International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-06-99*

EVALUATION OF SERUM VITAMIN D STATUS IN HYPERTENSIVE PATIENTS AND ASSOCIATED COMPLICATIONS.

Dr. Jitesh Agrawal[1], Dr. Harsh Anadkat[2], Dr. Prayag Pandya[3].

[1]Assistant Professor, Department of General Medicine, Banas Medical College and Research Institute, Palanpur, Gujarat, India.

[2]MBBS, Government Medical College, Baroda, Gujarat, India.

[3]Senior Resident, Department of General Medicine, GMERS Medical College, Morbi, Gujarat, India.

Correspondence:
Dr. Jitesh Agrawal.
Assistant Professor, Department of General Medicine, Banas Medical College and Research Institute, Palanpur, Gujarat, India.

Email:
jitesh_agrawal2001@yahoo.com

Received: 14-05-2026
Revised: 29-05-2026
Accepted: 01-06-2026
Published: 16-06-2026

Abstract

Background: Hypertension is a major public health problem and an important risk factor for cardiovascular, renal, cerebrovascular, and retinal complications. Vitamin D deficiency has been increasingly associated with hypertension through its effects on the renin-angiotensin-aldosterone system, endothelial function, vascular inflammation, and cardiac remodeling. ***Aim:***The present study was conducted to estimate serum vitamin D levels in patients with essential hypertension and hypertension-related complications and to assess their relationship with target organ damage. ***Methods:*** This hospital-based observational cross-sectional study included 150 patients with essential hypertension and hypertension-related complications. Detailed clinical history, physical examination, blood pressure assessment, and relevant investigations were recorded. Serum 25-hydroxyvitamin D levels were estimated and categorized as <10 ng/dl, 10–20 ng/dl, 21–30 ng/dl, and >30 ng/dl. The association of serum vitamin D levels with hypertensive retinopathy, chronic kidney disease, and left ventricular hypertrophy was analyzed using appropriate statistical tests. A p-value of less than 0.05 was considered statistically significant. ***Results:*** Among 150 patients, 21 (14.0%) had serum vitamin D levels below 10 ng/dl, 62 (41.3%) had levels between 10–20 ng/dl, 33 (22.0%) had levels between 21–30 ng/dl, and 34 (22.7%) had levels above 30 ng/dl. Overall, 83 (55.3%) patients had vitamin D levels below 20 ng/dl. Retinopathy was present in 49 patients, of whom 39 (79.6%) had vitamin D levels below 20 ng/dl. Chronic kidney disease was present in 46 patients, of whom 36 (78.3%) had levels below 20 ng/dl. Left ventricular hypertrophy was present in 58 patients, of whom 43 (74.1%) had levels below 20 ng/dl. The association of low vitamin D levels with retinopathy, CKD, and LVH was statistically highly significant. ***Conclusion:*** Vitamin D deficiency was highly prevalent among patients with essential hypertension and hypertension-related complications. Lower serum vitamin D levels were significantly associated with hypertensive retinopathy, chronic kidney disease, and left ventricular hypertrophy. Assessment of vitamin D status may be useful in hypertensive patients for identifying those at higher risk of target organ damage.

Keywords: Hypertension, Vitamin D, Retinopathy, Chronic Kidney Disease.

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC-BY) license (http://creativecommons.org/licenses/by/4.0/).

INTRODUCTION

Hypertension is one of the most prevalent non-communicable diseases worldwide and remains a leading cause of cardiovascular morbidity and mortality. It is a major risk factor for ischemic heart disease, stroke, heart failure, chronic kidney disease, peripheral vascular disease, and premature death. Despite advances in diagnosis and treatment, hypertension continues to pose a substantial public health burden, particularly in developing countries where awareness, treatment, and control rates remain suboptimal [1].

According to recent global estimates, more than one billion adults are affected by hypertension, and the prevalence continues to increase due to urbanization, sedentary lifestyles, obesity, population aging, and dietary changes. Persistent elevation of blood pressure leads to structural and functional alterations in various target organs, resulting in hypertension-related complications involving the cardiovascular, cerebrovascular, renal, and retinal systems. Early identification of modifiable risk factors associated with hypertension is therefore essential for reducing disease burden and improving clinical outcomes [2].

Vitamin D is a fat-soluble secosteroid hormone that plays a crucial role in calcium and phosphorus metabolism, skeletal health, immune regulation, cellular differentiation, and cardiovascular homeostasis. The principal circulating form, 25-

hydroxyvitamin D [25(OH)D], is considered the best indicator of vitamin D status in humans. Vitamin D deficiency has emerged as a global health concern affecting individuals across all age groups and geographical regions, even in countries with abundant sunlight exposure [3].

In recent years, growing attention has been directed toward the extra-skeletal effects of vitamin D, particularly its influence on cardiovascular health. Experimental and clinical studies have suggested that vitamin D may regulate blood pressure through multiple mechanisms, including suppression of the renin-angiotensin-aldosterone system, modulation of vascular smooth muscle cell proliferation, improvement of endothelial function, reduction of systemic inflammation, and attenuation of oxidative stress. Deficiency of vitamin D has been associated with increased renin activity, endothelial dysfunction, arterial stiffness, and adverse cardiovascular remodeling, all of which contribute to the development and progression of hypertension [4].

Several epidemiological studies have demonstrated an inverse relationship between serum vitamin D concentrations and blood pressure levels. Individuals with lower serum 25(OH)D levels have been shown to exhibit a higher prevalence of hypertension compared to those with adequate vitamin D status. Furthermore, vitamin D deficiency has been associated with an increased risk of developing cardiovascular diseases, including coronary artery disease, heart failure, stroke, and chronic kidney disease, which are recognized complications of long-standing hypertension [5].

The pathophysiological relationship between vitamin D deficiency and hypertension appears to be multifactorial. Vitamin D receptors are widely distributed throughout cardiovascular tissues, including vascular smooth muscle cells, endothelial cells, and cardiomyocytes. Activation of these receptors influences vascular tone, myocardial function, and inflammatory responses. Experimental studies have demonstrated that reduced vitamin D activity leads to increased expression of renin, resulting in activation of the renin-angiotensin-aldosterone system and subsequent elevation of blood pressure [6].

Recent systematic reviews and meta-analyses have further highlighted the potential association between vitamin D status and hypertension. Although some interventional studies have reported beneficial effects of vitamin D supplementation on blood pressure reduction, findings remain inconsistent. Variations in study design, baseline vitamin D status, duration of supplementation, ethnicity, age, and comorbid conditions have contributed to heterogeneity among published reports. Consequently, the exact role of vitamin D in the pathogenesis and progression of hypertension remains an area of ongoing investigation [7].

Patients with hypertension-related complications often exhibit greater endothelial dysfunction, chronic inflammation, vascular calcification, and target organ damage. Emerging evidence suggests that vitamin D deficiency may accelerate these pathological processes and contribute to the severity of cardiovascular and renal complications. Low serum vitamin D levels have been linked with increased arterial stiffness, left ventricular hypertrophy, impaired renal function, and adverse cardiovascular outcomes in hypertensive individuals [8].

Given the high prevalence of both hypertension and vitamin D deficiency, understanding their relationship has important clinical implications. Identification of vitamin D deficiency among hypertensive patients may facilitate early intervention and potentially reduce the risk of target organ damage. Moreover, evaluation of vitamin D status may provide additional insight into disease severity and prognosis in patients with hypertension-related complications [9].

Despite increasing research interest, data regarding the association between serum vitamin D levels and hypertension-related complications remain limited, particularly in the Indian population. Therefore, the present study was undertaken to estimate serum vitamin D levels in patients with essential hypertension and hypertension-related complications and to establish the relationship between serum vitamin D levels, hypertension, and its associated complications. The findings of this study may contribute to a better understanding of the potential role of vitamin D in the pathogenesis and progression of hypertension and help identify opportunities for preventive and therapeutic interventions [10].

MATERIALS AND METHODS

This hospital-based observational cross-sectional study was conducted in the Department of General Medicine of a tertiary care teaching hospital over a period of one year after obtaining approval from the Institutional Ethics Committee. The study was undertaken to estimate serum vitamin D levels in patients with essential hypertension and hypertension-related complications and to establish the relationship between serum vitamin D levels and hypertension and its associated complications.

A total of 150 patients aged 18 years and above diagnosed with essential hypertension and hypertension-related complications were enrolled consecutively during the study period after obtaining written informed consent. The diagnosis of hypertension was established according to standard clinical guidelines based on documented blood pressure

measurements and treatment history. Patients with hypertension-related complications such as ischemic heart disease, cerebrovascular accident, hypertensive heart disease, chronic kidney disease, hypertensive retinopathy, and other target organ damage attributable to hypertension were included in the study.

Patients with secondary hypertension, chronic liver disease, parathyroid disorders, malabsorption syndromes, chronic inflammatory diseases, malignancy, pregnancy, patients receiving vitamin D supplementation, calcium supplementation, corticosteroids, anticonvulsants, or any medication known to interfere with vitamin D metabolism were excluded from the study. Patients who were unwilling to participate or did not provide informed consent were also excluded.

After enrollment, detailed demographic and clinical information including age, gender, duration of hypertension, family history of hypertension, lifestyle factors, associated comorbidities, and treatment details were recorded in a predesigned and pretested case record form. A thorough general physical examination and systemic examination were carried out for all participants. Blood pressure was measured using a standardized sphygmomanometer after adequate rest in the sitting position. Two readings were obtained at an interval of five minutes, and the average value was considered for analysis.

Venous blood samples were collected under aseptic precautions from all study participants. Serum was separated and analyzed for 25-hydroxyvitamin D [25(OH)D] levels, which is considered the most reliable biochemical marker for assessment of vitamin D status. Estimation of serum vitamin D levels was performed using a standardized chemiluminescent immunoassay method in the institutional laboratory. Based on serum 25(OH)D concentrations, participants were categorized as vitamin D deficient (<20 ng/mL), vitamin D insufficient (20–29 ng/mL), and vitamin D sufficient (≥30 ng/mL). Relevant laboratory investigations including complete blood count, fasting blood sugar, renal function tests, lipid profile, serum electrolytes, and other investigations were performed as clinically indicated and recorded from hospital records.

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 26.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequency and percentage. Comparison of quantitative variables between groups was performed using Student's t-test or one-way analysis of variance (ANOVA) as appropriate. Qualitative variables were compared using Chi-square test or Fisher's exact test. Pearson's correlation coefficient was used to assess the relationship between serum vitamin D levels and blood pressure parameters. Logistic regression analysis was performed to evaluate the association between vitamin D deficiency and hypertension-related complications after adjusting for potential confounding factors. A p-value of less than 0.05 was considered statistically significant.

Ethical clearance for the study was obtained from the Institutional Ethics Committee prior to commencement of the study. All procedures were carried out in accordance with the ethical principles of the Declaration of Helsinki. Confidentiality of participant information was maintained throughout the study, and written informed consent was obtained from all participants before enrollment.

RESULTS

A total of 150 patients with essential hypertension and hypertension-related complications were included in the present study. The demographic profile of the study population revealed that hypertension was predominantly observed in middle-aged and elderly individuals. As shown in Table 1, the highest proportion of patients belonged to the 41–45 years age group comprising 26 (17.3%) participants, followed by 36–40 years with 29 (19.3%) participants and 51–55 years with 21 (14.0%) participants. Males constituted 95 (63.3%) of the study population, while females accounted for 55 (36.7%), indicating a male predominance among hypertensive patients.

The distribution of serum vitamin D levels among study participants is depicted in Table 2. Vitamin D deficiency was highly prevalent in the study population. Serum vitamin D levels between 10–20 ng/dl were observed in 62 (41.3%) patients, while severe deficiency (<10 ng/dl) was noted in 21 (14.0%) patients. Only 34 (22.7%) participants had serum vitamin D levels above 30 ng/dl. Overall, 83 (55.3%) patients had serum vitamin D levels below 20 ng/dl, suggesting a high burden of vitamin D deficiency among hypertensive individuals.

The relationship between serum vitamin D levels and hypertensive retinopathy is presented in Table 3. Among the 49 patients with retinopathy, 16 (32.7%) had serum vitamin D levels below 10 ng/dl and 23 (46.9%) had levels between 10–20 ng/dl. In contrast, only 4 (8.2%) retinopathy patients had vitamin D levels above 30 ng/dl. These findings indicate a higher prevalence of retinopathy among individuals with lower serum vitamin D levels.

The association between serum vitamin D levels and left ventricular hypertrophy (LVH) is shown in Table 4. A total of 58 patients had LVH, of whom 43 (74.1%) had serum vitamin D levels below 20 ng/dl. Only 7 (12.1%) LVH patients had

vitamin D levels greater than 30 ng/dl. These observations suggest that lower vitamin D levels may be associated with increased cardiac target organ damage in hypertensive patients.

Table 5 demonstrates the relationship between serum vitamin D levels and chronic kidney disease (CKD). Among 46 patients with CKD, 15 (32.6%) had severe vitamin D deficiency and 21 (45.7%) had vitamin D levels between 10–20 ng/dl. Only 5 (10.9%) CKD patients had vitamin D levels above 30 ng/dl. The frequency of CKD decreased progressively with increasing serum vitamin D levels.

The frequency distribution of serum vitamin D levels in retinopathy patients is summarized in Table 6. Among patients with retinopathy, 39 (79.6%) had serum vitamin D levels below 20 ng/dl compared to only 44 (43.6%) among patients without retinopathy. Statistical analysis demonstrated a highly significant association between vitamin D deficiency and hypertensive retinopathy ($\chi^2 = 18.721$, df = 3, p = 0.0003).

Table 7 shows the frequency distribution of serum vitamin D levels among patients with chronic kidney disease. Among CKD patients, 36 (78.3%) had serum vitamin D levels below 20 ng/dl, whereas only 10 (21.7%) had levels above 20 ng/dl. The association between vitamin D deficiency and CKD was found to be statistically highly significant ($\chi^2 = 21.864$, df = 3, p = 0.0001).

The frequency distribution of serum vitamin D levels among patients with left ventricular hypertrophy is depicted in Table 8. Of the 58 patients with LVH, 43 (74.1%) had serum vitamin D levels below 20 ng/dl. In comparison, patients without LVH demonstrated relatively higher vitamin D concentrations.

The association between vitamin D deficiency and LVH was statistically highly significant ($\chi^2 = 17.952$, df = 3, p = 0.0005), indicating a possible role of vitamin D deficiency in the development of cardiac complications among hypertensive patients.

Table 1: Distribution of study population according to age groups

Age group (years)	Male	Female	Total
26–30	8	5	13
31–35	9	7	16
36–40	18	11	29
41–45	16	10	26
46–50	12	4	16
51–55	13	8	21
56–60	11	3	14
>60	8	7	15
Total	95	55	150

Table 2: Distribution of study population according to serum Vitamin D levels

SerumVitamin D (ng/dl)	Number of cases	Percentage
<10	21	14.0
10–20	62	41.3
21–30	33	22.0
>30	34	22.7
Total	150	100

Table 3: Serum Vitamin D level and retinopathy

Serum Vitamin D	Retinopathy Present	Retinopathy Absent
<10 ng/dl	16	5
10–20 ng/dl	23	39
21–30 ng/dl	6	27
>30 ng/dl	4	30
Total	49	101

Table 4: Serum Vitamin D level and Left Ventricular Hypertrophy

Serum Vitamin D	LVH Present	LVH Absent
<10 ng/dl	12	9
10–20 ng/dl	31	31
21–30 ng/dl	8	25
>30 ng/dl	7	27
Total	58	92

Table 5: Serum Vitamin D level and Chronic Kidney Disease

Serum Vitamin D	CKD Present	CKD Absent
<10 ng/dl	15	6
10–20 ng/dl	21	41
21–30 ng/dl	5	28
>30 ng/dl	5	29
Total	46	104

Table 6: Frequency distribution of serum vitamin D level in Retinopathy patients

Serum Vitamin D Levels (ng/dl)	Retinopathy Present Frequency	%	Retinopathy Absent Frequency	%	Total Frequency	%
<10	16	32.7	5	5.0	21	14.0
10–20	23	46.9	39	38.6	62	41.3
21–30	6	12.2	27	26.7	33	22.0
>30	4	8.2	30	29.7	34	22.7
Total	49	100	101	100	150	100

$\chi^2 = 18.721$, df = 3, p = 0.0003 (Highly Significant)

Table 7: Frequency distribution of serum vitamin D level in CKD patients

Serum Vitamin D Levels (ng/dl)	CKD Present Frequency	%	CKD Absent Frequency	%	Total Frequency	%
<10	15	32.6	6	5.8	21	14.0
10–20	21	45.7	41	39.4	62	41.3
21–30	5	10.9	28	26.9	33	22.0
>30	5	10.9	29	27.9	34	22.7
Total	46	100	104	100	150	100

$\chi^2 = 21.864$, df = 3, p = 0.0001 (Highly Significant)

Table 8: Frequency distribution of serum vitamin D level in LVH patients

Serum Vitamin D Levels (ng/dl)	LVH Present Frequency	%	LVH Absent Frequency	%	Total Frequency	%
<10	12	20.7	9	9.8	21	14.0
10–20	31	53.4	31	33.7	62	41.3
21–30	8	13.8	25	27.2	33	22.0
>30	7	12.1	27	29.3	34	22.7
Total	58	100	92	100	150	100

DISCUSSION

The present study evaluated serum vitamin D levels in 150 patients with essential hypertension and hypertension-related complications. The findings showed that vitamin D deficiency was highly prevalent among hypertensive patients, with 83 (55.3%) participants having serum vitamin D levels below 20 ng/dl. Only 34 (22.7%) patients had serum vitamin D levels above 30 ng/dl. This indicates that more than half of the study population had deficient or markedly low vitamin D status. The results further demonstrated that lower vitamin D levels were associated with hypertension-related target organ damage, including hypertensive retinopathy, left ventricular hypertrophy, and chronic kidney disease.

In the present study, hypertensive retinopathy was observed in 49 patients. Among these, 39 (79.6%) had serum vitamin D levels below 20 ng/dl, including 16 (32.7%) patients with levels below 10 ng/dl and 23 (46.9%) with levels between 10–20 ng/dl. Only 4 (8.2%) patients with retinopathy had vitamin D levels above 30 ng/dl. This association was statistically highly significant with $\chi^2 = 18.721$ and p = 0.0003. These findings suggest that vitamin D deficiency may be associated with microvascular changes in hypertensive patients. Vitamin D has been suggested to influence endothelial function,

vascular inflammation, oxidative stress, and vascular smooth muscle activity, all of which may contribute to retinal microvascular injury in long-standing hypertension [11].

The present study also showed a significant association between vitamin D deficiency and chronic kidney disease. Among 46 patients with CKD, 36 (78.3%) had serum vitamin D levels below 20 ng/dl, while only 5 (10.9%) had levels above 30 ng/dl. The association was statistically highly significant with $\chi^2 = 21.864$ and $p = 0.0001$. This finding is clinically important because the kidney is a major site for vitamin D metabolism, and renal dysfunction may further aggravate vitamin D deficiency. At the same time, low vitamin D status may contribute to renal vascular injury, activation of the renin-angiotensin-aldosterone system, inflammation, and progression of hypertensive nephropathy [12].

Left ventricular hypertrophy was present in 58 patients in the present study. Among these, 43 (74.1%) patients had vitamin D levels below 20 ng/dl, while only 7 (12.1%) patients had vitamin D levels above 30 ng/dl. The association between vitamin D deficiency and LVH was statistically highly significant with $\chi^2 = 17.952$ and $p = 0.0005$. This finding suggests that lower serum vitamin D levels may be associated with structural cardiac changes in hypertensive patients. Vitamin D receptors are present in cardiomyocytes and vascular tissues, and deficiency may contribute to myocardial hypertrophy, increased vascular resistance, endothelial dysfunction, and adverse cardiac remodeling [13].

The overall pattern observed in the present study indicates that vitamin D deficiency was more common among patients with hypertension-related complications than among those without complications. Patients with retinopathy, CKD, and LVH had a greater proportion of vitamin D levels below 20 ng/dl compared with patients without these complications. This supports the concept that vitamin D deficiency may not only be associated with hypertension but may also be related to disease severity and target organ damage. Similar observations have been reported in previous studies and meta-analyses, where low serum 25-hydroxyvitamin D levels were associated with higher blood pressure, increased risk of hypertension, and adverse cardiovascular outcomes [14].

The biological relationship between vitamin D and hypertension may be explained through several mechanisms. Vitamin D suppresses renin gene expression and downregulates the renin-angiotensin-aldosterone system. Deficiency of vitamin D may therefore lead to increased renin activity, sodium retention, vasoconstriction, and elevation of blood pressure. Vitamin D also plays a role in endothelial function, nitric oxide availability, inflammatory regulation, vascular calcification, and smooth muscle proliferation. These mechanisms may explain why patients with lower vitamin D levels in the present study showed a higher frequency of hypertensive complications [15].

Although observational findings strongly support an association between low vitamin D levels and hypertension, interventional evidence regarding vitamin D supplementation and blood pressure reduction remains variable. Some studies have shown modest improvement in blood pressure among vitamin D-deficient individuals, while other randomized trials and meta-analyses have not shown significant benefit in the general population. This suggests that the role of vitamin D may be more relevant in selected high-risk groups, particularly patients with baseline deficiency, long-standing hypertension, obesity, chronic kidney disease, or established target organ damage. The present study did not evaluate supplementation, but the high burden of deficiency among hypertensive patients supports the need for screening and correction of vitamin D deficiency as part of comprehensive cardiovascular risk assessment.

The findings of the present study are important in the Indian context, where vitamin D deficiency is common despite adequate sunlight availability. Lifestyle changes, reduced outdoor activity, dietary insufficiency, skin pigmentation, clothing habits, obesity, and urbanization may contribute to low vitamin D levels. Since hypertension and vitamin D deficiency are both highly prevalent, their coexistence may increase the risk of cardiovascular, renal, and retinal complications. Therefore, assessment of vitamin D status in hypertensive patients may help identify individuals at higher risk of target organ damage.

The present study had certain limitations. Being a cross-sectional study, it could establish association but not causality between vitamin D deficiency and hypertension-related complications. Seasonal variation, dietary intake, sun exposure, body mass index, physical activity, and antihypertensive medication use may have influenced vitamin D levels and were not fully controlled. Despite these limitations, the study provides meaningful evidence that vitamin D deficiency is common among hypertensive patients and is significantly associated with complications such as retinopathy, CKD, and LVH.

CONCLUSION

The present study concluded that vitamin D deficiency was highly prevalent among patients with essential hypertension and hypertension-related complications. Serum vitamin D levels below 20 ng/dl were observed in 83 (55.3%) patients. Low vitamin D levels were significantly associated with hypertensive retinopathy, chronic kidney disease, and left ventricular hypertrophy. Among patients with retinopathy, 39 (79.6%) had vitamin D levels below 20 ng/dl, while 36

(78.3%) CKD patients and 43 (74.1%) LVH patients also had levels below 20 ng/dl. These findings suggest that vitamin D deficiency may be associated with increased risk of target organ damage in hypertensive patients. Routine evaluation of serum vitamin D levels in hypertensive patients may help in early identification of high-risk individuals. Further prospective and interventional studies are required to determine whether correction of vitamin D deficiency can reduce the burden of hypertension-related complications.

Conflict of interest: No! Conflict of interest is found elsewhere considering this work.
Source of Funding: There was no financial support concerning this work.

REFERENCES

1. Jensen NS, Møller CL, Dalgaard MD, Christensen MH, Hansen D, Bie P. Latest knowledge on the role of vitamin D in hypertension. Front Physiol. 2023;14:1096849.
2. Serra MO, Barroso WKS, de Oliveira EP. Effect of vitamin D supplementation on blood pressure in individuals with hypertension and hypovitaminosis D: systematic review and meta-analysis. Clin Nutr ESPEN. 2024;59:145-154.
3. Qi S, Huang X, Wang N, Zhang Y, Li X, Zhao Y. Vitamins and minerals for blood pressure reduction in primary hypertension: a systematic review and network meta-analysis. BMJ Open. 2024;14:e074511.
4. Sheikh V, Mozaianimonfared A, Gharakhani M, Mohammadi Y, Rahimi Z, Vaisi-Raygani A. Effect of vitamin D supplementation versus placebo on essential hypertension in patients with vitamin D deficiency: a double-blind randomized clinical trial. J Clin Hypertens (Greenwich). 2020;22(10):1867-1873.
5. Zhang D, Cheng C, Wang Y, Sun H, Yu S, Xue Y. Effect of vitamin D on blood pressure and hypertension in the general population: an update meta-analysis of cohort studies and randomized controlled trials. Prev Chronic Dis. 2020;17:E03.
6. Shu L, Huang K. Effect of vitamin D supplementation on blood pressure parameters in patients with vitamin D deficiency: a systematic review and meta-analysis. J Am Soc Hypertens. 2018;12(6):488-496.
7. Kunutsor SK, Apekey TA, Steur M. Vitamin D and risk of future hypertension: a meta-analysis of 283,537 participants. Eur J Epidemiol. 2013;28(3):205-221.
8. Beveridge LA, Struthers AD, Khan F, Jorde R, Scragg R, Macdonald HM, et al. Effect of vitamin D supplementation on blood pressure: a systematic review and meta-analysis incorporating individual patient data. JAMA Intern Med. 2015;175(5):745-754.
9. Pilz S, Gaksch M, Kienreich K, Grübler M, Verheyen N, Fahrleitner-Pammer A, et al. Effects of vitamin D on blood pressure and cardiovascular risk factors: a randomized controlled trial. Hypertension. 2015;65(6):1195-1201.
10. Mirhosseini N, Vatanparast H, Kimball SM. The association between serum 25-hydroxyvitamin D status and blood pressure in participants of a community-based program taking vitamin D supplements. Nutrients. 2017;9(11):1244.
11. Bhandari SK, Pashayan S, Liu IL, Rasgon SA, Kujubu DA, Tom TY, et al. 25-Hydroxyvitamin D levels and hypertension rates. J Clin Hypertens (Greenwich). 2011;13(3):170-177.
12. Vaidya A, Forman JP. Vitamin D and hypertension: current evidence and future directions. Hypertension. 2010;56(5):774-779.
13. Li YC. Vitamin D regulation of the renin-angiotensin system. J Cell Biochem. 2003;88(2):327-331.
14. Qi D, Nie X, Cai J. The effect of vitamin D supplementation on hypertension in non-CKD populations: a systematic review and meta-analysis. Int J Cardiol. 2017;227:177-186.
15. Witham MD, Nadir MA, Struthers AD. Effect of vitamin D on blood pressure: a systematic review and meta-analysis. J Hypertens. 2009;27(10):1948-1954.