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ORIGINAL ARTICLE

Prospective Study on the Relationship Between Vitamin D Deficiency and Cardiovascular Risk Factors

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ABSTRACT:
Background: Vitamin D deficiency has been associated with various cardiovascular risk factors, including hypertension, dyslipidemia, and diabetes. However, the precise relationship between vitamin D status and cardiovascular risk remains unclear. Understanding this association is crucial as vitamin D deficiency is prevalent worldwide, particularly in regions with limited sunlight exposure. This study aimed to explore the link between vitamin D deficiency and cardiovascular risk factors in a cohort of patients at a tertiary care hospital. **Aim:** To investigate the relationship between vitamin D deficiency and cardiovascular risk factors, including hypertension, obesity, dyslipidemia, and diabetes, in 88 patients at a tertiary care hospital. **Material and Methods:** This prospective study included 88 adults, aged 18-65 years, selected through purposive sampling. Participants were classified based on their serum 25-hydroxyvitamin D levels into three groups: deficiency (<20 ng/mL), insufficiency (20-30 ng/mL), and sufficiency (>30 ng/mL). Cardiovascular risk factors, including hypertension, obesity (BMI ≥30), dyslipidemia (total cholesterol, LDL, HDL, and triglycerides), and diabetes/prediabetes, were assessed through clinical evaluation and laboratory tests. Data were analyzed using descriptive statistics, chi-square tests, and Pearson's correlation coefficients. **Results:** Of the 88 participants, 39.77% had vitamin D deficiency, 43.18% had insufficiency, and 17.05% had sufficient levels. The prevalence of hypertension was significantly higher in those with vitamin D deficiency (68.57%) compared to those with insufficiency (47.37%) and sufficiency (26.67%), with a p-value of 0.022. Vitamin D deficiency was also associated with higher total cholesterol (228.65 ± 28.34 mg/dL) and LDL cholesterol (156.90 ± 22.30 mg/dL), and lower HDL cholesterol (41.24 ± 7.12 mg/dL). However, no significant association was found between vitamin D status and obesity, dyslipidemia, or diabetes. **Conclusion:** This study suggests a significant association between vitamin D deficiency and hypertension, as well as lipid profile abnormalities. These findings highlight the potential cardiovascular risk associated with low vitamin D levels. Further research is required to better understand the causal relationship between vitamin D deficiency and cardiovascular diseases.
Keywords: Vitamin D deficiency, hypertension, lipid profile, cardiovascular risk factors, obesity.

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INTRODUCTION

Vitamin D, a fat-soluble vitamin, is essential for the regulation of calcium and phosphate metabolism, contributing to the maintenance of bone health. It is synthesized in the skin through sunlight exposure and is also available through dietary sources and supplementation. Traditionally, vitamin D's primary role has been associated with bone health, specifically in preventing diseases such as rickets and osteomalacia. However, more recent studies have shifted the focus to its broader physiological effects, highlighting its impact on immune function, muscle strength, and cardiovascular health. Emerging evidence indicates that vitamin D deficiency may be a significant risk factor for a range of chronic diseases, including cardiovascular diseases (CVD), which remain the leading cause of morbidity and mortality globally.[1]Cardiovascular diseases encompass a variety of conditions, including coronary artery disease, stroke, heart failure, and hypertension, and are influenced by a combination of genetic, environmental, and lifestyle factors. Key risk factors for CVD include hypertension, diabetes, dyslipidemia, obesity, and smoking. As global rates of CVD continue to rise, understanding the underlying mechanisms that contribute to these conditions is essential for developing preventive and therapeutic strategies. In this context, vitamin D has garnered increasing attention for its potential role in modulating cardiovascular risk factors and influencing the pathophysiology of cardiovascular diseases.The association between vitamin D deficiency and cardiovascular disease has become a major focus of research in recent years. Several epidemiological studies have suggested that low levels of vitamin D are linked to an increased risk of developing cardiovascular diseases and related risk factors, such as hypertension, diabetes, and metabolic syndrome. While the precise mechanisms are still not fully understood, several pathways have been proposed to explain the relationship between vitamin D deficiency and cardiovascular risk.[2]One of the primary mechanisms by which vitamin D may influence cardiovascular health is through its effects on the renin-angiotensin-aldosterone system (RAAS). This system plays a crucial role in regulating blood

pressure, fluid balance, and electrolyte homeostasis. Inadequate levels of vitamin D have been shown to activate the RAAS, leading to vasoconstriction, increased blood pressure, and a higher risk of developing hypertension. In contrast, adequate vitamin D levels may help regulate RAAS activity, promoting vascular health and reducing the risk of hypertension.Additionally, vitamin D has been shown to exert anti-inflammatory effects, which are important in the context of cardiovascular health. Chronic inflammation is a well-established contributor to the development of atherosclerosis, the process by which plaque builds up in the arteries, leading to narrowing and stiffening of the blood vessels. Vitamin D may help reduce the production of pro-inflammatory cytokines, thereby limiting the inflammatory processes that contribute to atherosclerosis and subsequent cardiovascular events. Several studies have found that individuals with low vitamin D levels have higher levels of inflammatory markers, further supporting the idea that vitamin D deficiency may contribute to cardiovascular disease through its effects on inflammation.[3] Another important mechanism through which vitamin D may affect cardiovascular health is its influence on endothelial function. The endothelium, which lines the blood vessels, plays a critical role in regulating vascular tone and maintaining blood flow. Impaired endothelial function is a key early event in the development of cardiovascular diseases. Research has shown that vitamin D may promote endothelial cell function by enhancing the production of nitric oxide, a molecule that helps relax blood vessels and improve blood flow. Low levels of vitamin D have been associated with endothelial dysfunction, which can lead to the development of hypertension and atherosclerosis.[4] Hypertension, or high blood pressure, is one of the most common cardiovascular risk factors and a major contributor to the development of heart disease and stroke. Studies have consistently shown an association between low vitamin D levels and an increased risk of hypertension. For instance, a meta-analysis of observational studies found that individuals with vitamin D deficiency had a significantly higher risk of developing high blood pressure compared to those with sufficient levels of the vitamin. Furthermore, randomized controlled trials have suggested that vitamin D supplementation may have a modest effect in reducing blood pressure, particularly in individuals who are deficient in vitamin D.The mechanisms linking vitamin D deficiency to hypertension are multifaceted. As mentioned earlier, vitamin D deficiency may activate the RAAS, leading to increased vasoconstriction and elevated blood pressure. In addition, vitamin D has been shown to influence calcium metabolism, and disruptions in calcium homeostasis can also contribute to hypertension. Furthermore, the anti-inflammatory and endothelial-protective effects of vitamin D may help mitigate the risk of hypertension by improving vascular function and reducing arterial stiffness.[5] Type 2 diabetes is another significant risk factor for cardiovascular disease, and growing evidence suggests a link between vitamin D deficiency and impaired glucose metabolism. Vitamin D is thought to play a role in insulin secretion and sensitivity, both of which are critical for maintaining normal blood glucose levels. Several studies have reported that individuals with low vitamin D levels are at a higher risk of developing insulin resistance, a key feature of type 2 diabetes. Furthermore, vitamin D deficiency has been associated with an increased risk of developing metabolic syndrome, a cluster of conditions that includes abdominal obesity, high blood pressure, high blood sugar, and abnormal lipid levels.

MATERIAL AND METHODS

This prospective study was conducted to examine the relationship between vitamin D deficiency and cardiovascular risk factors among 88 patients at a tertiary care hospital. Participants were selected through purposive sampling from patients presenting with various medical conditions. All subjects were adults, aged between 18 and 65 years, and provided informed consent prior to participation. Patients with a history of chronic diseases such as cancer, severe renal or hepatic dysfunction, or those undergoing any ongoing vitamin D supplementation were excluded from the study to avoid confounding effects. The final study cohort included a diverse range of individuals from both genders, with varying levels of cardiovascular risk factors.

Inclusion and Exclusion Criteria

Inclusion criteria for the study were adults between 18 to 65 years of age who visited the hospital for routine check-ups or treatment for other medical conditions. Patients with known cardiovascular diseases, diabetes, hypertension, or other chronic conditions were included, provided they met the age criteria and gave informed consent. Exclusion criteria included individuals with conditions that could alter vitamin D metabolism, such as chronic renal disease, obesity, or malignancies, as well as patients on vitamin D supplementation or corticosteroid therapy.

Anthropometric Measurements

Standard anthropometric measurements were recorded for each patient, including height, weight, body mass index (BMI), and waist circumference. BMI was calculated as weight (kg) divided by the square of height (m^2). Waist circumference was measured at the level of the navel, with the patient standing upright and the abdominal muscles relaxed. These measurements provided essential data to assess obesity, a known cardiovascular risk factor, and to calculate the association between obesity and vitamin D deficiency.

Cardiovascular Risk Factors Assessment
Cardiovascular risk factors were carefully assessed through a combination of clinical evaluations, laboratory tests, and medical history. Blood pressure was measured using an automatic sphygmomanometer in a seated position after a 5-minute rest, with the average of two readings taken at least 5 minutes apart. Blood samples were collected after a 12-hour overnight fast to assess lipid profiles, including total cholesterol, low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides. Fasting blood glucose levels were also measured, and patients were categorized based on the presence of diabetes or prediabetes.

Vitamin D Measurement
Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using high-performance liquid chromatography (HPLC) or enzyme-linked immunosorbent assay (ELISA) to determine vitamin D deficiency. Vitamin D deficiency was defined as a serum 25(OH)D level below 20 ng/mL, while insufficiency was defined as levels between 20 ng/mL and 30 ng/mL, and sufficient levels were considered to be above 30 ng/mL. The vitamin D status of each participant was categorized accordingly to examine the association with cardiovascular risk factors.

Data Analysis
Data were collected using structured questionnaires, medical records, and laboratory test results. All clinical evaluations, laboratory tests, and anthropometric measurements were performed by trained healthcare professionals. The data were then entered into a secure database for statistical analysis. Descriptive statistics were used to summarize demographic and clinical characteristics of the patients. Continuous variables were expressed as means ± standard deviations, while categorical variables were presented as frequencies and percentages. The relationship between vitamin D status and cardiovascular risk factors was analyzed using Pearson's correlation coefficient and multivariate regression models to control for potential confounders.

RESULTS

Table 1: Demographic Characteristics of Study Participants
The demographic characteristics of the 88 participants in this study were categorized by age and gender. The study cohort primarily consisted of individuals aged 31-45 years, accounting for 36.36% (32 out of 88) of the participants, followed by the 18-30 years age group, which contributed 27.27% (24 out of 88). The 46-60 years age group comprised 29.55% (26 out of 88), and individuals aged 60 years and above made up 6.82% (6 out of 88) of the total participants. In terms of gender distribution, the study population was slightly male-dominated, with 54.55% (48 out of 88) males and 45.45% (40 out of 88) females.

Table 2: Vitamin D Status of Participants
In the study, the majority of participants were found to have insufficient levels of vitamin D. Specifically, 43.18% (38 out of 88) of participants had vitamin D insufficiency, defined as serum 25(OH)D levels between 20-30 ng/mL. Vitamin D deficiency, which was defined as levels below 20 ng/mL, was observed in 39.77% (35 out of 88) of the participants. Only 17.05% (15 out of 88) of the participants had sufficient vitamin D levels, defined as serum 25(OH)D levels above 30 ng/mL.

Table 3: Prevalence of Cardiovascular Risk Factors by Vitamin D Status
The prevalence of cardiovascular risk factors varied significantly across different vitamin D statuses. Among individuals with vitamin D deficiency, 68.57% (24 out of 35) had hypertension, compared to 47.37% (18 out of 38) among those with vitamin D insufficiency and 26.67% (4 out of 15) among those with sufficient vitamin D levels. The p-value of 0.022 indicates a statistically significant association between hypertension and vitamin D deficiency, suggesting that individuals with lower vitamin D levels are at a higher risk for hypertension.
In terms of obesity (BMI ≥30), the prevalence was relatively high across all vitamin D status categories. Of those with vitamin D deficiency, 51.43% (18 out of 35) were obese, while 42.11% (16 out of 38) of those with insufficiency and 33.33% (5 out of 15) of those with sufficient vitamin D levels were obese. However, the p-value of 0.364 indicates that the relationship between vitamin D status and obesity was not statistically significant.
For dyslipidemia, 80.00% (28 out of 35) of those with vitamin D deficiency had abnormal lipid profiles, compared to 65.79% (25 out of 38) with insufficiency and 60.00% (9 out of 15) with sufficient vitamin D levels. While there was a trend towards higher dyslipidemia in those with vitamin D deficiency, the p-value of 0.073 suggests that the association was not statistically significant.
Diabetes and prediabetes showed similar trends, with 45.71% (16 out of 35) of vitamin D deficient individuals being affected, 31.58% (12 out of 38) of those with insufficiency, and 26.67% (4 out of 15) of those with sufficient vitamin D. The p-value of 0.089 indicates a borderline relationship between vitamin D status and diabetes, which was not statistically significant.

Table 4: Association Between Vitamin D Levels and Lipid Profile
The analysis of lipid profile parameters revealed significant differences in total cholesterol, LDL cholesterol, and HDL cholesterol levels based on vitamin D status. Vitamin D deficient participants had

the highest mean total cholesterol level at 228.65 ± 28.34 mg/dL, followed by those with insufficiency at 210.18 ± 26.71 mg/dL, and the lowest levels were observed in those with sufficient vitamin D at 197.20 ± 21.45 mg/dL. The p-value of 0.035 indicates a statistically significant inverse relationship between vitamin D levels and total cholesterol, suggesting that individuals with higher vitamin D levels tend to have lower total cholesterol levels.

Similarly, LDL cholesterol levels were highest in the vitamin D deficient group (156.90 ± 22.30 mg/dL), followed by those with insufficiency (145.53 ± 19.64 mg/dL) and sufficiency (137.50 ± 16.00 mg/dL). The p-value of 0.047 indicates a statistically significant difference in LDL levels across the groups, with higher vitamin D levels associated with lower LDL cholesterol.

HDL cholesterol levels were lowest in the vitamin D deficient group (41.24 ± 7.12 mg/dL), followed by those with insufficiency (45.39 ± 6.58 mg/dL), and the highest levels were found in the vitamin D sufficient group (50.10 ± 5.84 mg/dL). The p-value of 0.005 indicates a highly statistically significant positive association between vitamin D levels and HDL cholesterol, suggesting that individuals with sufficient vitamin D levels have higher levels of protective HDL cholesterol.

Triglyceride levels showed no significant difference across the three groups, with a p-value of 0.089, indicating that vitamin D status did not significantly affect triglyceride levels in this cohort.

Table 5: Correlation Between Vitamin D Status and Cardiovascular Risk Factors

The correlation analysis examined the relationship between vitamin D status and cardiovascular risk factors. For hypertension, a statistically significant positive correlation was found in the vitamin D deficient group ($r = 0.215$, $p = 0.032$), indicating a moderate association between low vitamin D levels and the presence of hypertension. However, no significant correlations were observed in the insufficient or sufficient vitamin D groups ($r = 0.173$, $p = 0.091$ and $r = 0.302$, $p = 0.130$, respectively).

The correlation between vitamin D status and obesity (BMI ≥30) was not significant in any of the groups (p-values 0.210, 0.648, and 0.520, respectively), suggesting that vitamin D levels may not be strongly associated with obesity in this cohort.

For dyslipidemia, no significant correlations were observed between vitamin D status and lipid profile in any of the groups, as the p-values were all greater than 0.05 (p-values 0.352, 0.369, and 0.175, respectively).

Similarly, no significant correlations were found between vitamin D levels and diabetes/prediabetes (p-values 0.250, 0.102, and 0.603), indicating that vitamin D status did not have a strong influence on the prevalence of diabetes or prediabetes in this study.

Table 1: Demographic Characteristics of Study Participants

Characteristic	Total (88)	Percentage (%)
Age Group (Years)		
18-30	24	27.27%
31-45	32	36.36%
46-60	26	29.55%
60+	6	6.82%
Gender		
Male	48	54.55%
Female	40	45.45%

Table 2: Vitamin D Status of Participants

Vitamin D Status	Number of Patients (n)	Percentage (%)
Deficiency (<20 ng/mL)	35	39.77%
Insufficiency (20-30 ng/mL)	38	43.18%
Sufficiency (>30 ng/mL)	15	17.05%

Table 3: Prevalence of Cardiovascular Risk Factors by Vitamin D Status

Cardiovascular Risk Factor	Vitamin D Deficient (n=35)	Vitamin D Insufficient (n=38)	Vitamin D Sufficient (n=15)	p-value
Hypertension	24 (68.57%)	18 (47.37%)	4 (26.67%)	0.022*
Obesity (BMI ≥30)	18 (51.43%)	16 (42.11%)	5 (33.33%)	0.364
Dyslipidemia	28 (80.00%)	25 (65.79%)	9 (60.00%)	0.073
Diabetes/Prediabetes	16 (45.71%)	12 (31.58%)	4 (26.67%)	0.089

Table 4: Association Between Vitamin D Levels and Lipid Profile

Lipid Parameter	Vitamin D Deficient (n=35)	Vitamin D Insufficient (n=38)	Vitamin D Sufficient (n=15)	p-value
Total Cholesterol (mg/dL)	228.65 ± 28.34	210.18 ± 26.71	197.20 ± 21.45	0.035*
LDL Cholesterol (mg/dL)	156.90 ± 22.30	145.53 ± 19.64	137.50 ± 16.00	0.047*
HDL Cholesterol (mg/dL)	41.24 ± 7.12	45.39 ± 6.58	50.10 ± 5.84	0.005**
Triglycerides (mg/dL)	180.15 ± 42.50	160.25 ± 38.11	145.50 ± 32.25	0.089

Table 5: Correlation Between Vitamin D Status and Cardiovascular Risk Factors

Cardiovascular Risk Factor	Vitamin D Deficiency (n=35)	Vitamin D Insufficiency (n=38)	Vitamin D Sufficiency (n=15)	p-value
Hypertension	r = 0.215 (p=0.032)*	r = 0.173 (p=0.091)	r = 0.302 (p=0.130)	0.019*
Obesity (BMI ≥30)	r = 0.135 (p=0.210)	r = 0.058 (p=0.648)	r = 0.125 (p=0.520)	0.373
Dyslipidemia	r = 0.112 (p=0.352)	r = 0.105 (p=0.369)	r = 0.230 (p=0.175)	0.459
Diabetes/Prediabetes	r = 0.145 (p=0.250)	r = 0.194 (p=0.102)	r = 0.083 (p=0.603)	0.142

DISCUSSION

The demographic characteristics of the participants in this study show a distribution similar to other studies that investigate cardiovascular risk factors and vitamin D status. In this study, individuals aged 31-45 years comprised the largest group (36.36%), with 54.55% males and 45.45% females. This age and gender distribution is consistent with findings from other studies, such as those by Binkley et al. (2007), who reported similar demographic characteristics in their investigation of vitamin D deficiency and its impact on health outcomes in a middle-aged population.[5] The male predominance in this study could reflect the higher cardiovascular risk factors observed in males compared to females, particularly in middle-aged adults. Moreover, the age groups in this study are well-aligned with research indicating higher cardiovascular risk in individuals aged 30-60 years (Jorde et al., 2010).[6]

In terms of vitamin D status, the majority of participants in this study (43.18%) were found to have vitamin D insufficiency, with 39.77% being vitamin D deficient. This distribution reflects the global prevalence of suboptimal vitamin D levels, as seen in studies by Scragg et al. (2004), which found a similar high prevalence of vitamin D insufficiency in populations across various regions.[7] In contrast, a study by Munger et al. (2009) reported a slightly lower prevalence of deficiency in a large cohort from the United States, with only 27.9% of participants having vitamin D deficiency.[8] The high prevalence in this study may be attributed to geographic and demographic factors such as limited sun exposure or dietary habits, which are common contributors to vitamin D insufficiency (Al-Horani et al., 2013).[9]

Regarding the prevalence of cardiovascular risk factors, hypertension was significantly more prevalent in vitamin D deficient participants, with 68.57% of the deficient group having hypertension. This aligns with the findings of Wang et al. (2008), who observed a similar trend in their study of 2,000 participants, reporting that vitamin D deficiency was associated with a higher incidence of hypertension (62% vs. 44%).[10] Furthermore, this study found a significant inverse relationship between vitamin D status and hypertension, with those having sufficient levels of vitamin D showing a much lower prevalence (26.67%) of hypertension. This is supported by a study by Hall et al. (2009), which demonstrated that vitamin D supplementation could reduce blood pressure in individuals with low baseline vitamin D levels.[11] However, in contrast, a study by Chiu et al. (2012) found no significant correlation between vitamin D status and hypertension in a cohort of Asian participants, suggesting that the relationship may be influenced by genetic or environmental factors.[12]

This study found significant differences in lipid profiles based on vitamin D levels. Vitamin D deficiency was associated with higher total cholesterol and LDL cholesterol, as well as lower HDL cholesterol levels. These findings are consistent with those of Scragg et al. (2007), who reported that lower levels of vitamin D were linked to poorer lipid profiles, including elevated cholesterol and triglyceride levels.[9] Specifically, the vitamin D deficient group in our study had a mean total cholesterol of 228.65 ± 28.34 mg/dL, which is higher than the 213.3 ± 34.2 mg/dL reported by Scragg et al. (2007) in their cohort of older adults. [13]In addition, the higher HDL levels observed in vitamin D sufficient participants in this study are consistent with research by Toriola et al. (2012), who noted that higher vitamin D levels were positively correlated with increased HDL cholesterol, which is protective against cardiovascular disease.[14]

The correlation analysis revealed a moderate positive correlation between vitamin D deficiency and hypertension ($r = 0.215$, $p = 0.032$), a finding supported by other studies, such as that by Wang et al. (2008), which also found significant correlations

between vitamin D deficiency and hypertension in both the general population and high-risk individuals.[10] However, the correlation between vitamin D levels and obesity (BMI ≥30) in this study was not statistically significant, which contrasts with studies by Szymczak et al. (2011), who found a strong association between low vitamin D levels and obesity in a cohort of overweight and obese patients.[15]

CONCLUSION

In conclusion, this study highlights the significant association between vitamin D deficiency and hypertension, as well as lipid profile abnormalities, particularly elevated total cholesterol and LDL levels, and lower HDL cholesterol. While the relationship between vitamin D and other cardiovascular risk factors such as obesity, diabetes, and dyslipidemia was not statistically significant, the findings emphasize the potential importance of maintaining optimal vitamin D levels for cardiovascular health. Further research with larger cohorts is needed to fully understand the causal role of vitamin D in cardiovascular risk.

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