International Journal of General Medicine

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

High Prevalence and Risk Factors Associated with Vitamin D Deficiency Among Chinese Hospital Staff: A Cross-Sectional Study

Fang Gao[1,*], Xialin Zhang[2,*], Xiaolan Wang[2], Junyan Zhang[3], Fang Wang[1], Yan Zhou[4], Jing Wang[1], Xuewen Li[5], Ruijuan Zhang[2]

[1]Department of Prevention Care in Healthcare, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, People's Republic of China; [2]Department of Hematology, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, People's Republic of China; [3]Department of Clinical Epidemiology and Evidence-Based Medicine, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, People's Republic of China; [4]Department of Laboratory, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, People's Republic of China; [5]Department of Cardiology, Shanxi Bethune Hospital, Shanxi Academy of Medical Sciences, Tongji Shanxi Hospital, Third Hospital of Shanxi Medical University, Taiyuan, People's Republic of China

*These authors contributed equally to this work

Correspondence: Ruijuan Zhang; Xuewen Li, Email 13593169668@163.com; xuewenli1010@126.com

Purpose: To determine the current status of vitamin D status and the associated factors for its deficiency among Chinese hospital staff.

Methods: The physical examination data of 2509 hospital staff members was analyzed alongside that of 1507 patients who visited the hospital during the corresponding period of the examination. Serum concentration of 25-hydroxyvitamin D (25(OH)D) were measured in the participants. The hospital staff also completed surveys about general information, laboratory examination, and occupational characteristics.

Results: The median vitamin D status (serum 25(OH)D concentration) of the participants was 9.0 ng/mL, ranging from 6.5 to 44.7 ng/mL, and the prevalence of deficiency (<12.3 ng/mL) was 81.47% (2044/2509). The multivariable logistic regression revealed that nurses (OR = 1.54, 95% CI 1.09–2.19, p = 0.015), BMI below 18 (OR = 2.39, 95% CI 1.02–5.58, p = 0.045) associated with higher prevalence of vitamin D deficiency. In the contrast, age above 30 (OR = 0.69, 95% CI 0.53–0.91, p = 0.009) and a high level of uric acid (OR = 0.56, 95% CI 0.41–0.78, p = 0.001) associated with lower prevalence of vitamin D deficiency. The prevalence of vitamin D deficiency was higher among the hospital staff (81.47%) compared to the patients who visited the hospital during the same time period (65.69%). A substantial disparity was observed in the propensity score matching dataset (69.14% vs 79.94%, p < 0.001).

Conclusion: Hospital staff are a high-risk group for vitamin D deficiency. Paying attention to vitamin D status and supplementation of this vitamin are pertinent aspects of hospital staff health care. Outdoor activities, vitamin D supplementation, and foods rich in vitamin D should be advocated.

Keywords: vitamin D deficiency, 25-hydroxyvitamin D, hospital staff, cross-sectional

Introduction

Vitamin D deficiency is prevalent worldwide in the 21st century and has been recognized as a global health problem.[1] In recent years, vitamin D has been better understood and has been identified to play an important role in regulating calcium and phosphorus metabolism to maintain the physiological functions of the musculoskeletal system. Moreover, it is a widely expressed and multifaceted vitamin whose receptors are found in various organ systems throughout the body. Vitamin D deficiency is closely associated with the development of various acute and chronic diseases, such as metabolic

Received: 29 December 2023
Accepted: 23 April 2024
Published: 3 May 2024

syndrome related disorders, autoimmune diseases, diabetes, psychiatric diseases, respiratory and cardiovascular diseases, and cancer.[2,3] Therefore, the prevention of vitamin D deficiency is a crucial and urgent public health problem.

Vitamin D is a lipid-soluble vitamin, and in healthy individuals, approximately 90% of it is synthesized endogenously via the interaction of solar ultraviolet B (UVB) radiation with the precursor molecule 7-dehydrocholesterol in the skin. To a lesser extent, this vitamin comes from dietary intake and supplementation. Vitamin D precursors of dermal and dietary origin are hydroxylated in the liver to form 25(OH)D_3, which subsequently enters the bloodstream and is hydroxylated in the renal and extra-renal (including immune system cells, placenta and many others tissues) to form 1.25$(OH)_2D_3$. 25 (OH)D is the main circulating form of vitamin D in the bloodstream, and its serum concentration is used as a measure of an individual's vitamin D status (serum 25(OH)D concentration).[4]

Currently, extensive data indicate that the prevalence of vitamin D deficiency in humans is gradually increasing worldwide. It has been reported that the lowest threshold of serum 25(OH)D <25 or 30 nmol/L (10 or 12ng/mL) can be used in both lower- and high-income countries.[5] The prevalence of individuals with a critical value of vitamin D status of <30 nmol/L (or 12 ng/mL) is 18–46% in Africa,[6] 22.82% in Asia,[7] and 13% in Europe,[8] with Asians being most susceptible to vitamin D deficiency. Numerous factors influence vitamin D deficiency, including hours of sunlight, latitude, occupation, skin pigmentation, age, dietary habits, sex, and genetics. As endogenous vitamin D synthesis is highly dependent on sunlight, insufficient solar radiation may be a major cause of vitamin D deficiency.[9–11] Due to the absorption of UVB by the ozone layer, it is difficult for people living below 33° latitude to get enough vitamin D from light exposure.[12] As a tertiary hospital, Shanxi Bethune Hospital is situated at 37°54′ north latitude and contends with a relative scarcity of sunlight, averaging around 170 hours per month from November to February annually (source: https://en.wikipedia.org/wiki/Taiyuan), coinciding with the period when our hospital staff undergo their physical examinations. Several studies have shown a significantly increased risk of vitamin D deficiency in people engaged in shift work and office work; hence, occupation is a key factor resulting in insufficient solar radiation exposure and thus low vitamin D status.[13] Hospital staff, as a special group, mostly work in shifts, and this work pattern hinders endogenous vitamin D synthesis via solar UVB exposure. Therefore, it is reasonable to assume that healthcare workers are at risk for vitamin D deficiency. Studies on vitamin D status in medical personnel conducted in various countries, such as Spain,[14] Turkey,[15] India,[16] and Korea,[17] have reported some degree of deficiency, which supports this hypothesis. Although China is the largest country in Asia and has a large number of hospital staff, there is a dearth of studies on vitamin D status and risk factors among hospital staff in the Chinese context. Therefore, in this research, we determined the serum concentration of 25(OH)D in the hospital staff at Shanxi Bethune Hospital, China, and explored the risk factors associated with vitamin D deficiency.

Methods

Study Design

This investigation was conducted as a cross-sectional study, analyzing physical examination data collected from both hospital staff and patients attending the outpatient department at Shanxi Bethune Hospital during the same timeframe when hospital staff underwent their physical examinations, spanning from January to March 2022. The data were retrieved from the Hospital Information System in May 2023 by staff members of the Information Department who were not involved in the study being presented. Prior to analysis, all identifying information, was removed from the dataset to protect patient privacy. The primary outcome was to compare the prevalence of vitamin D deficiency among different categories of hospital staff.

Participants

The survey was approved by the Ethics Committee of Shanxi Bethune Hospital and was conducted in accordance with the tenets of the Declaration of Helsinki.

Data from physical examinations conducted on 2509 hospital staff members at Shanxi Bethune Hospital, China. These staff members were categorized as follows: 312 administrative staff, 608 licensed physicians, 253 medical scientists, and 1336 nurses (four categories).

The inclusion criteria for hospital staff

- Age ≥ 23 and ≤60
- Staff of Shanxi Bethune Hospital

The exclusion criteria for hospital staff

- Staff with malignant neoplasms
- Retired employees

The inclusion criteria for patients

- Age ≥ 23 and ≤60
- Visited outpatients department at the same time period of staff physical examination
- Took blood test examination with the result of VitD concentration

The exclusion criteria for patients

- With malignant neoplasms

Measurements

According to the vitamin D evaluation criteria, a vitamin D status of <12 ng/mL (30 nmol/L) was accepted as vitamin D deficiency, 12–20 ng/mL (30–50 nmol/L) as insufficiency, and >20 ng/mL (50 nmol/L) as sufficiency.[18] In 2011, the Institute of Medicine in US recommended that vitamin D status of <12.5 ng/mL (31.25 nmol/L) should be considered as vitamin D deficiency.[19] Another research in 2011 reported that recommended defining 25(OH)D < 20ng/mL as vitamin D deficiency.[20] Among all individuals, vitamin D status were measured using the enzyme-linked immunosorbent assay (Immuno-diagnostic System Limited, Hong Kong, China). According to the product manual of the enzyme-linked immunosorbent assay vitamin D status <12.3 ng/mL (30.75 nmol/L) was defined as vitamin D deficiency in this presented study.

Information pertaining to demographic characteristics, anthropometric measures, health screening, occupational exposure (surgical operational work and radiation exposure), and laboratory indexes was acquired. Besides vitamin D status, the following variables were collected including thyroid-stimulating hormone (TSH), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), lipid, uric acid (UA), cholesterol (CHO), triglyceride (TG), and glucose (Glc). The variables of height and weight were collected to generate body mass index (BMI). Blood pressure was assessed after individuals had been seated for 5 minutes, using a cuff for measurement.

Additionally, vitamin D status data were gathered from 1507 patients aged 23 to 60, matching the age range of the hospital staff, who visited Shanxi Bethune Hospital during the same period. This data was collected to evaluate the vitamin D status of the hospital staff. All blood samples were taken fasting.

Surgical relevant work refers to those staff members who perform surgery as part of their daily tasks, while radiation exposure refers to those who work regularly with radiation, such as personnel in radiology and interventional procedures involving catheterization.

Statistical Analysis

Descriptive statistics were used for continuous variables with a normal distribution, and the data were expressed as mean and standard deviation. Median and interquartile range (Q1-Q3) were reported for abnormally distributed continuous variables. Comparisons of normally distributed data were made using Student's *t*-test and one-way analysis of variance, whereas the Wilcoxon rank-sum test was employed for non-normally distributed quantitative data. Categorical variables were analyzed using the chi-square or Fisher's exact test. Univariate and multivariate logistic regression analyses were performed to assess factors related to vitamin D deficiency, and the results were presented as adjusted odds ratios (ORs) and 95% confidence intervals (95% CIs). Propensity score matching (PSM) was conducted to align the demographic characteristics of patients with those of hospital staff, including age and sex. PSM was employed with a caliper of 0.02 to establish a 1:1 ratio in the PSM dataset. Statistical analyses were performed using Stata SE 13 (Serial number 401306302851), R software version 3.6.1 (http://cran.r-project.org/), and easy-R (www.empowerstats.com). Stata SE 13 was utilized for both univariate and multivariate logistic regression analyses. R software was employed to generate the PSM dataset. Easy-R was utilized on Student's *t*-test, one-way analysis of variance, Wilcoxon rank-sum test, chi-square test, and Fisher's exact test.

Sample size was calculated based on the following parameters: the lowest prevalence of vitamin D deficiency among staff was 70%, while the highest rate was 80%. Two hundred and twenty samples were needed for each medical category when α equals 0.05 and β equals 0.2.

Results

Participant Characteristics

Of the 2509 individuals, 1945 were women and 564 were men, with a mean age of 34.96 ± 6.36 (min-max: 23–60) years. A total of 312 were administrative staff, 608 individuals were licensed physicians, 253 were medical scientists, and 1376 were nurses. The demographic information of all participants are listed in Table 1. Significant differences were observed among the four categories of hospital staff in terms of sex, age, BMI, hypertension, surgery-related work, and radiation exposure, with all p-values being below 0.001 (Table 1).

The serum vitamin D status, presented as the median followed by the interquartile range (Q1~Q3). Among hospital staff, the median value of serum 25(OH)D was 9.0 ng/mL (7.50~11.20) and ranged from 6.5 to 44.7 ng/mL. A total of 2044 participants (81.47%) exhibited a vitamin D status of <12.3 ng/mL. The median concentration of serum 25(OH)D of the four categories of hospital staff were as follows: 9.6 (7.90~12.20), 9.4 (7.70~11.62), 9.6 (7.90~12.20), and 8.7 (7.30~10.60), yielding a statistically significant p-value of 0.0001 (Table 2). Table 2 also indicates a significant difference among the four categories of staff in terms of Vitamin D deficiency, thyroid-stimulating hormone (TSH), low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), UA, cholesterol (CHO), triglyceride (TG), and Glc.

Univariable and Multivariable Analysis for Vitamin D Deficiency Among Hospital Staff

According to the findings of univariable analysis, females (OR = 1.60, 95% CI 1.28–2.01, p < 0.0001), individuals engaged in nursing (OR = 1.95, 95% CI 1.45–2.63, p < 0.0001), BMI below 18 (OR = 2.69, 95% CI 1.16–6.23, p = 0.0211), and staff involved in surgical relevant work (OR = 1.40, 95% CI 1.13–1.74, p = 0.024) associated to higher prevalence of vitamin D deficiency. Meanwhile, employees above 30 years of age (OR = 0.57, 95% CI 0.44–0.74, p < 0.0001), BMI above 24 (OR = 0.69, 95% CI 0.56–0.85, p = 0.0004), individual with hypertension (OR = 0.77, 95% CI 0.62–0.96, p = 0.0191), high a level of UA (OR = 0.47, 95% CI 0.35–0.63, p < 0.0001), and high level of CHO (OR = 0.70, 95% 0.55–0.88, p = 0.0029) associated with to lower prevalence of vitamin D deficiency (Table 3).

Table 1 Demographic Information of All Hospital Staff

	Overall (n=2509)	AS (n=312)	LP (n=608)	MS (n=253)	Nurse (n=1336)	Statistics	P-value
Sex (male)	564 (22.48%)	141 (45.19%)	238 (39.14%)	97 (38.34%)	88 (6.59%)	χ^2=419.43	<0.001
Age							
Mean ± SD	34.96 ±6.36	37.53 ±7.30	36.89 ±6.03	35.8 ±5.28	33.33 ±5.97	F=72.14	< 0.001
Median (q1-q3)	34 (31~38)	36 (33~41)	37 (32~41)	36 (33~39)	33 (29~36)		
Min-max	23~60	24~60	26~59	24~59	23~58		
BMI (kg/m^2)							
Mean ± SD	23.25 ±3.47	24.02 ±3.80	23.97 ±3.61	23.81 ±3.65	22.64 ±3.16	F=31.04	< 0.001
Within normal range (18~24)	1520 (60.58%)	171 (54.81%)	321 (52.80%)	139 (54.94%)	889 (66.54%)	χ^2=58.19	<0.001
Underweight (<18)	86 (3.43%)	8 (2.56%)	15 (2.47%)	7 (2.77%)	56 (4.19%)		
Overweight or obesity (>24)	903 (35.99%)	133 (42.63%)	272 (44.74%)	107 (42.29%)	391 (29.27%)		
Hypertension	704 (28.06%)	115 (36.86%)	198 (32.57%)	94 (37.15%)	297 (22.23%)	χ^2=50.94	<0.001
Surgical relevant work	915 (36.47%)	3 (0.96%)	252 (41.45%)	9 (3.56%)	651 (48.73%)	χ^2=381.22	< 0.001
Radiation exposure	213 (8.49%)	0 (0.00%)	120 (19.74%)	47 (18.58%)	46 (3.44%)	χ^2=204.88	< 0.001

Abbreviations: AS, Administrative staff; LP, Licensed physicians; MS, Medical scientists; BMI, Body Mass Index.

Table 2 Laboratory Testing Results for All Hospital Staff

	Overall (n=2509)	AS (n=312)	LP (n=608)	MS (n=253)	Nurse (n=1336)	Statistics	P-value
Vitamin D (ng/mL)							
Median (q1-q3)	9.00 (7.50~11.20)	9.60 (7.90~12.20)	9.40 (7.70~11.62)	9.60 (7.90~12.20)	8.70 (7.30~10.60)	χ^2=−5.89	0.0001
Min-max	6.50~44.70	6.50~36.90	6.50~40.00	6.50~44.70	6.50~43.70		
Vitamin D deficiency	2044 (81.47%)	235 (75.32%)	475 (78.12%)	190 (75.10%)	1144 (85.63%)	χ^2=34.43	<0.001
TSH (μIU/mL) (median (q1-q3))	2.30 (1.62~3.24)	2.09 (1.52~3.13)	2.24 (1.61~3.10)	2.23 (1.62~3.20)	2.38 (1.67~3.35)	χ^2=10.253	0.0165
FT3 (pg/mL) (mean ± SD)	3.71 ±0.46	3.77 ±0.45	3.70 ±0.40	3.72 ±0.43	3.70 ±0.49	F=2.45	0.062
FT4 (ng/dL) (mean ± SD)	0.86 ±0.15	0.86 ±0.13	0.87 ±0.13	0.86 ±0.14	0.86 ±0.16	F=0.52	0.670
LDL-C (mmol/L) (mean ± SD)	2.93 ±0.66	3.12 ±0.67	3.05 ±0.65	2.99 ±0.69	2.81 ±0.64	F=31.73	< 0.001
HDL-C (mmol/L) (mean ± SD)	1.38 ±0.29	1.32 ±0.29	1.36 ±0.30	1.35 ±0.30	1.41 ±0.29	F=12.14	< 0.001
UA (μmol/L) (median (q1-q3))	270.8 (229.1~329.7)	299.2 (254.6~377.8)	291.9 (236.3~369.7)	285.0 (242.2~353.5)	255.5 (219.9~298.6)	F=76.40	< 0.001
CHO (mmol/L) (mean ± SD)	4.61 ±0.86	4.83 ±0.86	4.75 ±0.82	4.65 ±0.92	4.49 ±0.84	F=21.40	< 0.001
TG (mmol/L) (median (q1-q3))	0.91 (0.67~1.36)	1.10 (0.75~1.70)	1.03 (0.76~1.54)	1.04 (0.72~1.62)	0.82 (0.62~1.15)	χ^2=137.839	0.0001
Glc (mmol/L) (mean ± SD)	4.88 ±0.78	4.96 ±0.87	4.99 ±0.88	4.94 ±1.01	4.80 ±0.63	F=10.07	< 0.001

Abbreviations: AS, Administrative staff; LP, Licensed physicians; MS, Medical scientists; TSH, thyroid stimulating hormone; FT3, free thyroxine 3; FT4, free thyroxine 4; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; CHO, cholesterol; TG, triacylglycerol; Glc, glucose.

Table 3 Univariable and Multivariable Logistic Regression for the Vitamin D Deficiency Among All Hospital Staff

		Number (%)	Univariable Analysis		Multivariable Analysis	
			OR (95% CI)	P-value	OR (95% CI)	P-value
Sex	Female	1945 (77.52%)	1.60 (1.28, 2.01)	<0.0001	1.06 (0.80, 1.41)	0.677
Age	>30	1899 (75.69%)	0.57 (0.44, 0.74)	<0.0001	0.69 (0.53, 0.91)	0.009
Job category	AS	312 (12.44%)	1.0			
	LP	608 (24.23%)	1.17 (0.85, 1.61)	0.3376	1.08 (0.76, 1.53)	0.685
	MS	253 (10.08%)	0.99 (0.67, 1.45)	0.9516	0.96 (0.64, 1.42)	0.821
	Nurse	1336 (53.25%)	1.95 (1.45, 2.63)	<0.0001	1.54 (1.09, 2.19)	0.015
TSH (μIU/mL)	Within normal range (0.56–5.91)	2338 (93.18%)	1.0			
	Subpar to normal range (≤0.56)	63 (2.51%)	0.66 (0.37, 1.18)	0.1640		
	Superior to normal range (≥5.91)	108 (4.30%)	1.13 (0.67, 1.89)	0.6428		
FT3 (pg/mL)	Within normal range (2.30–4.80)	2471 (98.49%)	1.0			
	Superior to normal range (≥4.80)	38 (1.51%)	1.51 (0.59, 3.89)	0.3934		
FT4 (ng/dL)	Within normal range (0.59–1.25)	2473 (98.57%)	1.0			
	Subpar to normal range (≤0.59)	22 (0.88%)	0.48 (0.20, 1.19)	0.1130		
	Superior to normal range (≥1.25)	14 (0.56%)	0.56 (0.18, 1.80)	0.3321		
BMI (kg/m^2)	18–24	1520 (60.58%)	1.0			
	<18	86 (3.43%)	2.69 (1.16, 6.23)	0.0211	2.39 (1.02, 5.58)	0.045
	>24	903 (35.99%)	0.69 (0.56, 0.85)	0.0004	0.87 (0.69, 1.10)	0.238
Hypertension		704 (28.06%)	0.77 (0.62, 0.96)	0.0191		
LDL-C (mmol/L)	Within normal range (<3.37)	1921 (76.56%)	1.0			
	Superior to normal range (≥3.37)	588 (23.44%)	0.72 (0.58, 0.91)	0.0054	1.08 (0.73, 1.59)	0.695

(*Continued*)

Table 3 (Continued).

		Number (%)	Univariable Analysis		Multivariable Analysis	
			OR (95% CI)	P-value	OR (95% CI)	P-value
HDL-C (mmol/L)	Within normal range (1.03–1.55)	1667 (66.44%)	1.0			
	Subpar to normal range (≤1.03)	219 (8.73%)	0.83 (0.58, 1.17)	0.2785		
	Superior to normal range (≥1.55)	623 (24.83%)	1.04 (0.82, 1.32)	0.7411		
UA (μmol/L)	Within normal range (208–428)	2243 (89.40%)	1.0			
	Subpar to normal range (≤208)	36 (1.43%)	0.86 (0.38, 1.99)	0.7304	0.80 (0.34, 1.87)	0.610
	Superior to normal range (≥428)	230 (9.17%)	0.47 (0.35, 0.63)	<0.0001	0.56 (0.41, 0.78)	0.001
CHO (mmol/L)	Within normal range (3.25–5.2)	1895 (75.53%)	1.0			
	Subpar to normal range (≤3.25)	78 (3.11%)	0.64 (0.38, 1.09)	0.0998	0.60 (0.35, 1.04)	0.066
	Superior to normal range (≥5.2)	536 (21.36%)	0.70 (0.55, 0.88)	0.0029	0.82 (0.56, 1.20)	0.303
TG (mmol/L)	Within normal range (≤1.7)	2113 (84.22%)	1.0			
	Superior to normal range (>1.7)	396 (15.78%)	0.91 (0.70, 1.20)	0.5162		
Glc (mmol/L)	Within normal range (3.9-6-1)	2418 (96.37%)	1.0			
	Subpar to normal range (≤3.9)	32 (1.28%)	0.98 (0.40, 2.40)	0.9648		
	Superior to normal range (≥6.1)	59 (2.35%)	0.80 (0.43, 1.49)	0.4842		
Surgical relevant work		915 (36.47%)	1.40 (1.13, 1.74)	0.0024	1.19 (0.93, 1.53)	0.155
Radiation exposure		213 (8.49%)	0.84 (0.59, 1.18)	0.3091	1.09 (0.75, 1.58)	0.660

Note: Vitamin D deficiency is defined as 25(OH)D < 12.3ng/mL.
Abbreviations: AS, Administrative staff; LP, Licensed physicians; MS, Medical scientists; TSH, thyroid stimulating hormone; FT3, free thyroxine 3; FT4, free thyroxine 4; LDL-C, low-density lipoprotein cholesterol; HDL-C, high-density lipoprotein cholesterol; UA, uric acid; CHO, cholesterol; TG, triacylglycerol; Glc, glucose.

The multivariable logistic regression revealed that nurses (OR = 1.54, 95% CI 1.09–2.19, p = 0.015), BMI below 18 (OR = 2.39, 95% CI 1.02–5.58, p = 0.045) associated with higher prevalence of vitamin D deficiency. In the contrast, age above 30 (OR = 0.69, 95% CI 0.53–0.91, p = 0.009) and a high level of UA (OR = 0.56, 95% CI 0.41–0.78, p = 0.001) associated with lower prevalence of vitamin D deficiency. All the univariable and multivariable analysis results are displayed in Table 3. For other results of vitamin D deficiency analysis, please check Table S1.

Comparing Vitamin D Deficiency in Patients and Hospital Staff

The demographic characteristics of 1507 patients and 2509 hospital staff were detailed in Table 4, encompassing both the original dataset and the PSM dataset. As presented in Table 5, among the 1507 patients, 990 (65.69%) exhibited vitamin D deficiency, while among the 2509 hospital staff, 2044 (82.47%) were identified with vitamin D deficiency (p < 0.001).

Table 4 Demographic Information of All Patients and Hospital Staff

	Before PSM				After PSM			
	Patients (n=1507)	Hospital Staff (n=2509)	P-value	SMD	Patients (n=982)	Hospital Staff (n=982)	P-value	SMD
Sex (male)	507 (33.64%)	564 (22.48%)	<0.001	0.250	291 (29.63%)	291 (29.63%)	1.000	<0.001
Age (mean ± SD)	41.84 (11.39)	34.96±6.36	<0.001	0.745	36.17 (8.34)	36.17 (8.34)	1.000	<0.001

Abbreviation: PSM, propensity score matching.

Table 5 Comparison of Vitamin D Level Between Patients and Hospital Staff

	Original Dataset			PSM Dataset		
	Patients (n=1507)	Hospital Staff (n=2509)	P-value	Patients (n=982)	Hospital Staff (n=982)	P-value
Vitamin D level			<0.001			0.001
Mean ± SD	12.29±7.15	10.06±4.06		11.60±6.26	10.31±4.49	
Median (q1~q3)	10.1 (7.50~14.30)	9.0 (7.50~11.20)		9.8 (7.20~13.60)	9.2 (7.50~11.47)	
Min-max	6.50~81.00	6.50~44.70		6.50~57.70	6.50~44.70	
Vitamin D deficiency	990 (65.69%)	2044 (81.47%)	<0.001	679 (69.14%)	785 (79.94%)	<0.001

Abbreviation: PSM, propensity score matching.

A significant difference was observed in Table 5 between these two groups regarding the prevalence of vitamin D deficiency in the analysis of the PSM dataset (69.14% vs 79.94%, $p < 0.001$).

Discussion

Several factors affect vitamin D deficiency, and the Chinese hospital staff are more prone to it owing to risk factors such as shorter hours of sunlight exposure, a higher proportion of women, night shifts, anxiety, and stress.[21–23] Our analysis of the factors associated to the serum vitamin D status among hospital staff revealed significant correlations with age, occupation, BMI, and UA level. Whether age is a risk factor for vitamin D deficiency has remained a controversial topic. A comparison of vitamin D status of hospital and community physicians in Israel suggested that older physicians had higher serum vitamin D status than younger physicians. Another study on Iranian female nurses also illustrated that younger nurses (<50 years) had lower vitamin D status than older nurses (≥50 years).[24] The findings from univariate and multivariate analyses in the present study suggested that healthcare workers aged >30 years are less prone to vitamin D deficiency. This result could be attributed to the fact that healthcare workers become aware of the need for vitamin D supplementation as their age and experience increase. In addition, younger healthcare workers may be at higher risk of vitamin D deficiency because of excessive sun protection, night shifts, and daytime sleep.

The occupation may be associated to vitamin D status.[1] A Korean study showed that 89% of childbearing-aged nurses with a lower vitamin D status.[17] Furthermore, a study from Thailand found that 95.4% of nurses were with vitamin D deficiency.[25] In the presented study, nursing work was related to a higher prevalence of vitamin D deficiency in both univariate and multivariate analyses. The following two factors could be responsible for this finding. First, the nursing profession is a shift-work system, with most of the time spent indoors, resulting in less exposure to solar UVB and disturbances in the physiological circadian rhythm.[13] A considerable number of nurses need to work continuously during night shifts. A significant portion of nurses are required to work consecutive night shifts, necessitating the adjustment of their breaks to daytime hours, further reducing their exposure to daylight. Second, a large Chinese population base and large number of patients lead to a high nursing workload and higher stress in daily life than in other occupations.[17,26] Moreover, the results of this study implied that vitamin D status were significantly lower in individuals engaged in nursing work than in those engaged in administrative duties ($p = 0.015$). Therefore, it is important to focus on eradicating vitamin D deficiency in the nursing staff to improve the overall health of this population.

Another important issue is that the majority of hospital staff work in shifts. Almost all hospital staff are required to work night shifts to varying degrees. Sleep or sleep quality is also associated with vitamin D deficiency. It is reported that workers who engage in shift driving have a significantly higher incidence of vitamin D deficiency than those who have a regular schedule. Another research reported rotating shift workers who with vitamin D deficiency have higher chances of apnea, even after adjustment for confounding factors.[27,28] There has a population-based cross-sectional study indicated that sleep quality and vitamin D status are two factors that interact with each other. People with poor sleep quality also have lower vitamin D status.[29] Therefore, little or poor sleep quality is also an important health issue for hospital staff, and this issue is also correlated with vitamin D status.

Vitamin D deficiency was associated with metabolic syndromes disorders, such as obesity, hypertension, hyperglycemia, and hyperuricemia.[30] Another study examined the link between low vitamin D status and obesity, but weight loss did not aid in increased serum vitamin D status.[31] Our study revealed a significant association between hospital staff with a BMI < 18 and vitamin D deficiency, with these individuals being 2.39 times more likely to be deficient compared to those with a BMI between 18 and 24. This finding suggests that low body weight may indeed pose a risk factor for vitamin D deficiency. Given that individuals with lower body weight are inherently more vulnerable to nutritional deficiencies, it is understandable why they may exhibit lower vitamin D status. Nonetheless, certain studies have also identified significantly lower BMI in vitamin D-deficient female, which agreed with the results of this study. The possible reason for this finding could be the higher proportion of female in the present study. In studies related to vitamin D status and hypertension, the findings suggested that vitamin D deficiency was negatively associated with the incidence of hypertension and that the increased or higher vitamin D status might play a protective role against the development of hypertension. A large cross-sectional study in the United States observed a negative correlation between vitamin D status and blood pressure.[32] Another observational study revealed that vitamin D status were negatively associated with the risk of developing hypertension, and the systolic blood pressure tended to decrease as serum vitamin D status increased.[33] These results allude that vitamin D metabolic signaling pathways are vital in the regulation of vascular tone.[34] In addition, systolic blood pressure has been reported to be higher in vitamin D-deficient and insufficient populations than in vitamin D-sufficient populations, and the protective effect of this vitamin against high blood pressure was observed to be related to its regulation of vascular endothelial cells. However, in the present study, no significant correlation was noted between hypertension and vitamin D deficiency, which could be ascribed to the younger age of the hospital staff in the sample and the lower prevalence of hypertension. A complex bidirectional association prevails between vitamin D and UA levels, and studies have proved that elevated serum UA levels may be linked to increased vitamin D status. Vitamin D deficiency is associated with hyperuricemia, as shown by the fact that an increase of 1 mg/dL in blood UA level increases the vitamin D status by 0.5 ng/mL and that patients with vitamin D deficiency are approximately 1.5 times more likely to have hyperuricemia than those with normal levels.[35] Nevertheless, the outcomes of the present study suggest that vitamin D deficiency is not likely to occur in people with elevated serum UA levels, which could be explained by the fact that hyperuricemia inhibits the expression of the 1α-hydroxylase CYP27B1 gene, which encodes a key enzyme that converts 25(OH)D to osteotriol [1,25(OH)2D]. As a consequence, the conversion of 25(OH)D to calcitriol is impeded, leading to an increase in relative serum levels of 25(OH)D.[36]

Globally, vitamin D deficiency is becoming a common condition, and several fundamental research as well as clinical application studies has emphasized its close association with chronic and acute diseases. Investigations have established that vitamin D deficiency is the result of a combination of factors, with the most important ones being reduced UVB availability, stemming from lower solar radiation exposure, and low dietary intake.[37] Moreover, Vitamin D deficiency is strongly linked to the development of metabolic disorders, autoimmune diseases, diabetes, psychiatric diseases, respiratory and cardiovascular diseases, and cancer.[38,39] Studies have demonstrated that severe vitamin D deficiency, with vitamin D status of <30 nmol/L (or 12 ng/mL), significantly exacerbates the risk of mortality, infection, and several other diseases.[40] In general, factors that influence sun exposure and diet affect vitamin D status, including individual, social and cultural factors[41.] Owing to our enhanced understanding of vitamin D as a multifaceted vitamin, its deficiency has been found to be strongly associated with the development of chronic and acute diseases. The high prevalence of vitamin D deficiency is expected to increase the global disease burden. Yang et al showed that the prevalence of vitamin D status of <20 ng/mL in Chinese children and adolescents was 22.6%.[42] Moreover, Zhang et al observed that the prevalence of vitamin D deficiency in the elderly Chinese population was 69.2–94.3%.[43] This study revealed that the serum vitamin D status of the hospital staff, especially those engaged in nursing, were significantly lower than those of the general population. Further analysis of the factors influencing vitamin D status indicated that age, body weight, and serum UA levels were associated with vitamin D status.[44]

In this cross-sectional study, by using PSM analyzed the vitamin D status of hospital staff and patients attending our outpatient clinic during the same period, which revealed that the prevalence of vitamin D deficiency was higher in hospital staff than in contemporaneous outpatients. This result also supported that the high prevalence of vitamin D deficiency in hospital staff.[15] Such results once again corroborate that vitamin D deficiency is a widespread public health problem. Vitamin D is an important nutrient, but about 90% of the world's population is deficient in this nutrient. Appropriate vitamin D supplementation or consumption of vitamin D-rich foods such as fish oil can enhance health to a certain extent. It has been shown that while vitamin D supplementation does not reduce the incidence of cardiovascular disease, it does reduce the incidence of fractures due to osteoporosis.[45] As a result, awareness of vitamin D supplementation is increasing. Hospital staff are characterized by stressful jobs and irregular lifestyles, which may lead to even lower vitamin D status.

Limitations

Due to the cross-sectional study design, it was challenging to fully elucidate the relationship between occupation and vitamin D deficiency. Furthermore, in this study, only age, sex, and vitamin D status were accessible for patients visiting the outpatient department. The absence of patient BMI, occupations, and daily lifestyle patterns may lead to analytical constraints, potentially resulting in a lack of representativeness in comparing vitamin D levels between hospital staff and patients. A prospective study is expected to elucidate the causes of vitamin D deficiency among hospital staff.

Conclusion

The findings from this study clearly show that hospital staff are at a greater risk for vitamin D deficiency. This finding may be related to the nature of work and lifestyle of healthcare workers. Particularly, the nursing staff who are involved in shift work are more prone to vitamin D deficiency. Therefore, the importance of maintaining adequate vitamin D status should be considered in the health management of hospital staff to prevent adverse health outcomes associated with its deficiency. Outdoor activities, vitamin D supplementation, and foods rich in vitamin D should be advocated.

Data Sharing Statement

The data analyzed during the current meta-analysis is included in this published article and its supplementary information files, and other relevant data is available from Ruijuan Zhang on reasonable request.

Ethical Approval and Consent to Participate

This study was approved by the Institutional Ethical Review Board of Shanxi Bethune Hospital (No. YXLL-2023-185, YXLL-SL-2022-221), according to the ethical guidelines of the Helsinki Declaration. All hospital staff signed Informed consent for clinical data use. As all data utilized in this study were anonymized, the requirement for informed consent was therefore waived.

Acknowledgments

The authors would like to sincerely thank Jingfang He and Cuiqin Liu of Bothwin Clinical Study Consultant for their unwavering assistance and commitment to data analysis. The authors would like to extend their gratitude to Jun Li from Xi'an Chest Hospital and Tianbo Zhang from the Third Hospital of Shanxi Medical University for their support during this study.

Funding

The authors have no funding to report.

Disclosure

The authors declare no competing interests.

References

1. Cui AY, Zhang TS, Xiao PL. et al. Global and regional prevalence of vitamin D deficiency in population-based studies from 2000 to 2022: a pooled analysis of 7.9 million participants. *Front Nutr*. 2023;10:13. doi:10.3389/fnut.2023.1070808

2. Holick MF. Vitamin D deficiency. *N. Engl J Med*. 2007;357:266–281. doi:10.1056/NEJMra070553
3. Renke G, Starling-Soares B, Baesso T, et al. Effects of vitamin D on cardiovascular risk and oxidative stress. *Nutrients*. 2023;15:17. doi:10.3390/nu15030769
4. Borel P, Caillaud D, Cano NJ. Vitamin D Bioavailability: state of the Art. *Crit Rev Food Sci Nutr*. 2015;55:1193–1205. doi:10.1080/10408398.2012.688897
5. Cashman KD. Vitamin D deficiency: defining, prevalence, causes, and strategies of addressing, calcif. *Tissue Int*. 2020;106:14–29. doi:10.1007/s00223-019-00559-4
6. Mogire RM, Mutua A, Kimita W. Prevalence of vitamin D deficiency in Africa: a systematic review and meta-analysis (vol 8, pg e134, 2020). *Lancet Glob. Health*. 2022;10:E481–E481.
7. Jiang ZW, Pu R, Li N, et al. High prevalence of vitamin D deficiency in Asia: a systematic review and meta-analysis. *Crit Rev Food Sci Nutr*. 2023;63:3602–3611. doi:10.1080/10408398.2021.1990850
8. Cashman KD, Dowling KG, Skrábaková Z, et al. Vitamin D deficiency in Europe: pandemic? *Am J Clin Nutr*. 2016;103:1033–1044. doi:10.3945/ajcn.115.120873
9. Fuleihan GE, Bouillon R, Clarke B, et al. Serum 25-hydroxyvitamin D levels: variability, knowledge gaps, and the concept of a desirable range. *J Bone Miner Res*. 2015;30:1119–1133. doi:10.1002/jbmr.2536
10. Holick MF, Chen TC. Vitamin D deficiency: a worldwide problem with health consequences. *Am. J. Clin. Nutr*. 2008;87:1080S–1086S.
11. Valtueña J, González-Gross M, Huybrechts I, et al. Factors associated with vitamin d deficiency in European adolescents: the HELENA study. *J Nutr Sci Vitaminol*. 2013;59:161–171.
12. Wacker M, Holick MF. Sunlight and Vitamin D: a global perspective for health. *Dermato Endocrinol*. 2013;5:51–108. doi:10.4161/derm.24494
13. Sowah D, Fan XN, Dennett L, et al. Vitamin D levels and deficiency with different occupations: a systematic review. *BMC Public Health*. 2017;17:25. doi:10.1186/s12889-017-4436-z
14. Ojeda D, Cabezón M, Agurto M, et al. Vitamin D levels among anesthesiologists and other physicians, Rev. *Medica Chile*. 2019;147:1415–1422. doi:10.4067/s0034-98872019001101415
15. Dogruel F, Gönen ZB, Canpolat DG, et al. Investigation of Vitamin D levels in medical staff in a dental clinic, Niger. *J Clin Pract*. 2019;22:573–577. doi:10.4103/njcp.njcp_523_18
16. Beloyartseva M, Mithal A, Kaur P, et al. Widespread vitamin D deficiency among Indian health care professionals. *Arch Osteoporo*. 2012;7:187–192. doi:10.1007/s11657-012-0096-x
17. Pang Y, Kim O, Choi JA, et al. Vitamin D deficiency and associated factors in South Korean childbearing women: a cross-sectional study. *BMC Nurs*. 2021;20:8. doi:10.1186/s12912-021-00737-6
18. Dawson-Hughes B, Heaney RP, Holick MF, et al. Estimates of optimal vitamin D status. *Osteoporosis Int*. 2005;16:713–716. doi:10.1007/s00198-005-1867-7
19. The National Academies Press. *Dietary Reference Intakes for Calcium and Vitamin D*. Washington, DC: The National Academies Press; 2011.
20. Holick MF, Binkley NC, Bischoff-Ferrari HA, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an endocrine society clinical practice guideline (vol 96, pg 1911, 2011). *J Clin Endocrinol Metab*. 2011;96:3908.
21. Vanga SR, Good M, Howard PA, et al. Role of Vitamin D in Cardiovascular Health. *Am J Cardiol*. 2010;106:798–805. doi:10.1016/j.amjcard.2010.04.042
22. Holick MF. Sunlight, ultraviolet radiation, vitamin D and skin cancer: how much sunlight do we need? *Adv Exp Med Biol*. 2014;810:1–16.
23. Shan HP, Yang XH, Zhan XL, et al. Overwork is a silent killer of Chinese doctors: a review of Karoshi in China 2013–2015. *Public Health*. 2017;147:98–100. doi:10.1016/j.puhe.2017.02.014
24. Rajebi H, Khodadad A, Fahimi G, et al. Vitamin D deficiency among female nurses of children's medical center hospital and its related factors. *Acta Medica Iranica*. 2016;54:146–150.
25. Hattapornsawan Y, Pangsuwan S, Ongphiphadhanakul B, et al. Prevalence of vitamin D deficiency in nurses at the royal irrigation hospital. *J Med Assoc Thai Chotma Thangp*. 2012;95:1569–1574.
26. Zhou M, Zhuang WW, Yuan YY, et al. Investigation on vitamin D knowledge, attitude and practice of university students in Nanjing, China (vol 19, pg 78, 2016). *Public Health Nutr*. 2016;19:190. doi:10.1017/s1368980015001160
27. de Menezes-Junior LAA, Fajardo VC, Neto RM, et al. Association of hypovitaminosis D with sleep parameters in rotating shift worker drivers, sleep science (Sao Paulo). *Sleep Sci*. 2023;16:84–91. doi:10.1055/s-0043-1767748
28. de Menezes LAA, de Freitas SN. Rotating shift workers with vitamin D deficiency have a higher risk of obstructive sleep apnea. *Sleep Breath*. 2023;27:727–735. doi:10.1007/s11325-022-02603-4
29. de Menezes LAA, Sabiao TD, de Moura SS, et al. Influence of sunlight on the association between 25-hydroxyvitamin D levels and sleep quality in Brazilian adults: a population-based study. *Nutrition*. 2023;110:11. doi:10.1016/j.nut.2023.112008
30. Sarac I, Djekic-Ivankovic M, Debeljak-Martacic J. The role of vitamin D in metabolic and cardiovascular health. *Front Nutr*. 2023;10:4. doi:10.3389/fnut.2023.1193758
31. Karampela I, Sakelliou A, Vallianou N, et al. Vitamin D and Obesity: current Evidence and Controversies, Curr. *Obes Rep*. 2021;10:162–180. doi:10.1007/s13679-021-00433-1
32. Forman JP, Giovannucci E, Holmes MD, et al. Plasma 25-hydroxyvitamin D levels and risk of incident hypertension. *Hypertension*. 2007;49:1063–1069. doi:10.1161/hypertensionaha.107.087288
33. Latic N, Erben RG. Vitamin D and cardiovascular disease, with emphasis on hypertension, atherosclerosis, and heart failure. *Int J Mol Sci*. 2020;21:15. doi:10.3390/ijms21186483
34. Cashman KD. Global differences in vitamin D status and dietary intake: a review of the data, Endocr. *Connect*. 2022;11:18. doi:10.1530/ec-21-0282
35. Isnuwardana R, Bijukchhe S, Thadanipon K, et al. Association between vitamin d and uric acid in adults: a systematic review and meta-analysis. *Horm Metab Res*. 2020;52:732–741. doi:10.1055/a-1240-5850
36. Chen W, Roncal-Jimenez C, Lanaspa M, et al. Uric acid suppresses 1 alpha hydroxylase in vitro and in vivo, Metab. *Clin Exp*. 2014;63:150–160. doi:10.1016/j.metabol.2013.09.018
37. Kennel KA, Drake MT, Hurley DL. Vitamin D deficiency in adults: when to test and how to treat. *Mayo Clin Proc*. 2010;85:752–758. doi:10.4065/mcp.2010.0138

38. Forrest KYZ, Stuhldreher WL. Prevalence and correlates of vitamin D deficiency in US adults. *Nutr. Res*. 2011;31:48–54. doi:10.1016/j.nutres.2010.12.001
39. Hsu HJ, Wu IW, Hsu KH, et al. Vitamin D deficiency, cardiothoracic ratio, and long-term mortality in hemodialysis patients. *Sci Rep*. 2020;10:11. doi:10.1038/s41598-020-64359-9
40. Amrein K, Scherkl M, Hoffmann M, et al. Vitamin D deficiency 2.0: an update on the current status worldwide. *Eur J Clin Nutr*. 2020;74:1498–1513. doi:10.1038/s41430-020-0558-y
41. Wang TJ, Zhang F, Richards JB, et al. Common genetic determinants of vitamin D insufficiency: a genome-wide association study. *Lancet*. 2010;376:180–188. doi:10.1016/s0140-6736(10)60588-0
42. Yang CS, Mao M, Ping L, et al. Prevalence of vitamin D deficiency and insufficiency among 460,537 children in 825 hospitals from 18 provinces in mainland China. *Medicine*. 2020;99:6. doi:10.1097/md.0000000000022463
43. Zhang WG, Stoecklin E, Eggersdorfer M. A glimpse of vitamin D status in Mainland China. *Nutrition*. 2013;29:953–957. doi:10.1016/j.nut.2013.01.010
44. Alathari BE, Sabta AA, Kalpana CA, et al. Vitamin D pathway-related gene polymorphisms and their association with metabolic diseases: a literature review. *J Diabetes Metabolic Disorder*. 2020;19:1701–1729. doi:10.1007/s40200-020-00561-w
45. Minisola S, Merlotti D. The effect of vitamin D on metabolic bone disease and chronic diseases. *Nutrients*. 2023;15:4. doi:10.3390/nu15224775