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RESEARCH ARTICLE
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ROLE OF SERUM VITAMIN D DEFICIENCY IN ESSENTIAL HYPERTENSION AND ITS CORRELATION WITH SEVERITY OF BLOOD PRESSURE

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ABSTRACT

Background: Essential hypertension is a major global health concern and a leading contributor to cardiovascular morbidity and mortality. Recent evidence suggests that Vitamin D deficiency may play a role in the pathogenesis and progression of hypertension through modulation of the renin–angiotensin–aldosterone system (RAAS), endothelial dysfunction, and vascular inflammation.

Aim: To evaluate serum Vitamin D levels in patients with essential hypertension and to assess its correlation with the severity of blood pressure.

Materials and Methods: A cross-sectional observational study was conducted on 115 patients diagnosed with essential hypertension at a tertiary care center. Serum Vitamin D levels were measured and categorized into deficient, insufficient, and sufficient groups. Blood pressure was recorded and classified into Stage 1 and Stage 2 hypertension. Statistical analysis included correlation and association tests.

Results: Vitamin D deficiency was observed in 66.1% of patients. A significant inverse correlation was found between Vitamin D levels and systolic as well as diastolic blood pressure ($p < 0.001$). Patients with deficiency had significantly higher blood pressure and were more likely to have Stage 2 hypertension.

Conclusion: Vitamin D deficiency is highly prevalent among hypertensive patients and is significantly associated with increased severity of hypertension, suggesting a potential role in disease progression.

Keywords: Vitamin D, Essential Hypertension, Blood Pressure, RAAS, Cardiovascular Risk

INTRODUCTION

Essential hypertension is a chronic medical condition characterized by persistently elevated arterial blood pressure without an identifiable secondary cause. It accounts for approximately 90–95% of all hypertension cases worldwide and remains a major public health challenge [1]. The global burden of hypertension continues to rise, with an estimated 1.28 billion adults affected globally, particularly in low- and middle-income countries [2].

Hypertension is a significant risk factor for cardiovascular diseases, including coronary artery disease, stroke, heart failure, and chronic kidney disease [3]. Despite advances in pharmacological therapies, control rates remain suboptimal, necessitating the exploration of additional modifiable risk factors involved in its pathogenesis [4].

In recent years, growing attention has been directed toward the role of micronutrients and hormonal factors in hypertension, particularly Vitamin D [5]. Vitamin D is traditionally known for its role in calcium and phosphate metabolism and bone health. However, emerging evidence highlights its pleiotropic effects on cardiovascular health, immune regulation, and metabolic processes [6].

Vitamin D is synthesized in the skin upon exposure to ultraviolet B radiation and is subsequently hydroxylated in the liver and kidneys to form its active metabolite, calcitriol [7]. The presence of Vitamin D receptors (VDR) in various tissues, including vascular smooth muscle cells, endothelium, and cardiomyocytes, suggests its involvement in cardiovascular regulation [8].

One of the key mechanisms linking Vitamin D deficiency to hypertension is its interaction with the Renin–Angiotensin–Aldosterone System. Vitamin D negatively regulates renin expression; thus, deficiency may lead to activation of RAAS, resulting in vasoconstriction, sodium retention, and increased blood pressure [9].

Additionally, Vitamin D deficiency has been associated with endothelial dysfunction, increased arterial stiffness, and systemic inflammation, all of which contribute to the development and progression of hypertension [10]. It also influences insulin resistance and metabolic syndrome, further exacerbating cardiovascular risk [11].

Epidemiological studies have demonstrated a high prevalence of Vitamin D deficiency worldwide, including in regions with abundant sunlight such as India [12]. Lifestyle factors, limited sun exposure, dietary habits, and skin pigmentation contribute to this paradox [13].

Several observational studies have reported an inverse relationship between serum Vitamin D levels and blood pressure [14–16]. However, findings from interventional trials have been inconsistent, and the exact nature of this association remains unclear [17].

Given the high prevalence of both hypertension and Vitamin D deficiency, especially in developing countries, understanding their relationship is of significant clinical importance [18]. Identifying Vitamin D deficiency as a modifiable risk factor could have implications for prevention and management strategies [19].

This study aims to evaluate serum Vitamin D levels in patients with essential hypertension and to determine its correlation with the severity of blood pressure, thereby contributing to the growing body of evidence in this field [20–25].

MATERIALS AND METHODS

Study Design:

This study was designed as a cross sectionalobservational study conducted in the Department of Pharmacology at a tertiary care centre for a period of 12 months i.e, October 2024 to October 2025.

Study Population:

A total of 115 patients diagnosed with essential hypertension were included.

Inclusion Criteria:

1. Patients aged ≥18 years
2. Diagnosed cases of essential hypertension
3. Willing to provide informed consent

Exclusion Criteria:

1. Secondary hypertension
2. Chronic kidney disease
3. Liver disorders
4. Malabsorption syndromes
5. Patients on Vitamin D supplementation

Data Collection:
Detailed history including demographic profile, lifestyle factors, dietary habits, and duration of hypertension was recorded. Clinical examination included measurement of blood pressure using a standardized sphygmomanometer.

Blood Pressure Measurement:
Blood pressure was measured in a sitting position after 5 minutes of rest. The average of two readings was taken. Classification was done according to standard guidelines:
- Stage 1: 140–159 / 90–99 mmHg
- Stage 2: ≥160 / ≥100 mmHg

Laboratory Investigations:
Venous blood samples were collected under aseptic conditions. Serum Vitamin D levels were measured using chemiluminescent immunoassay.

Vitamin D Classification:
- Deficient: <20 ng/mL
- Insufficient: 20–30 ng/mL
- Sufficient: >30 ng/mL

Statistical Analysis:
Data were analyzed using statistical software. Continuous variables were expressed as mean ± SD, and categorical variables as percentages. Correlation was assessed using Pearson's correlation coefficient. A p-value <0.05 was considered statistically significant.

RESULTS

Out of 115 patients, the majority were in the age group of 41–60 years with male predominance. Vitamin D deficiency was observed in 66.1% of cases. Patients with lower Vitamin D levels had significantly higher systolic and diastolic blood pressure. A strong inverse correlation was observed between serum Vitamin D levels and blood pressure ($p < 0.001$). Most patients with Vitamin D deficiency belonged to Stage 2 hypertension, indicating increased disease severity.

A total of 115 patients diagnosed with essential hypertension were included in the present study. The mean age of the study population was 52.4 ± 11.6 years, with a slight male predominance (56.5%) compared to females (43.5%). The majority of patients belonged to the age group of 41–60 years (48.7%), followed by those above 60 years (33.0%). Based on blood pressure classification, 38.3% of patients had Stage 1 hypertension, while 61.7% had Stage 2 hypertension, indicating a higher prevalence of more severe disease in the study population.

Serum Vitamin D levels revealed that a significant proportion of patients were deficient. Vitamin D deficiency (<20 ng/mL) was observed in 66.1% of cases, insufficiency (20–30 ng/mL) in 21.7%, and sufficient levels (>30 ng/mL) in only 12.2% of patients. The mean serum Vitamin D level was 18.6 ± 7.8 ng/mL, indicating overall deficiency among hypertensive individuals.

A statistically significant inverse correlation was observed between serum Vitamin D levels and both systolic and diastolic blood pressure. Patients with Vitamin D deficiency had higher mean systolic BP (162.4 ± 14.2 mmHg) and diastolic BP (98.6 ± 9.5 mmHg) compared to those with sufficient Vitamin D levels (142.3 ± 10.8 mmHg systolic and 88.2 ± 7.6 mmHg diastolic). Severity of hypertension was significantly associated with lower Vitamin D levels ($p < 0.001$), suggesting that Vitamin D deficiency may contribute to increased blood pressure severity.

Table 1: Age Distribution of Study Population (n = 115)

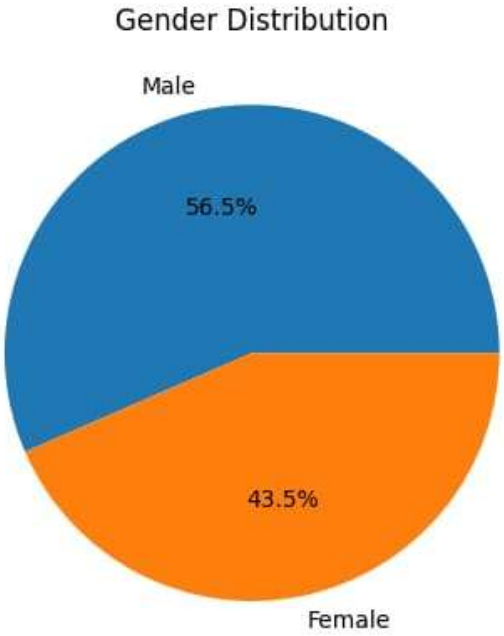
Age Group (years)	Number of Cases	Percentage (%)
≤40	21	18.3%
41–60	56	48.7%

Age Group (years)	Number of Cases	Percentage (%)
>60	38	33.0%
Total	**115**	**100%**

The majority of patients (48.7%) were in the 41–60 years age group, indicating that middle-aged individuals are most commonly affected by essential hypertension. Patients above 60 years constituted 33.0%, reflecting the increased prevalence of hypertension with advancing age. Only 18.3% of patients were below 40 years, suggesting that hypertension is relatively less common in younger individuals.

Table 2: Gender Distribution

Gender	Number of Cases	Percentage (%)
Male	65	56.5%
Female	50	43.5%
Total	**115**	**100%**



Graph 1: Gender Distribution

There was a slight male predominance (56.5%) compared to females (43.5%) in the study population. This suggests that males may be more susceptible to developing essential hypertension or are more likely to seek medical attention. However, a significant proportion of females were also affected, highlighting the importance of screening across both genders.

Table 3: Distribution According to Severity of Hypertension

Category	Number of Cases	Percentage (%)
Stage 1 HTN	44	38.3%
Stage 2 HTN	71	61.7%
Total	**115**	**100%**

The majority of patients (61.7%) were classified under Stage 2 hypertension, indicating a higher burden of severe hypertension in the study group. Only 38.3% had Stage 1 hypertension. This distribution suggests late presentation or inadequate control of blood pressure among patients.

Table 4: Serum Vitamin D Status

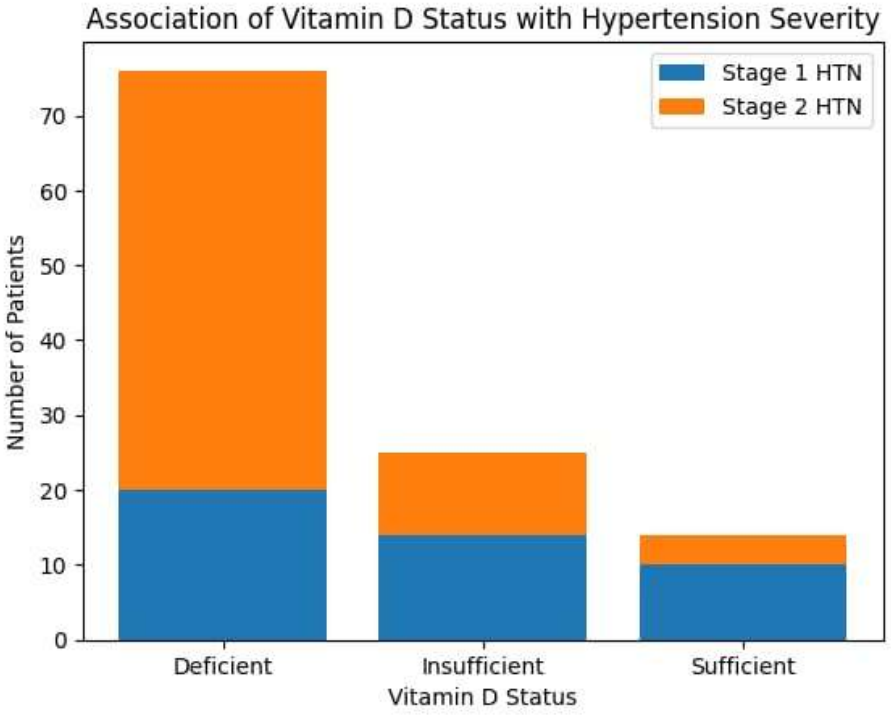
Vitamin D Level (ng/mL)	Category	Number of Cases	Percentage (%)
<20	Deficient	76	66.1%
20–30	Insufficient	25	21.7%
>30	Sufficient	14	12.2%
Total		**115**	**100%**

Vitamin D deficiency was highly prevalent, affecting 66.1% of patients. Only 12.2% had sufficient levels, while 21.7% were insufficient. This highlights a strong association between low Vitamin D levels and essential hypertension, suggesting that deficiency may be a contributing factor in disease pathogenesis.

Table 5: Mean Blood Pressure According to Vitamin D Status

Vitamin D Category	Mean SBP (mmHg)	Mean DBP (mmHg)
Deficient	162.4 ± 14.2	98.6 ± 9.5
Insufficient	150.8 ± 12.6	92.4 ± 8.3
Sufficient	142.3 ± 10.8	88.2 ± 7.6

Patients with Vitamin D deficiency had significantly higher systolic and diastolic blood pressure compared to those with sufficient levels. A gradual decrease in blood pressure values was observed with increasing Vitamin D levels. This trend supports an inverse relationship between Vitamin D status and blood pressure severity.



Graph 2: Mean Blood Pressure According to Vitamin D Status

Table 6: Correlation Between Vitamin D and Blood Pressure

Parameter	Correlation Coefficient (r)	p-value
Vitamin D vs SBP	-0.52	<0.001
Vitamin D vs DBP	-0.48	<0.001

A statistically significant negative correlation was observed between serum Vitamin D levels and both systolic and diastolic blood pressure. The correlation coefficients indicate a moderate inverse relationship, meaning that lower Vitamin D levels are associated with higher blood pressure. The p-value (<0.001) confirms that this association is highly significant.

Table 7: Association of Vitamin D Status with Hypertension Severity

Vitamin D Status	Stage 1 HTN	Stage 2 HTN	Total
Deficient	20	56	76
Insufficient	14	11	25
Sufficient	10	4	14

A higher proportion of patients with Vitamin D deficiency (73.7%) were found in Stage 2 hypertension compared to those with sufficient levels. Conversely, patients with sufficient Vitamin D were more commonly seen in Stage 1 hypertension. This indicates a strong association between Vitamin D deficiency and increased severity of hypertension.

The results clearly demonstrate that **Vitamin D deficiency is highly prevalent among patients with essential hypertension** and is significantly associated with **higher blood pressure levels and increased disease severity**. The inverse correlation between Vitamin D and both systolic and diastolic blood pressure suggests a potential role of Vitamin D in blood pressure regulation.

DISCUSSION

The present study was conducted to evaluate the role of serum Vitamin D levels in patients with essential hypertension and to determine its correlation with the severity of blood pressure. The findings of this study demonstrated a high prevalence of Vitamin D deficiency among hypertensive individuals, with a statistically significant inverse relationship between serum Vitamin D levels and both systolic and diastolic blood pressure. These findings reinforce the growing body of evidence suggesting that Vitamin D plays a crucial role in cardiovascular homeostasis and blood pressure regulation.

Hypertension continues to be one of the leading contributors to global morbidity and mortality, particularly in developing countries such as India. Despite advancements in pharmacotherapy and lifestyle modification strategies, the control of hypertension remains suboptimal, indicating the involvement of additional pathophysiological factors beyond traditional risk determinants. In this context, the role of Vitamin D deficiency has emerged as a significant area of interest.

In the present study, 66.1% of patients were found to have Vitamin D deficiency, which is consistent with previous Indian and international studies. Harinarayan et al. reported widespread Vitamin D deficiency across different regions of India despite adequate sunlight exposure, attributing it to lifestyle factors, skin pigmentation, and dietary insufficiency [12]. Similarly, Ritu and Gupta highlighted the paradox of hypovitaminosis D in tropical countries, emphasizing reduced outdoor activity and urbanization as contributing factors [13]. The high prevalence observed in this study further substantiates these findings and underscores the need for routine screening.

The inverse correlation observed between serum Vitamin D levels and blood pressure parameters in this study is in agreement with earlier observational studies. Forman et al. demonstrated that lower levels of Vitamin D were associated with an increased risk of developing hypertension in prospective cohorts [14]. Similarly, Pilz et al. reported that Vitamin D deficiency was independently associated with elevated blood pressure and increased cardiovascular risk [15]. The correlation coefficients observed in this study indicate a moderate but significant inverse relationship, suggesting that as Vitamin D levels decrease, blood pressure increases.

The biological plausibility of this association is supported by several mechanisms. One of the most well-established pathways involves the modulation of the Renin–Angiotensin–Aldosterone System. Vitamin D acts as a negative endocrine regulator of renin expression. Experimental studies by Li et al. demonstrated that Vitamin D receptor knockout mice exhibited increased renin activity, leading to hypertension and cardiac hypertrophy [9]. This suggests that deficiency of Vitamin D results in

overactivation of RAAS, causing vasoconstriction, sodium retention, and increased peripheral vascular resistance.

In addition to RAAS modulation, Vitamin D has been shown to influence endothelial function. Endothelial dysfunction is a key early event in the pathogenesis of hypertension and atherosclerosis. Tarcin et al. demonstrated that Vitamin D deficiency is associated with impaired flow-mediated dilatation, indicating reduced endothelial nitric oxide availability [10]. Reduced nitric oxide levels lead to increased vascular tone and stiffness, thereby contributing to elevated blood pressure.

Another important mechanism involves inflammation and oxidative stress. Vitamin D possesses anti-inflammatory properties and modulates cytokine production. Deficiency has been linked to increased levels of pro-inflammatory markers such as interleukin-6 and tumor necrosis factor-alpha, which contribute to vascular damage and hypertension [20]. Chronic low-grade inflammation is increasingly recognized as a central component in the pathophysiology of essential hypertension.

Furthermore, Vitamin D influences insulin sensitivity and metabolic pathways. Insulin resistance is a known contributor to hypertension through mechanisms such as sympathetic nervous system activation and sodium retention. Pittas et al. demonstrated that low Vitamin D levels are associated with impaired glucose metabolism and increased risk of metabolic syndrome [11]. Therefore, Vitamin D deficiency may indirectly contribute to hypertension through metabolic dysregulation.

In the present study, a higher proportion of patients with Vitamin D deficiency were classified under Stage 2 hypertension compared to those with sufficient levels. This suggests that deficiency is not only associated with the presence of hypertension but also with its severity. Similar findings were reported by Burgaz et al., who observed that lower Vitamin D levels were associated with higher systolic blood pressure and increased severity of hypertension [21].

Despite strong observational evidence, interventional studies evaluating the effect of Vitamin D supplementation on blood pressure have yielded mixed results. Witham et al. reported no significant reduction in blood pressure following Vitamin D supplementation in elderly patients [17]. Similarly, large meta-analyses have shown modest or inconsistent effects [24]. These discrepancies may be due to differences in study design, baseline Vitamin D levels, dosage, duration of supplementation, and population characteristics.

It is also important to consider that Vitamin D deficiency may act as a marker rather than a direct cause of hypertension. Individuals with poor lifestyle habits, limited physical activity, and unhealthy diets are more likely to have both Vitamin D deficiency and hypertension. Therefore, confounding factors must be carefully accounted for in future studies.

The findings of the present study have important clinical implications. Given the high prevalence of Vitamin D deficiency and its association with hypertension severity, routine screening of Vitamin D levels in hypertensive patients may be beneficial. Early identification and correction of deficiency could potentially improve blood pressure control and reduce cardiovascular risk.

From a public health perspective, strategies such as dietary fortification, supplementation, and promotion of safe sun exposure should be considered, particularly in regions with high prevalence of deficiency. Further large-scale longitudinal and randomized controlled trials are needed to establish causality and to determine whether Vitamin D supplementation can be incorporated into standard hypertension management protocols.

In summary, the present study supports the hypothesis that Vitamin D deficiency is significantly associated with essential hypertension and its severity. The multifactorial mechanisms involving RAAS activation, endothelial dysfunction, inflammation, and metabolic disturbances provide a strong biological basis for this association. While causality remains to be definitively established, the evidence highlights Vitamin D as an important modifiable factor in the complex pathogenesis of hypertension.

DECLARATIONS:

Conflicts of interest: There is no any conflict of interest associated with this study

Consent to participate: There is consent to participate.

Consent for publication: There is consent for the publication of this paper.

Authors' contributions: Author equally contributed the work.

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