.592	< 0.001
BMI, kg/m ² , median (IQR)	24.62 (23.60–25.55)	25.57 (23.61–27.51)	0.178	0.164	0.232
Calcium, mg/dL, median (IQR)	8.50 (7.90–9.00)	9.35 (8.80–9.60)	0.002	0.486	< 0.001
Phosphate, mg/dL, median (IQR)	2.90 (2.80–3.30)	3.60 (3.00–4.00)	0.004	0.390	0.003

^aStudent's *t* test for age; Mann–Whitney *U* test for other variables. ^bSpearman correlation with serum 25(OH)D concentration (*n* = 55).

Multivariable analysis

With 23 deficiency events, the multivariable model was restricted to three predictors: age, daily working duration and daily sunlight exposure. Professional group and sleep duration were represented through their closely related variables, age and working duration, and comorbidity was not modelled because no deficiency occurred in that subgroup. Increasing age (aOR 0.88 per year; 95% CI 0.79–0.97; *P* = 0.011) and working >8 hours/day (aOR 5.01; 95% CI 1.22–20.51; *P* = 0.025) were independently associated with deficiency, whereas sunlight exposure <1 hour/day was not significant after adjustment (aOR 1.08; 95% CI 0.07–16.56; *P* = 0.956) (Table 5).

Table 5. Multivariable logistic regression for factors associated with vitamin D deficiency

Predictor	Adjusted OR (95% CI)	P value
Age (per 1-year increase)	0.88 (0.79–0.97)	0.011
Working duration >8 h/day (vs ≤8 h/day)	5.01 (1.22–20.51)	0.025
Sunlight exposure <1 h/day (vs ≥1 h/day)	1.08 (0.07–16.56)	0.956

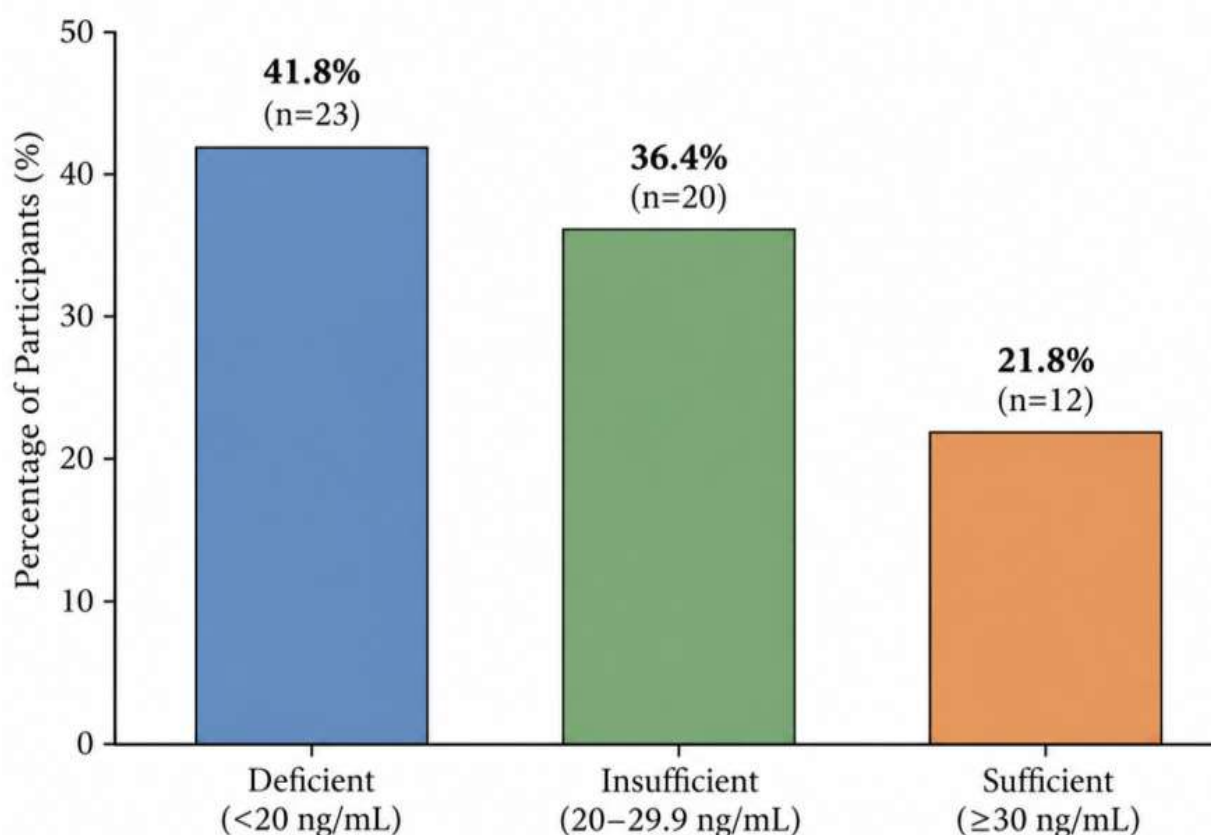


Figure 1. Distribution of vitamin D status among neurosurgical ICU healthcare workers (*n* = 55).

DISCUSSION

The present cross-sectional study evaluated vitamin D status and its demographic, occupational, lifestyle, and biochemical correlates among healthcare workers employed in a neurosurgical intensive care unit in North India. Vitamin D deficiency, defined as serum 25(OH)D <20 ng/mL, was present in 41.8% of participants. An additional 36.4% had vitamin D insufficiency, leaving only 21.8% with concentrations ≥30 ng/mL. Consequently, more than three-quarters (78.2%) of the study population had serum 25(OH)D

below 30 ng/mL. The major factors associated with deficiency in univariable analysis were professional group, longer working hours, limited sunlight exposure, shorter sleep duration, and younger age. Serum vitamin D was also positively correlated with serum calcium and phosphate. In the multivariable model, younger age and working for more than 8 hours per day remained independently associated with vitamin D deficiency.

The observed prevalence confirms that inadequate vitamin D status is common even among medically

knowledgeable, apparently healthy healthcare personnel working in a sun-rich region. Although the 41.8% prevalence of deficiency in our cohort was lower than that reported in several previous healthcare-worker populations, the combined prevalence of deficiency and insufficiency remained substantial. Multani et al. evaluated 214 resident doctors working at a teaching hospital and reported a high burden of adverse skeletal and vitamin D-related risk factors in a group characterized by irregular lifestyles and limited opportunities for sunlight exposure [11]. More specifically, Bishnoi et al. studied 120 anaesthesiologists from tertiary-care hospitals in Chandigarh and found vitamin D deficiency in 84.2% and insufficiency in a further 8.3%, with a mean serum vitamin D concentration of only 14.56 ± 9.39 ng/mL [12]. A recent Indian study involving 317 healthcare workers similarly reported deficiency in 71.9% and insufficiency in 22.1% [13].

Differences in prevalence between studies should be interpreted in relation to differences in occupational composition, age distribution, geographic location, season of sampling, supplementation practices, assay methodology, and thresholds used to categorize vitamin D status. The present cohort included physicians, nursing officers, technicians, and nursing orderlies rather than only doctors. Furthermore, some participants had a history of previous vitamin D intake, although individuals currently receiving supplementation were excluded. Therefore, the lower prevalence of deficiency in our study does not necessarily indicate a lower occupational risk. The finding that 78.2% of participants remained below 30 ng/mL demonstrates that optimal vitamin D status was uncommon.

Professional designation was significantly related to vitamin D status. Deficiency was observed in 66.7% of physicians compared with 29.7% of nursing and technical personnel. Doctors working in critical-care environments frequently spend prolonged periods in enclosed clinical areas, undertake emergency duties, and may have fewer opportunities for routine daytime outdoor exposure. The findings of Bishnoi et al. are relevant in this context: anaesthesiologists worked an average of 10.70 ± 1.56 hours per day, and 84.2% were vitamin D deficient [12]. Resident doctors have also been identified as an occupational group vulnerable to poor bone and vitamin D status [11]. These comparisons support the possibility that the nature and duration of clinical duties contribute to vitamin D inadequacy, although professional designation itself should not be interpreted as a causal factor.

Working duration was one of the strongest occupational findings in the present analysis. Vitamin D deficiency occurred in 65.0% of participants working >8 hours per day, compared with 28.6% of those working ≤ 8 hours. After adjustment for age and sunlight exposure, working >8 hours remained independently associated with vitamin D deficiency,

with an adjusted odds ratio of 5.01. Prolonged indoor work can reduce the time available for effective ultraviolet-B exposure, particularly when duty hours overlap with daylight periods. Research among indoor office workers has similarly documented a high frequency of vitamin D deficit and reported associations with sedentary lifestyle, dietary factors, BMI, and indices of sunlight exposure [14]. The present result therefore supports consideration of occupational duration as an important component of vitamin D risk assessment among ICU staff.

Daily sunlight exposure showed a clear association in the unadjusted analysis. Half of the participants reporting <1 hour of sunlight exposure per day were deficient, compared with only 9.1% of those reporting at least 1 hour. However, the association did not remain statistically significant after multivariable adjustment. This loss of significance should not be interpreted as evidence that sunlight exposure is unimportant. Only 11 participants reported ≥ 1 hour of daily exposure, resulting in a very wide confidence interval in the adjusted model. The study was therefore underpowered to estimate this association precisely. The direction of the unadjusted finding remains biologically plausible and consistent with studies of indoor occupational groups, in whom restricted outdoor exposure is commonly associated with lower vitamin D concentrations [14].

Sleep duration also differed according to vitamin D status. Deficiency affected 51.4% of participants sleeping less than 6 hours per day compared with 22.2% of those sleeping ≥ 6 hours. Lee et al., in a study involving hospital-based daytime and night-shift workers, found that vitamin D deficiency among daytime workers was associated with shorter total sleep duration and greater daytime sleepiness [15]. A systematic review and meta-analysis has also reported improvement in sleep-quality measures following vitamin D supplementation, although heterogeneity among the included trials was substantial [16]. The relationship between vitamin D and sleep is likely complex and potentially bidirectional. In the ICU setting, short sleep may coexist with long duties, rotating schedules, reduced outdoor activity, and circadian disruption; therefore, the present cross-sectional design cannot determine whether low vitamin D contributes to poor sleep or whether occupational patterns causing short sleep simultaneously limit sunlight exposure.

An interesting finding was the inverse relationship between age and vitamin D deficiency. Deficient participants were significantly younger than non-deficient participants, and each additional year of age was associated with approximately 12% lower adjusted odds of deficiency. Although vitamin D inadequacy is traditionally considered common in older adults, similar patterns have been reported in some Indian populations. In the Chandigarh Urban Bone Epidemiological Study involving 915 healthy North

Indian adults, serum 25(OH)D showed a weak positive correlation with age, and vitamin D supplementation was more frequent among older participants [17]. In the present occupational cohort, younger healthcare workers may have had more demanding duty patterns, greater proportions of residency or junior clinical work, or different lifestyle patterns. However, these explanations were not directly tested and should not be regarded as established mechanisms.

The biochemical findings also merit attention. Participants with vitamin D deficiency had significantly lower serum calcium and phosphate levels, and serum vitamin D showed positive correlations with both calcium ($p=0.486$) and phosphate ($p=0.390$). Data from the North Indian CUBES cohort also demonstrated a statistically significant positive relationship between serum calcium and 25(OH)D, although the strength of that association was relatively weak [17]. Vitamin D is central to intestinal calcium and phosphate absorption and maintenance of mineral homeostasis; nevertheless, serum calcium is tightly regulated and may remain within the reference range despite vitamin D deficiency. Indian research examining vitamin D thresholds in relation to calcium-phosphate homeostasis has further shown that interpretation of vitamin D status should consider the broader biochemical and skeletal context rather than an isolated laboratory value [18].

No significant association was observed with sex, BMI, vegetarian versus non-vegetarian diet, dairy intake, physical activity, mode of transport, income, or previous vitamin D use. Lack of statistical significance does not establish absence of an effect, particularly with a sample of only 55 participants. For example, deficiency was numerically lower among participants reporting previous vitamin D intake (27.8%) than among those without previous intake (50.0%). Bishnoi et al. reported a much lower prevalence of deficiency among doctors who had previously taken vitamin D supplements than among those who had not [12]. The present study may therefore have lacked adequate statistical power to detect modest dietary or supplementation-related associations.

The absence of vitamin D deficiency among the 11 participants with comorbidities should be interpreted cautiously. Given the small subgroup size, exclusion of major chronic illnesses, and possible effects of greater healthcare surveillance, lifestyle changes, or prior supplementation, this finding should not be considered evidence of a protective effect of comorbidity and requires confirmation in larger studies.

STRENGTHS OF THE STUDY

The study has several strengths. It examined a clearly defined occupational population working within a closed neurosurgical ICU, measured serum 25(OH)D rather than relying on dietary or symptom-based assessment, and simultaneously evaluated occupational

exposure, lifestyle characteristics, serum calcium, and serum phosphate. The identification of longer working duration as an independent correlate provides an occupational-health perspective that may be particularly relevant to critical-care personnel.

LIMITATIONS

This was a single-centre study with a modest sample, which limits generalizability, and its cross-sectional design precludes causal inference. Lifestyle and occupational variables, including sunlight exposure, were self-reported and not objectively measured. Sampling during a single monsoon month did not capture seasonal variation, and parathyroid hormone was not measured. The number of deficiency events also restricted the multivariable model to a few predictors. Larger multicentre studies with objective assessment of sunlight exposure and seasonal sampling are needed to confirm these findings and define modifiable risk factors.

CONCLUSION

Vitamin D deficiency was common among healthcare workers of the neurosurgical intensive care unit, affecting 41.8% of participants, while 78.2% had serum 25(OH)D concentrations below 30 ng/mL. Younger age and working more than 8 hours per day were independently associated with deficiency, while limited sunlight exposure and shorter sleep duration were associated on univariable analysis. These findings suggest that occupational factors contribute substantially to inadequate vitamin D status in critical-care staff. Periodic screening and targeted supplementation for younger staff and those working prolonged duty hours, particularly resident doctors, may be considered as part of institutional occupational-health programmes.

DECLARATIONS

Ethical Approval and Consent to Participate

The study was conducted in accordance with the principles of the Declaration of Helsinki and the approved study protocol. Ethical approval was obtained from the appropriate Institutional Ethics Committee before commencement of the study. Written informed consent was obtained from all participants prior to enrolment.

Consent for Publication

Not applicable. No individual-level identifiable information or identifiable images are presented in this manuscript.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Both authors contributed to the conception and design of the study, data collection, analysis and interpretation of findings, drafting and critical revision of the manuscript, and approved the final version for publication.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to applicable ethical and institutional restrictions.

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AI-Assisted Writing Disclosure

The authors declare that no generative artificial intelligence tool was used to generate the scientific findings, data, statistical analyses, or conclusions of this manuscript. Any language editing, if applicable, did not alter the scientific content or interpretation of the study.

REFERENCES

1. Kalra S, Zargar AH, Das AK, Baidya A, Dasgupta A, Selvan C, et al. Prevention and treatment of vitamin D deficiency in India: an expert group consensus. *Indian J Endocrinol Metab.* 2025;29(1):13-26. doi:10.4103/ijem.ijem_264_24.
2. Venkatesh U, Sharma A, Ananthan VA, Subbiah P, Durga R, CSIR Summer Research Training Team. Micronutrient's deficiency in India: a systematic review and meta-analysis. *J Nutr Sci.* 2021;10: e110. doi:10.1017/jns.2021.102.
3. Siddiquee MH, Bhattacharjee B, Siddiqi UR, MeshbahurRahman M. High prevalence of vitamin D deficiency among the South Asian adults: a systematic review and meta-analysis. *BMC Public Health.* 2021;21:1823. doi:10.1186/s12889-021-11888-1.
4. Sowah D, Fan X, Dennett L, Hagtvedt R, Straube S. Vitamin D levels and deficiency with different occupations: a systematic review. *BMC Public Health.* 2017;17:519. doi:10.1186/s12889-017-4436-z.
5. Beloyartseva M, Mithal A, Kaur P, Kalra S, Baruah MP, Mukhopadhyay S, et al. Widespread vitamin D deficiency among Indian health care professionals. *Arch Osteoporos.* 2012;7:187-192. doi:10.1007/s11657-012-0096-x.
6. Nandyala S, Mohamed A, Bhargava A, Chaurasia S, Senthil S, Vaddavalli PK. Vitamin D deficiency in healthcare professionals across the network of an eye care organization in India. *Indian J Ophthalmol.* 2021;69(2):455-456. doi:10.4103/ijo.IJO_2371_20.
7. Singh SK, Prakash V, Tiwari S, Daliparthi DP, Singh S, Jain P. Summer and winter prevalence of vitamin D deficiency of young resident doctors in North India. *Nutr Diet.* 2011;68(4):280-284. doi:10.1111/j.1747-0080.2011.01553.x.
8. Chodhary I, Mala TA, Arif T. Prevalence of vitamin D deficiency among doctors in a tertiary care centre in north India. *Int J Res Med Sci.* 2019;7(6):2362-2368. doi:10.18203/2320-6012.ijrms20192528.
9. Goswami R, Saha S, Sreenivas V, Singh N, Lakshmy R. Vitamin D-binding protein, vitamin D status and serum bioavailable 25(OH)D of young Asian Indian males working in outdoor and indoor environments. *J Bone Miner Metab.* 2017;35(2):177-184. doi:10.1007/s00774-016-0739-x.
10. Phelan J, Thangamuthu A, Muthumeenal S, Houston K, Everton M, Gowda S, et al. Vital D: a modifiable occupational risk factor of UK healthcare workers. *PLoS One.* 2024;19(4): e0296247. doi:10.1371/journal.pone.0296247.
11. Multani SK, Sarathi V, Shivane V, Bandgar TR, Menon PS, Shah NS. Study of bone mineral density in resident doctors working at a teaching hospital. *J Postgrad Med.* 2010;56(2):65-70. doi:10.4103/0022-3859.65272.
12. Bishnoi S, Gombar S, Ahuja V, Bhardwaj N, Kaur J. Vitamin D levels of anesthesiologists working in tertiary care hospital of South Asian country: an observational study. *J Anaesthesiol Clin Pharmacol.* 2021;37(2):237-242. doi:10.4103/joacp.JOACP_310_19.
13. Kori VK, Gohiya A, Shah AK, Patil M, Kumar V. Prevalence of vitamin D deficiency among health care workers of a tertiary care centre in India. *J Orthop Case Rep.* 2026;16(8):406-410. doi:10.13107/jocr.2026.v16.i08.7910.
14. Mahajan C, Singla N, Jain D. High incidence of vitamin D deficiency (VDD) among indoor workers: association with dietary and lifestyle factors. *Ecol Food Nutr.* 2024;63(2):40-62. doi:10.1080/03670244.2024.2306386.
15. Lee HJ, Choi H, Yoon IY. Impacts of serum vitamin D levels on sleep and daytime sleepiness according to working conditions. *J Clin Sleep*

- Med. 2020;16(7):1045-1054.
doi:10.5664/jcsm.8390.
16. Mirzaei-Azandaryani Z, Abdolalipour S, Mirghafourvand M. The effect of vitamin D on sleep quality: a systematic review and meta-analysis. *Nutr Health*. 2022;28(4):515-526. doi:10.1177/02601060221082367.
 17. Aggarwal A, Ram S, Garg A, Pal R, Bhansali A, Singh P, et al. Metabolic bone profile of healthy adult North Indian population from Chandigarh Urban Bone Epidemiological Study (CUBES). *Indian J Clin Biochem*. 2021;36(1):67-73. doi:10.1007/s12291-019-00857-6.
 18. Gupta N, Agarwal A, Jindal R, Santhosh SR. Estimating vitamin D threshold for the Indian population: delving into the actual disease burden. *Med J Armed Forces India*. 2023;79(Suppl 1) S224-S229. doi:10.1016/j.mjafi.2022.08.001.