Original Article

A Comparative Study of Serum Total Calcium, Phosphorus, and Their Ratio in Hypertensive and Normotensive Individuals

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Abstract

Background: Hypertension continues to be one of the most prevalent cardiovascular disorders worldwide. Alterations in calcium and phosphorus balance have been proposed as contributing factors in its development, yet the available evidence remains inconsistent. This study aimed to compare serum calcium, phosphorus, and the calcium-to-phosphorus (Ca:P) ratio between hypertensive and normotensive adults, and to assess their association with blood pressure. **Material and Methods:** The study included 30 cases with essential hypertension and 30 age-matched normotensive individuals as controls. Non-invasive blood pressure reading was recorded, and early-morning blood samples was taken and serum calcium phosphorus, urea, and creatinine levels were measured. Comparative analysis between the groups was performed and the Pearson's correlation was utilized to evaluate relationship of biochemical parameters with systolic and diastolic blood pressure. **Results:** Hypertensive individuals demonstrated significantly lower serum calcium and higher serum phosphorus levels compared to controls. Consequently, the Ca:P ratio was markedly reduced in the hypertensive group. Furthermore, serum calcium exhibited a strong inverse correlation with both systolic and diastolic blood pressure, whereas serum phosphorus showed a moderate positive correlation. The Ca:P ratio also demonstrated a strong negative correlation with blood pressure parameters. **Conclusion:** Individuals with essential hypertension exhibit substantial disturbances in mineral metabolism, characterized by reduced calcium, elevated phosphorus, and a lower Ca:P ratio. These imbalances show significant associations with higher blood pressure values, underscoring the possible role of mineral homeostasis in the pathophysiology of hypertension. Further studies are warranted to explore the therapeutic potential of correcting mineral imbalance in hypertensive patients.

Keywords: Hypertension, Calcium, Phosphorus, Ca:P ratio, Mineral imbalance, Cardiovascular risk.

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Introduction

Hypertension remains most crucial and modifiable trigger of health issues and mortality world-wide as it is closely linked to atherosclerotic cardiovascular disease, cerebrovascular disease, cardiac failure, and chronic renal disease.[1] Despite substantial advances, the mechanisms underlying essential hypertension are not fully defined, reflecting an intricate interaction of genetic susceptibility, extrinsic influences, lifestyle factors, and biochemical dysregulation.[2]

Within these biochemical pathways, mineral metabolism—particularly calcium and phosphorus—has drawn considerable attention. Although traditionally associated with skeletal health, these minerals exert important extra-skeletal effects. Calcium is central to vascular smooth muscle contraction, cardiac excitability, and neurotransmission.[2,3] Its intracellular concentration directly influences vascular tone and peripheral resistance, both key determinants of arterial pressure.[4,5] Observational and experimental data have suggested links between calcium status and hypertension; however, findings are inconsistent, ranging from positive to inverse associations or no association at all.[5-8]

Phosphorus, less frequently examined in this context, is fundamental to cellular energy metabolism and structural integrity. Elevated serum phosphorus has been associated with endothelial dysfunction, arterial stiffness, and vascular calcification, processes that can increase systemic vascular resistance and raise blood pressure.[9,10]

The calcium-to-phosphorus balance—often expressed as the Ca:P ratio—is governed by tightly regulated hormonal axes involving PTH (Hormone secreted by parathyroid gland),

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fibroblast growth factor-23 (FGF-23) and vitamin D3.[11] Disruption of this balance may act as an early metabolic signal of cardiovascular stress. While numerous studies have explored individual mineral levels in relation to hypertension, the role of the Ca:P ratio has been evaluated less extensively, and data from Indian populations remain limited.[12-16]

In view of these gaps and conflicting results in the literature this study was conducted to compare serum calcium, phosphorus, and the Ca:P ratio between hypertensive and normotensive adults, and to assess the correlations of these markers with systolic and diastolic blood pressure.[12-16]

Materials and Methods

Over the course of eighteen months, this cross-sectional study was executed in the general medicine department of a medical college in Himachal Pradesh. A total of sixty individuals were recruited and divided into two groups. The case group consisted of 30 adults aged 18–65 years diagnosed with Essential hypertension is identified as a systolic blood pressure reading that is more than 140 mmHg alongside diastolic blood pressure more than ninety mmHg on at least two separate occasions. The control group comprised 30 age-matched normotensive individuals with systolic blood pressure and diastolic blood pressure less than 140 and 90 mmHg respectively.

Participants with conditions known to affect calcium or phosphorus metabolism—including stage III to IV CKD and individuals with undocumented renal function—were excluded from the study. A standardized proforma was used to collect comprehensive demographic data, medical history, lifestyle choices (such as smoking and alcohol consumption), and family history of hypertension.

After at least five minutes of rest, the participant's blood pressure was taken while seated using a conventional mercury sphygmomanometer. For analysis, the mean of two measurements obtained five minutes apart from the right arm was taken into consideration.

Fasting venous blood samples were collected under aseptic precautions for estimation of serum total calcium, phosphorus, urea, and creatinine. All biochemical parameters were measured using standard spectrophotometric techniques in the institutional clinical laboratory. The calcium-to-phosphorus (Ca:P) ratio was calculated from the measured values.

Data analysis was done using SPSS version 27.0. Unpaired t-test was utilized to compare continuous variables between groups, which were displayed as mean ± standard deviation (SD). The Chi-square test was used to assess categorical variables that were represented as frequencies and percentages. The relationship between metabolic markers and blood pressure was evaluated using Pearson's correlation coefficient. Statistical significance was defined as a p-value of less than 0.05.

Results

Thirty hypertension patients and thirty normotensive controls made up the study's total of sixty participants. 53.3% of the study population were female, with an average age of 52.62 ± 10.43 years. Age, sex distribution, body mass index (BMI), and lifestyle characteristics including alcohol consumption and smoking did not differ statistically significantly between the two groups (all $p > 0.05$), indicating proper matching. As anticipated, the hypertension group's systolic and diastolic blood pressure readings were considerably greater than the controls' ($p < 0.001$).

Biochemical Parameters:

Marked differences in biochemical markers were noted between the groups. Hypertensive individuals demonstrated lower mean serum calcium levels (8.66 ± 0.81 mg/dL) compared with normotensive subjects (9.15 ± 0.95mg/dL; p=0.04). In contrast, serum phosphorus levels were significantly elevated among hypertensive participants (3.74 ± 0.97 mg/dL) relative to controls (3.01 ± 0.67 mg/dL; p<0.01). Blood urea levels were also higher in the hypertensive group (32.39 ± 6.80 mg/dL vs. 27.80 ± 9.41 mg/dL; p = 0.04), whereas serum creatinine did not differ significantly between the groups (p = 0.91). Consequently, the Ca:P ratio was significantly lower in hypertensive subjects (2.51 ± 0.83) as compared to normotensives (3.22 ± 0.97; p < 0.01).

Correlation Analysis

Serum calcium and both systolic blood pressure (r= −0.554, p=0.001) and diastolic blood pressure (r= −0.577, p=0.001) had a strong inverse connection, according to Pearson's correlation analysis. systolic blood pressure (r=0.491, p=0.006) and diastolic blood pressure (r=0.477, p=0.008) showed a somewhat favourable connection with serum phosphorus. The Ca:P ratio had the highest negative connection with diastolic blood pressure (r= −0.564, p=0.001) and systolic blood pressure (r= −0.600, p<0.001).

Hypertension Stage-wise Trends

Subgroup analysis within the hypertensive cohort demonstrated notable trends. Serum phosphorus levels were highest among patients with Stage I hypertension (4.00 mg/dL) and lowest in Stage II (2.54 mg/dL; p = 0.018). The Ca:P ratio was lowest in Stage I hypertension (2.26) and highest in Stage II (3.81; p = 0.002). Although serum calcium levels varied across stages but the difference was not significant statistically (p=0.156).

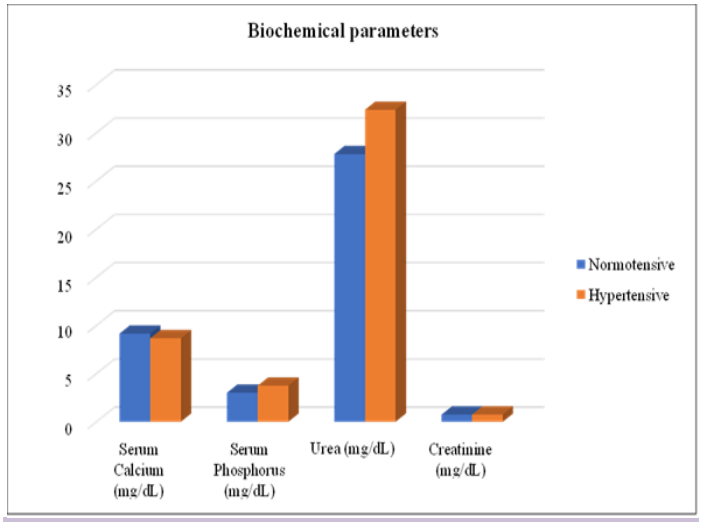

Figure 1: Bar chart illustrating differences in serum calcium, phosphorus, urea, creatinine, and Ca:P ratio between hypertensive and normotensive participants.

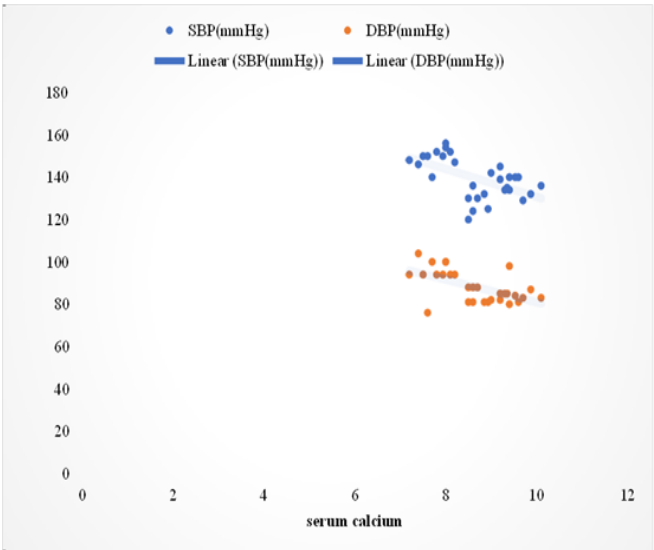

Figure 2: Scatter diagram depicting an inverse corelation between serum calcium and both systolic and diastolic blood pressure.

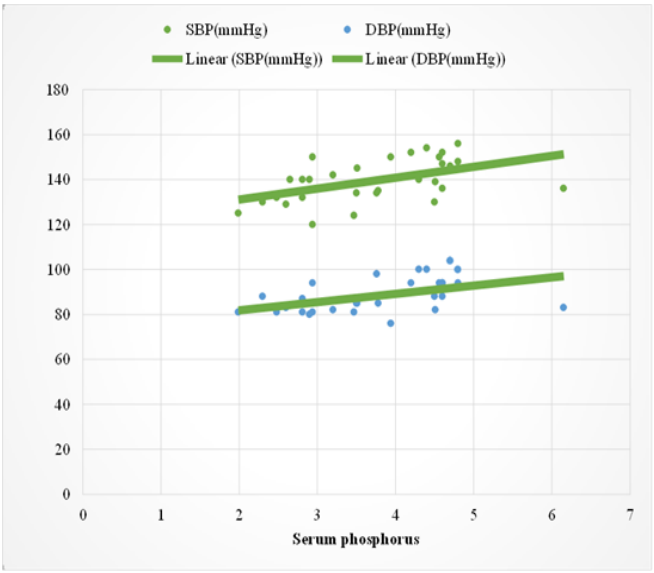

Figure 3: Scatter plot showing a positive correlation between serum phosphorus and systolic/diastolic blood pressure.

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population

Parameter	Hypertensive (n = 30)	Normotensive (n = 30)	p-value
Age (years), Mean ± SD	53.87 ± 10.25	51.37 ± 10.57	0.34
Female (%)	63.3% (19/30)	43.3% (13/30)	0.121
BMI (kg/m²), Mean ± SD	20.60 ± 1.69	20.41 ± 1.55	0.65
Mean SBP (mmHg)	139.60 ± 9.60	121.67 ± 8.40	<0.001
Mean DBP (mmHg)	88.23 ± 7.47	76.90 ± 7.60	<0.001
Non-smoker / Non-drinker (%)	90.0%	80.0%	0.314

Table 2. Biochemical Profile in Hypertensive vs. Normotensive Groups

Laboratory Parameter	Hypertensive (n = 30)	Normotensive (n = 30)	p-value
Serum calcium (mg/dL)	8.66 ± 0.81	9.15 ± 0.95	0.04
Serum phosphorus (mg/dL)	3.74 ± 0.97	3.01 ± 0.67	<0.01
Blood urea (mg/dL)	32.39 ± 6.80	27.80 ± 9.41	0.04
Creatinine (mg/dL)	0.76 ± 0.23	0.75 ± 0.22	0.91
Ca:P ratio	2.51 ± 0.83	3.22 ± 0.97	<0.01

Table 3: Correlation of Biochemical Parameters with Blood Pressure

Parameter	SBP (r-value)	p-value	DBP (r-value)	p-value
Serum calcium	−0.554	0.001	−0.577	0.001
Serum phosphorus	+0.491	0.006	+0.477	0.008
Ca:P ratio	−0.600	<0.001	−0.564	0.001

Table 4. Mineral Profile Across Hypertension Stages

Parameter	Pre-HTN (n = 4)	Stage I (n = 23)	Stage II (n = 3)	p-value
Serum calcium (mg/dL)	8.80 ± 0.41	8.53 ± 0.84	9.47 ± 0.48	0.156
Serum phosphorus (mg/dL)	3.19 ± 0.99	4.00 ± 0.88	2.54 ± 0.47	0.018
Ca:P ratio	2.95 ± 0.81	2.26 ± 0.67	3.81 ± 0.59	0.002

Discussion

Study demonstrates a clear alteration in calcium and phosphorus homeostasis among individuals with essential hypertension. Hypertensive subjects exhibited lower serum calcium, higher serum phosphorus, and a markedly reduced Ca:P ratio, all of which showed significant correlations with systolic and diastolic BP. These findings support the hypothesis that mineral dysregulation may contribute to the development of hypertension.

The finding of decreased serum calcium in hypertensive individuals aligns with previous research showing that blood pressure and calcium levels are inversely correlated. Several physiological mechanisms may explain this relationship.[2,12,13] Reduced extracellular calcium stimulates PTH release, causing increased intracellular calcium in smooth muscle cells of blood vessels, enhanced vasoconstriction causing elevated peripheral vascular resistance.[4,9] Additionally, some studies describe a "renal calcium leak" phenomenon in essential hypertension, resulting in secondary hyperparathyroidism and reduced circulating calcium levels.[8] These mechanisms help justify the strong negative correlation between calcium and both SBP and DBP observed in this study.

The present study also reports significantly higher phosphorus levels in hypertensive patients, consistent with emerging

evidence linking hyperphosphatemia to vascular dysfunction and hypertension.[10,13] Elevated serum phosphorus contributes to endothelial damage, arterial stiffness, and vascular calcification, thereby increasing vascular resistance and blood pressure. This is in accordance with the positive correlations found between phosphorus and blood pressure parameters in the current analysis.

Importantly, the Ca:P ratio—a more comprehensive reflection of mineral balance—demonstrated the strongest inverse association with systolic and diastolic pressures. A lower Ca:P ratio indicates a relative phosphorus excess and has been associated with heightened cardiovascular risk and vascular injury.[13] Thus, the reduced Ca:P ratio in hypertensive patients in this study reinforces the importance of evaluating mineral balance rather than individual electrolyte levels alone.

In the stage-wise subgroup analysis, the Ca:P ratio showed a paradoxical rise in stage II hypertension. Although this finding did not reach firm conclusions due to the small subgroup, it may indicate compensatory hormonal responses involving PTH or FGF-23, or renal functional adaptation in advanced hypertension. Further studies with larger samples are needed to validate this observation.

Some large population studies, such as data from Western cohorts, have reported a positive association between serum calcium and hypertension.[11,14] These differences may reflect genetic, dietary, and environmental variations, as well as differences in controlling for confounding factors such as albumin or ionized calcium. The current findings agree more closely with results reported in Asian and Indian populations,[2,15,16] suggesting potential regional or ethnic influences in mineral–blood pressure regulation.

Strengths & Limitations

Key strengths include a well-matched control group, strict exclusion of individuals with renal dysfunction, and assessment of both individual minerals and Ca:P ratio. However, there were some limitations in this study like the sample size was modest and limiting generalizability. Only total calcium was measured, while ionized calcium—the biologically active form—was not evaluated. Important regulatory factors such as PTH, vitamin D, and FGF-23 were not assessed. Additionally, given the cross-sectional design, causality cannot be established.

Clinical Implications & Future Research

These findings underscore the importance of evaluating calcium–phosphorus equilibrium in hypertensive patients. Nutritional strategies ensuring adequate calcium intake and moderation of phosphorus-rich foods might serve as a useful adjunct to standard antihypertensive therapy. Future large-scale, prospective studies measuring ionized calcium and mineral-regulating hormones are needed to determine whether correcting mineral imbalance can help improve blood pressure control and cardiovascular outcomes.

Conclusion

This study demonstrates that individuals with essential hypertension exhibit distinct disturbances in metabolism of minerals like calcium and phosphorus which is characterized by low serum calcium, elevated serum phosphorus, and a significantly reduced Ca:P ratio. These biochemical alterations showed strong correlations with elevated systolic and diastolic blood pressure, indicating that mineral imbalance might have a crucial and important contributory role in pathophysiology of hypertension.

Among the evaluated parameters, the Ca:P ratio emerged as a particularly valuable marker, displaying the strongest association with blood pressure indices. This suggests that the relative balance between calcium and phosphorus may be more informative than individual mineral levels alone when assessing metabolic influences on blood pressure regulation.

The findings highlight the potential relevance of evaluating and addressing mineral homeostasis in the clinical management of hypertension. Ensuring adequate dietary calcium intake and monitoring phosphorus levels may serve as useful adjuncts to conventional antihypertensive strategies. Future large-scale studies, particularly those incorporating ionized calcium and regulatory hormones such as parathyroid hormone, vitamin D, and FGF-23, are needed to further clarify these associations and explore whether correcting mineral imbalance leads to improved cardiovascular outcomes.

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Conflicts of interest

There are no conflicts of interest.

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