

SOCIAL DETERMINANTS OF VITAMIN D DEFICIENCY IN HYPERTENSIVE PATIENTS: ASSOCIATION WITH AGE, GENDER, BMI, SUNLIGHT EXPOSURE & BP CONTROL

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Abstract

Background: Vitamin D insufficiency is emerging as a significant cardiovascular risk factor, and it may influence blood pressure regulation via inflammatory, metabolic, and vascular mechanisms. The primary goal of this study was to evaluate the socioeconomic factors that contribute to vitamin D insufficiency in the hypertensive population, as well as their interaction with age, gender, BMI, exposure to sunlight, and hypertension management.

Methods: This was hospital-based analytical cross-sectional study involving 140 hypertensive patients from Jan to December, 2025 at HMC Hospital. The participants were chosen by consecutive sampling. Demographic data, sunlight exposure, anthropometric data and clinical characteristics were collected. The serum 25-hydroxyvitamin D level was tested, and the chi-square test and logistic regression analysis were used to assess the relationships between vitamin D deficiency and the measured parameters.

Results: Vitamin D deficiency was detected in 68.6% of subjects, with a mean of 18.7 ± 8.5 ng/mL. Older age, female sex, high BMI, low sun exposure, and uncontrolled hypertension were significantly related to deficiency ($p < 0.05$). Multivariate analysis revealed that low sunlight exposure, obesity, advanced age, female gender, and uncontrolled blood pressure were independent risk factors for vitamin D deficiency.

Conclusions: Vitamin D deficiency is very common among people with hypertension, and it is related to several demographic and lifestyle factors. Identifying high-risk persons early and correcting modifiable risk factors such as obesity and lack of sunlight exposure can help improve vitamin D status and optimize hypertension management.

Keywords: Vitamin D deficiency; Hypertension; Social determinants; BMI; Sunlight exposure.

INTRODUCTION

Vitamin D deficiencies has emerged as a major global public health issue, affecting not only skeletal health but also immune system regulation, inflammatory control, and metabolic functioning..[1] Vitamin D is produced in the skin when the sun's ultraviolet B (UVB) radiation strikes it and is necessary for maintaining calcium balance in the body, as well as influencing several biological pathways through vitamin D receptor expression in other tissues such as vascular smooth muscle, endothelial cells, and cardiac tissues.[2, 3] Vitamin D deficiency has been linked to endothelial dysfunction, increased vascular inflammation, activation of the renin-angiotensin-aldosterone pathway, and arterial stiffness, all of which are involved in the initiation and progression of hypertension.[4]

High blood pressure remains one of the leading causes of cardiovascular disease worldwide.[4] Worldwide, an estimated 1.2 billion adults suffer from hypertension, and a large number of these individuals are not adequately controlled, despite having access to adequate therapeutic options.[5] Complications from uncontrolled blood pressure include coronary artery disease, stroke, heart failure, and chronic renal disease.[6] Emerging data suggests that vitamin D may influence blood pressure regulation, with low serum vitamin D levels associated with an increased risk of hypertension, higher levels of systolic and diastolic blood pressure, and reduced efficacy of antihypertensive medication.[7, 8]

Vitamin D deficiency is well recognized as a major issue worldwide, particularly in locations outside of the tropics where lifestyle patterns, work, clothing choices, urbanization, nutritional considerations, and socioeconomic issues all have a substantial impact on vitamin D levels.[8] Several studies have found that, despite receiving a lot of sunlight, a large segment of the population in South Asia, particularly in Pakistan, has low vitamin D levels.[9, 10] It is known that several factors contribute to vitamin D deficiency, including limited outdoor activity, indoor occupations, decreased direct sunlight exposure, increased body mass index (BMI), and nutritional inadequacy.[11]

Vitamin D is also affected by age and gender.[12] Cutaneous vitamin D synthesis is decreased, older adults are more sedentary and have impaired metabolism of vitamin D, which puts them at risk for vitamin D deficiency.[13] Likewise, gender differences can be found as a result of differences in sun exposure, clothing patterns, physical activity, and hormones.[14] Another important aspect is obesity, as vitamin D is fat-soluble yet can bind to adipose tissue, resulting in lower levels of vitamin D in the bloodstream among persons with a higher BMI. [15] The link between BMI, vitamin D insufficiency, and blood pressure regulation should be investigated further, as obesity is a significant risk factor for hypertension.

There is no evidence to support the link between the social determinants of vitamin D insufficiency and hypertension outcomes in Pakistan, where both hypertension and vitamin D deficiency are becoming more common. Although accumulating data suggests a causal link between vitamin D deficiencies and hypertension, there are numerous critical gaps in the involvement of social variables in vitamin D status in the setting of hypertension. It may be helpful to identify if factors such as age, gender, BMI, and exposure to sunlight add to vitamin D deficiency and impact blood pressure control, to inform targeted preventive strategies. The purpose of this study was to investigate the socioeconomic determinants of vitamin D deficiency in hypertensive persons, as well as its relationship with age, gender, BMI, solar exposure, and blood pressure management.

METHODOLOGY

The study used a hospital-based analytical cross-sectional design to examine the socioeconomic determinants of vitamin D deficiency among hypertension patients, as well as their relationships with age, gender, body mass index (BMI), sunlight exposure, and blood pressure control. The study was conducted in the HMC Hospital. This study will last six months, from Jan to December, 2025 at HMC Hospital. Sample size was determined using the OpenEpi sample size calculator based on a previously reported prevalence of 70% vitamin D deficiency in known hypertensive patients, a 95% confidence interval, and an 8% margin of error.[16] The sample size calculated was 140 participants. The sampling technique employed was non-probability consecutive sampling, and all eligible patients attending the medicine outpatient department during the study period were recruited up to the desired sample size.

Patients aged 18 and older with a verified diagnosis of hypertension were included in the study. The study comprised those who expressed an interest and agreed to be tested for vitamin D levels. The study excluded patients with chronic renal illness, chronic liver disease, cancer, pregnancy, vitamin D metabolism abnormalities, and those who had taken vitamin D supplements during the previous three months.

Written informed consent was obtained before data collection by a structured questionnaire. Demographic data, such as age, gender, and clinical data (duration of hypertension, use of antihypertensive medications) were collected. Patient interviews were used to evaluate lifestyle-related factors, mainly daily exposure to sunlight. The anthropometric measurements were taken, such as height and weight, and the BMI was determined as weight in kg/sqm.

Standardized technique was used for blood pressure measurements and patients were classified as controlled or uncontrolled based on recommended clinical criteria. Venous blood samples were taken in aseptic condition and serum 25-hydroxyvitamin D level was determined by using a proper laboratory method. The vitamin D status was determined using the vitamin D standard reference values, and patients were classed as Vitamin D deficient or sufficient. The data collected was analyzed using SPSS version 26. Continuous data were reported as mean \pm SD, whereas categorical variables were presented as frequencies and percentages. The chi-square test was performed to assess the relationship between vitamin D deficiency and independent variables such as age, gender, BMI, blood pressure control, and sunlight exposure. Logistic regression analysis was utilized to identify factors linked with vitamin D insufficiency independently. A p-value of < 0.05 indicated statistical significance.

RESULTS

A total of 140 hypertensive patients were included in the study. Demographic and clinical characteristics revealed that the majority of participants were in the middle age group, and males predominated. Over 50% of the participants had controlled blood pressure and an important part were in uncontrolled hypertension. (Table 1)

High prevalence of abnormal vitamin D status was detected in hypertensive patients, as determined by vitamin D assessment. The mean serum vitamin D level of the study subjects indicated overall inadequate vitamin D status. (Table 2)

An association study revealed that demographic and clinical characteristics had a significant influence on vitamin D insufficiency. Vitamin D deficiency was more prevalent in older age groups than in younger groups. Similarly, women had a higher rate of deficit than men. A strong relationship was also discovered between BMI categories and vitamin D deficiency, with an increasing prevalence of vitamin D deficiency among obese people. Patients with uncontrolled hypertension were more likely to be vitamin D deficient than patients with managed hypertension, and poor sunshine exposure was substantially related to vitamin D insufficiency. (Table 3)

In a multivariate logistic regression analysis of patients with hypertension, vitamin D insufficiency was associated with several independent variables. After adjusting for potential confounders, the association between vitamin D insufficiency and several other factors remained significant: advanced age, female sex, obesity, limited sun exposure, and poor blood pressure control. (Table 4)

Table 1. Demographic and Clinical Characteristics of Study Participants (n=140)

Variables	Frequency (n)	Percentage (%)
Age group (years)		
18–40	32	22.9
41–60	66	47.1
>60	42	30.0
Gender		
Male	78	55.7
Female	62	44.3
BMI category		
Normal weight (18.5–24.9 kg/m ²)	38	27.1
Overweight (25–29.9 kg/m ²)	54	38.6
Obese (≥30 kg/m ²)	48	34.3
Duration of hypertension		
<5 years	58	41.4
5–10 years	51	36.4
>10 years	31	22.2
Blood pressure control status		
Controlled hypertension	76	54.3
Uncontrolled hypertension	64	45.7

Table 2. Vitamin D Status Among Hypertensive Patients (n=140)

Vitamin D Status	Frequency (n)	Percentage (%)
Deficient (<20 ng/mL)	96	68.6
Insufficient (20–29 ng/mL)	28	20.0
Sufficient (≥30 ng/mL)	16	11.4
Mean serum vitamin D level: 18.7 ± 8.5 ng/mL		

Table 3. Association of Vitamin D Deficiency with Age, Gender, BMI, Sunlight Exposure, and BP Control

Variable	Vitamin D Deficient n (%)	Vitamin D Sufficient n (%)	p-value
Age group			
18–40 years	18 (56.3)	14 (43.7)	
41–60 years	46 (69.7)	20 (30.3)	
>60 years	32 (76.2)	10 (23.8)	0.041
Gender			

Male	49 (62.8)	29 (37.2)	
Female	47 (75.8)	15 (24.2)	0.048
BMI category			
Normal weight	19 (50.0)	19 (50.0)	
Overweight	39 (72.2)	15 (27.8)	
Obese	38 (79.2)	10 (20.8)	0.009
Sunlight exposure			
<30 minutes/day	70 (80.5)	17 (19.5)	
≥30 minutes/day	26 (49.1)	27 (50.9)	<0.001
Blood pressure control			
Controlled	46 (60.5)	30 (39.5)	
Uncontrolled	50 (78.1)	14 (21.9)	0.028

Table 4. Logistic Regression Analysis Showing Predictors of Vitamin D Deficiency

Predictor	Adjusted Odds Ratio (AOR)	95% CI	p-value
Age >60 years	2.1	1.01–4.52	0.046
Female gender	1.9	1.02–3.71	0.041
Obesity (BMI ≥30)	2.8	1.31–5.96	0.008
Low sunlight exposure	3.6	1.72–7.45	<0.001
Uncontrolled hypertension	2.2	1.04–4.65	0.038

DISCUSSION

In the present study, a high prevalence of vitamin D deficiency was observed among the hypertensive patients, with over two-thirds being vitamin D deficient. This study suggests that there is significant hypovitaminosis D in people with hypertension, and indicates that vitamin D deficiency is an increasingly recognized cardiovascular and metabolic risk factor. Ismail et al.2020 discovered the same results with vitamin D levels in hypertension patients, noting that vitamin D deficiency was seen and that it could be connected with elevated cardiovascular risk profiles.[17] The Nepalese investigation conducted in the hospital-based cross-sectional study also highlighted the prevalent occurrence of vitamin D deficits in individuals with hypertension and their connection with cardiometabolic risk factors, which complemented the findings of the current study. [18]

In this study, old age was strongly related to vitamin D insufficiency. Elderly patients with hypertension were more likely to have low levels of vitamin D. This relationship can be accounted for by age-related impairment of cutaneous vitamin D production, outdoor physical activity, and vitamin D metabolism. Old age was also found to be an important factor associated with lower vitamin D levels in previous studies on hypertension. [8, 19] A meta-analysis of the effect of vitamin D interventions on blood pressure found larger cardiovascular effects, particularly in older persons, showing that age may influence the connection between vitamin D status and BP outcomes.[20]

The current investigation found that the prevalence of vitamin D deficiencies was higher in women than in men. Opposing gender differences have been reported in previous studies, with women more commonly affected because of differences in vitamin D exposure from the sun, lifestyle behaviors, clothing, as well as hormonal influences on vitamin D metabolism.[11, 21] The findings indicate the importance of considering gender-specific socio-behavioral factors when assessing vitamin D deficiencies among hypertensives.

The current investigation indicated a significant link between BMI and vitamin D deficiency, with obese participants having a higher risk of vitamin D deficiency than non-obese subjects. This data is consistent with previous findings that show a negative relationship between obesity and vitamin D levels in the blood due to vitamin D sequestration in fat, poor bioavailability, and metabolism.[22] Furthermore, vitamin D deficiency is negatively correlated with obesity-related characteristics in research studying cardiometabolic risk factors, supporting the link between BMI and vitamin D deficiency.

One of the most important elements in the current study on vitamin D deficiency was the amount of sun exposure patients received. The primary source of vitamin D is the synthesis from the skin following exposure to ultraviolet B (UVB) radiation, and limiting activity outside and exposure to sunshine can considerably increase the vitamin D shortage.[23] These have also been seen worldwide, and lifestyle change, indoor occupation, and decreased physical activity have all been cited as contributing to a fall in vitamin D levels in many areas with sufficient environmental sunlight.

This study provides valuable clinical population data, being the first to consider modifiable social determinants like BMI and sunlight exposure and to focus on a clinical sample of patients with hypertension. The current study

emphasizes the synergistic influence of demographic, behavioral, and metabolic aspects in vitamin D deficiency, whereas prior studies have mostly focused on the association between vitamin D levels and hypertension. Thus, the identification of high-risk hypertensive individuals, especially those with obesity, low sunlight exposure, and suboptimal BP control, through screening may offer a chance to target preventive interventions.

LIMITATIONS

This study had some limitations that should be considered while interpreting the findings. First, the cross-sectional nature of the study precluded causal inference because it could not be ruled out that vitamin D deficiency may have preceded hypertension control. Second, the study took place in one hospital context and included only a small number of participants, possibly limiting the generalizability of the results to the larger population of the hypertensive population. Third, vitamin D status influencing factors, including dietary vitamin D intake, genetic polymorphisms and seasonal differences in sunlight exposure, were not explored in depth. Also, while the exposure to sunlight was assessed by patient history, the answers may have been biased due to recall bias.

CONCLUSION

Vitamin D deficiency was discovered to be a widespread problem in hypertension patients and was substantially influenced by modifiable social and lifestyle factors. Older age, female gender, greater BMI, limited sunshine exposure, and uncontrolled blood pressure are all significant risk factors for vitamin D deficiency. The results indicate that assessment of vitamin D status should be part of a comprehensive cardiovascular risk assessment, especially in high-risk hypertensive patients. There is also the possibility that lifestyle-related factors like insufficient sun exposure and obesity might be a factor in improving vitamin D status and contributing to better blood pressure control. Clinically, this combination of nutrition and behavior with standard hypertension treatment could be a useful strategy to reduce cardiovascular risk in vulnerable populations.

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