

Original Research Article

PROSPECTIVE ANALYSIS OF SERUM VITAMIN D AND CALCIUM IN PREGNANT WOMEN AND THEIR ASSOCIATION WITH PRE-ECLAMPSIA

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ABSTRACT

Background: Pre-eclampsia is a major hypertensive disorder of pregnancy that contributes significantly to maternal and fetal morbidity and mortality. Emerging evidence suggests that micronutrient deficiencies, particularly of vitamin D and calcium, may influence its development by altering vascular, metabolic, and placental function. **Aim:** To assess serum vitamin D and calcium levels in pregnant women and analyze their association with the development of pre-eclampsia.

Material and Methods: This prospective observational study was conducted from May 2024 to November 2024 at Anugrah Narayan Magadh Medical College and Hospital, Gaya on 130 pregnant women between 20 and 36 weeks of gestation. Participants were divided into two groups: Group A (n = 65, pre-eclamptic women diagnosed per ACOG criteria) and Group B (n = 65, normotensive controls). Detailed demographic, dietary, and clinical data were collected. Serum 25(OH) vitamin D was measured using CLIA, and serum calcium using the Arsenazo III method. Statistical analysis included t-tests, chi-square tests, Pearson correlation, and multiple linear regression.

Results: Group A had significantly higher BMI (26.8 ± 2.5 vs. 25.2 ± 2.3 kg/m², p = 0.003), lower sun exposure (0.9 ± 0.4 vs. 1.5 ± 0.6 hours, p < 0.001), and reduced dietary calcium intake (520 ± 110 vs. 690 ± 125 mg/day, p < 0.001) compared to Group B. Serum vitamin D (18.2 ± 6.5 vs. 26.1 ± 7.3 ng/mL, p < 0.001) and calcium (8.12 ± 0.74 vs. 9.01 ± 0.68 mg/dL, p < 0.001) were significantly lower in pre-eclamptic women. Vitamin D deficiency (<20 ng/mL) was more common in Group A (58.46%) than Group B (27.69%). Multiple regression analysis showed serum vitamin D (B = -0.68, p = 0.002), calcium (B = -2.15, p = 0.005), sun exposure (B = -1.80, p = 0.032), and dietary calcium (B = -0.011, p = 0.011) were significant predictors of systolic BP (Adjusted R² = 0.48, p < 0.001).

Conclusion: Low serum vitamin D and calcium levels were significantly associated with pre-eclampsia. Nutritional deficiencies and reduced sun exposure emerged as modifiable contributors. Early screening and supplementation of these nutrients may reduce the risk and severity of pre-eclampsia.

Keywords: Pre-eclampsia, Vitamin D, Calcium, Pregnancy, Hypertension.

INTRODUCTION

Pre-eclampsia remains one of the most serious complications of pregnancy, posing significant risks to both maternal and fetal health. Characterized by the new onset of hypertension and proteinuria after 20 weeks of gestation, it can progress to lifethreatening conditions such as eclampsia, HELLP syndrome, or multi-organ failure. Globally, it accounts for a substantial proportion of maternal mortality and morbidity, especially in low- and middle-income countries. Despite advancements in obstetric care, the etiology and pathogenesis of preeclampsia are still not fully understood, and effective predictive and preventive strategies remain limited. Recent research has increasingly emphasized the importance of micronutrients, particularly vitamin D and calcium, in the regulation of vascular function, immune modulation, and placental development. Both vitamin D and calcium are critical in maintaining endothelial integrity, smooth muscle function, and maternal-fetal calcium transport. Deficiency of these nutrients during pregnancy has been linked with abnormal placentation, impaired vasodilation, and heightened responses—factors known inflammatory to contribute to the pathophysiology of pre-eclampsia. Vitamin D, a fat-soluble secosteroid hormone, is synthesized endogenously in the skin upon exposure to ultraviolet B radiation or obtained through dietary sources and supplements. During pregnancy, vitamin D plays a pivotal role in immune tolerance, placental implantation, and regulation of angiogenic and anti-angiogenic factors. Its deficiency has been associated with increased oxidative stress, proinflammatory cytokine release, and impaired trophoblastic invasion-all contributing to poor placental perfusion and endothelial dysfunction. Numerous observational studies and meta-analyses have shown a higher incidence of pre-eclampsia among women with suboptimal vitamin D levels, suggesting a potentially modifiable risk factor for adverse maternal outcomes.^[1-4]

Calcium, an essential mineral involved in vascular tone and neuromuscular excitability, is another key player in maternal cardiovascular adaptation during pregnancy. Adequate calcium intake has been associated with reduced risk of gestational hypertension and pre-eclampsia. The proposed mechanisms include calcium's ability to modulate intracellular smooth muscle activity, reduce parathyroid hormone and renin release, and enhance vasodilation. Insufficient calcium intake, on the other hand, may lead to increased intracellular calcium levels in vascular smooth muscles, resulting in vasoconstriction and elevated blood pressure. Intervention trials have demonstrated that calcium supplementation, particularly when initiated early in pregnancy or among women at high risk, significantly reduces the risk of pre-eclampsia and its severity.^[2,5]

However, the relationship between serum levels of vitamin D and calcium and their association with pre-eclampsia continues to be complex and contextdependent. Ethnic, geographic, dietary, and seasonal factors influence vitamin D synthesis and calcium metabolism, making it essential to explore population-specific patterns and correlations. Moreover, the threshold values for deficiency and sufficiency, especially during pregnancy, remain a matter of ongoing debate, further complicating clinical recommendations.

Emerging evidence has also highlighted a possible interaction between vitamin D and calcium

homeostasis in influencing pregnancy outcomes. Vitamin D facilitates active calcium absorption in the intestines and maintains serum calcium levels through its effects on the parathyroid gland and renal calcium reabsorption. Thus, dual deficiency could potentially amplify the risk of hypertensive disorders during pregnancy. Conversely, adequate levels of both nutrients may offer synergistic protective effects, promoting maternal vascular health and placental function.

The COVID-19 pandemic has further underlined the need to explore maternal micronutrient status, as several studies have reported altered vitamin D metabolism and immune dysregulation in infected individuals. Pregnant women, already immunologically vulnerable, may be especially susceptible to compounded risks if deficient in vitamin D or calcium. Recent pilot studies in post-COVID pregnancy populations have suggested a higher incidence of gestational hypertension and pre-eclampsia in women with low vitamin D levels.^[5,6] Such findings reinforce the importance of evaluating these biomarkers prospectively to better understand their predictive and therapeutic value.

Although systematic reviews and meta-analyses support the association between low vitamin D levels and pre-eclampsia, heterogeneity in study design, diagnostic criteria, sample size, and laboratory methods has led to inconsistent conclusions.^[7,8] As such, there is a pressing need for well-designed, prospective, population-specific studies to validate these associations and explore the underlying mechanisms. Specifically, simultaneous evaluation of serum vitamin D and calcium in pregnant women, along with their correlation to blood pressure profiles and proteinuria, may offer valuable insights into their collective role in preeclampsia.

Given this background, the present study was designed as a prospective analysis to evaluate serum vitamin D and calcium levels among pregnant women and investigate their association with the occurrence of pre-eclampsia. The study also aims to explore the potential predictive value of these biomarkers and examine their interrelationship with maternal blood pressure and clinical indicators of pre-eclampsia. By addressing these objectives, the study seeks to contribute to the growing body of evidence on nutritional determinants of hypertensive disorders in pregnancy and inform future preventive strategies tailored to high-risk populations.

MATERIALS AND METHODS

This prospective observational study was conducted from May 2024 to November 2024 at Anugrah Narayan Magadh Medical College and Hospital Gaya in the Department of Obstetrics and Gynecology in collaboration with the Department of Biochemistry. The study aimed to assess serum levels of Vitamin D and calcium in pregnant women and analyze their association with the development of pre-eclampsia. A total of 130 pregnant women were enrolled consecutively after obtaining informed written consent. Participants were recruited from the antenatal outpatient clinic and inpatient wards. Based on clinical and diagnostic criteria, the subjects were divided into two groups:

- Group A (Pre-eclampsia group): 65 pregnant women diagnosed with pre-eclampsia as per the American College of Obstetricians and Gynecologists (ACOG) criteria—defined as blood pressure ≥140/90 mmHg on two occasions at least four hours apart after 20 weeks of gestation with proteinuria ≥300 mg/24 hours or a protein/creatinine ratio ≥0.3.
- **Group B** (Normotensive control group): 65 healthy, normotensive pregnant women matched for gestational age and parity without any known medical or obstetric complications.

Inclusion Criteria

- Singleton pregnancy between 20 and 36 weeks of gestation.
- Age between 18 and 40 years.
- Willingness to participate and provide informed consent.

Exclusion Criteria

- Pre-existing chronic hypertension, renal disease, or diabetes mellitus.
- Multiple pregnancy.
- Current use of Vitamin D or calcium supplements exceeding daily recommended allowances.
- Known metabolic bone disorders or malabsorption syndromes.

Methodology

Detailed demographic and obstetric data were recorded using a structured proforma, which included information on maternal age, gestational age at enrolment, parity, body mass index (BMI), dietary calcium and vitamin D intake, duration and timing of sun exposure, and relevant medical or obstetric history such as pre-existing illnesses or prior hypertensive disorders of pregnancy.

For biochemical analysis, 5 mL of venous blood was collected aseptically from each participant. The samples were allowed to clot, centrifuged to separate serum, and stored at -20° C until further processing. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using the chemiluminescence immunoassay (CLIA) technique, which offers high sensitivity and specificity for quantifying vitamin D levels. Simultaneously, serum calcium levels were estimated using a colorimetric method based on the Arsenazo III reagent, performed on an automated biochemistry analyzer to ensure accuracy and consistency of results. The reference ranges used for interpretation were as follows: Vitamin D sufficiency was defined as serum levels >30 ng/mL, insufficiency as 20-30 ng/mL, and deficiency as <20 ng/mL. For serum calcium, normal levels were considered to lie within the range of 8.5-10.5 mg/dL.

Statistical Analysis

Data were compiled and analyzed using SPSS version 25.0. Continuous variables were expressed as mean \pm standard deviation (SD), and categorical variables as frequency and percentage. Independent t-test and chi-square test were used for group comparisons. Pearson correlation was applied to evaluate the association between Vitamin D and calcium levels with systolic and diastolic blood pressure. A p-value of <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic and ObstetricCharacteristics of Study Participants

The demographic comparison between the preeclampsia group (Group A) and the normotensive control group (Group B) revealed no statistically significant differences in mean maternal age (27.6 \pm 4.2 vs. 26.9 \pm 3.9 years, p = 0.24), gestational age at enrollment $(31.8 \pm 3.1 \text{ vs. } 32.1 \pm 2.8 \text{ weeks}, \text{ p} =$ 0.52), or proportion of primigravida participants (64.62% vs. 60.00%, p = 0.59). However, a significant difference was observed in the mean body mass index (BMI), which was notably higher in the pre-eclamptic group $(26.8 \pm 2.5 \text{ kg/m}^2)$ compared to controls $(25.2 \pm 2.3 \text{ kg/m}^2)$ (p = 0.003). This suggests a possible contributory role of higher BMI in the pathogenesis of pre-eclampsia. Moreover, average daily sun exposure was significantly lower among pre-eclamptic women $(0.9 \pm 0.4$ hours vs. 1.5 ± 0.6 hours, p < 0.001), which may have contributed to their reduced vitamin D levels. Dietary calcium intake also showed a marked deficiency in Group A (520 \pm 110 mg/day) compared to Group B (690 \pm 125 mg/day). with high statistical significance (p < 0.001). Additionally, mean hemoglobin levels were significantly lower in Group A (10.2 \pm 1.1 g/dL) than in controls $(11.1 \pm 1.2 \text{ g/dL}, \text{ p} = 0.001)$, indicating a higher prevalence of anemia in the preeclamptic group.

Table 2: Blood Pressure and ProteinuriaParameters

Blood pressure measurements demonstrated a clear and statistically significant distinction between the groups. The mean systolic blood pressure in Group A was 148.6 \pm 8.7 mmHg, substantially elevated compared to 116.4 \pm 7.9 mmHg in Group B (p < 0.001). Similarly, the mean diastolic blood pressure was significantly higher in pre-eclamptic women (96.2 \pm 5.5 mmHg) than in controls (74.5 \pm 6.3 mmHg) (p < 0.001). The calculated mean arterial pressure (MAP) further supported these findings, being 113.7 \pm 6.2 mmHg in Group A versus 88.5 \pm 5.9 mmHg in Group B (p < 0.001). Proteinuria, a hallmark of pre-eclampsia, was significantly more pronounced in Group A with a 24-hour urinary protein excretion of 475.3 \pm 102.4 mg compared to 98.2 \pm 22.6 mg in the control group (p < 0.001). Likewise, the urine protein/creatinine ratio was markedly elevated in the pre-eclamptic group (0.43 \pm 0.09 vs. 0.12 \pm 0.03, p < 0.001). Edema was clinically evident in a large majority of Group A (78.46%) as opposed to only 18.46% in Group B, further reinforcing the clinical diagnosis (p < 0.001). **Table 3: Vitamin D Status Distribution with Severity of Deficiency**

Vitamin D insufficiency and deficiency were markedly more common among women with preeclampsia. Only 12.31% of women in Group A had sufficient serum vitamin D levels (>30 ng/mL), compared to 32.31% in Group B (p = 0.008). Mild deficiency (10–20 ng/mL) was seen in 44.62% of pre-eclamptic women, significantly higher than 23.08% in the control group. Severe deficiency (<10 ng/mL) was nearly three times more prevalent in Group A (13.84%) compared to Group B (4.62%). These findings suggest a strong inverse association between vitamin D levels and pre-eclampsia risk.

Table 4: Biochemical Profile of Study Groups

The biochemical parameters further highlighted differences between the two groups. Serum vitamin D levels were significantly lower in the preeclamptic group (18.2 ± 6.5 ng/mL) compared to the control group (26.1 ± 7.3 ng/mL), with a p-value of <0.001. Similarly, serum calcium levels were reduced in Group A (8.12 ± 0.74 mg/dL) versus Group B (9.01 ± 0.68 mg/dL) (p < 0.001). Interestingly, serum phosphorus was higher in Group A (4.2 \pm 0.6 mg/dL) compared to Group B (3.7 \pm 0.5 mg/dL) (p = 0.003), possibly reflecting altered calcium-phosphate metabolism. Elevated alkaline phosphatase levels were observed in pre-eclamptic women (152 \pm 38 IU/L) compared to controls (131 \pm 29 IU/L, p = 0.002), indicating a possible hepatic or placental involvement. Serum albumin levels were significantly lower in Group A (3.1 \pm 0.4 g/dL) than Group B (3.4 \pm 0.3 g/dL, p = 0.001), consistent with protein loss and systemic inflammation in pre-eclampsia.

Table 5: Multiple Linear Regression Analysis

Multiple linear regression was employed to identify independent predictors of systolic blood pressure among pre-eclamptic women. The analysis revealed that serum vitamin D had a significant negative association with systolic BP (B = -0.68, p = 0.002), indicating that for every unit decrease in vitamin D, systolic BP increased by 0.68 mmHg. Serum calcium also showed a significant inverse relationship (B = -2.15, p = 0.005), suggesting a potentially protective role of calcium against blood pressure elevation. Additionally, reduced sun exposure (B = -1.80, p = 0.032) and low dietary calcium intake (B = -0.011, p = 0.011) were also found to be significant contributors to higher systolic blood pressure. The model had a strong predictive value with an adjusted R^2 of 0.48, indicating that nearly half the variance in systolic blood pressure could be explained by these four parameters. The overall model was highly significant (p < 0.001).

Table 1: Demographic and Obstetric Characteristics of Study Participants				
Parameter	Group A (Pre-eclampsia) (n = 65)	Group B (Control) (n = 65)	P Value	
Mean Age (years)	27.6 ± 4.2	26.9 ± 3.9	0.24	
Gestational Age (weeks)	31.8 ± 3.1	32.1 ± 2.8	0.52	
Primigravida (%)	42 (64.62%)	39 (60.00%)	0.59	
BMI (kg/m ²)	26.8 ± 2.5	25.2 ± 2.3	0.003*	
Average Daily Sun Exposure (hrs)	0.9 ± 0.4	1.5 ± 0.6	< 0.001*	
Dietary Calcium Intake (mg/day)	520 ± 110	690 ± 125	< 0.001*	
Mean Hemoglobin (g/dL)	10.2 ± 1.1	11.1 ± 1.2	0.001*	

Table 2: Blood Pressure and Proteinuria Parameters				
Parameter	Group A (Pre-eclampsia)	Group B (Control)	P Value	
Systolic BP (mmHg)	148.6 ± 8.7	116.4 ± 7.9	< 0.001*	
Diastolic BP (mmHg)	96.2 ± 5.5	74.5 ± 6.3	< 0.001*	
Mean Arterial Pressure (mmHg)	113.7 ± 6.2	88.5 ± 5.9	< 0.001*	
Proteinuria (mg/24hr)	475.3 ± 102.4	98.2 ± 22.6	< 0.001*	
Urine Protein/Creatinine Ratio	0.43 ± 0.09	0.12 ± 0.03	< 0.001*	
Edema Present (%)	51 (78.46%)	12 (18.46%)	< 0.001*	

Table 3: Vitamin D Status Distribution with Severity of Deficiency

Vitamin D Category	Group A (n = 65)	Group B (n = 65)	P Value
Sufficient (>30 ng/mL)	8 (12.31%)	21 (32.31%)	0.008*
Insufficient (20–30 ng/mL)	19 (29.23%)	26 (40.00%)	
Mild Deficiency (10–20)	29 (44.62%)	15 (23.08%)	
Severe Deficiency (<10)	9 (13.84%)	3 (4.62%)	

Table 4: Biochemical Profile of Study Groups

Parameter	Group A (Pre-eclampsia)	Group B (Control)	P Value
Serum Vitamin D (ng/mL)	18.2 ± 6.5	26.1 ± 7.3	< 0.001*
Serum Calcium (mg/dL)	8.12 ± 0.74	9.01 ± 0.68	< 0.001*
Serum Phosphorus (mg/dL)	4.2 ± 0.6	3.7 ± 0.5	0.003*
Serum Alkaline Phosphatase (IU/L)	152 ± 38	131 ± 29	0.002*
Serum Albumin (g/dL)	3.1 ± 0.4	3.4 ± 0.3	0.001*

Predictor Variable	Unstandardized Coefficient (B)	Standard Error (SE)	Standardized Coefficient (β)	<i>t</i> -value	<i>P</i> -value
Serum Vitamin D (ng/mL)	-0.68	0.21	-0.39	-3.24	0.002 *
Serum Calcium (mg/dL)	-2.15	0.74	-0.31	-2.91	0.005 *
Sun Exposure (hrs/day)	-1.80	0.82	-0.26	-2.20	0.032 *
Dietary Calcium (mg/day)	-0.011	0.004	-0.28	-2.62	0.011 *
Constant	158.7	6.3		_	< 0.001 *

Table 5: Multiple Linear Regression Analysis for Predictors of Systolic Blood Pressure in Pre-eclamptic Women (Group A, n = 65)

DISCUSSION

In the present study, while maternal age and parity were statistically similar across both groups, women with pre-eclampsia had significantly higher BMI $(26.8 \pm 2.5 \text{ kg/m}^2)$ than normotensive controls (25.2 \pm 2.3 kg/m², p = 0.003), supporting the association between increased adiposity and hypertensive disorders in pregnancy. These findings align with Liu et al. (2017),^[9] who reported a higher prevalence of pre-eclampsia in women with elevated BMI and poor nutritional intake. Additionally, daily sun exposure was significantly lower among the preeclampsia group $(0.9 \pm 0.4 \text{ hours})$ compared to controls (1.5 \pm 0.6 hours, p < 0.001), indicating insufficient UV exposure to maintain optimal vitamin D synthesis. The role of sunlight as a determinant of vitamin D status has been emphasized by Yu et al. (2019),^[10] in their cohort of Southern Chinese women. In terms of dietary calcium, pre-eclamptic women consumed significantly less calcium (520 \pm 110 mg/day) compared to controls (690 ± 125 mg/day, p < 0.001), which was comparable to the study by Newmark et al. (2004),^[11] advocating for the fortification of staple foods with calcium. Mean hemoglobin was also lower in the affected group $(10.2 \pm 1.1 \text{ g/dL vs.} 11.1 \pm 1.2 \text{ g/dL}, p = 0.001),$ reinforcing observations from Rumiris et al. (2006),^[12] that anemia and oxidative stress may coexist in hypertensive pregnancies.

The present study confirms the clinical diagnosis of pre-eclampsia, with mean systolic and diastolic blood pressures significantly elevated in Group A $(148.6 \pm 8.7 \text{ mmHg} \text{ and } 96.2 \pm 5.5 \text{ mmHg})$ respectively) compared to Group B (116.4 \pm 7.9 mmHg and 74.5 \pm 6.3 mmHg respectively), with p < 0.001 for both. Mean arterial pressure also showed a clear distinction (113.7 \pm 6.2 mmHg vs. 88.5 \pm 5.9 mmHg, p < 0.001). These values are consistent with findings reported by Hall et al. (2001),^[13] who documented similar hemodynamic derangements in early-onset severe pre-eclampsia. Additionally, our study demonstrated significantly higher proteinuria $(475.3 \pm 102.4 \text{ mg}/24\text{hr})$ and protein/creatinine ratio (0.43 ± 0.09) in pre-eclamptic women, compared to controls (98.2 \pm 22.6 mg/24hr and 0.12 \pm 0.03 respectively), which mirrors the glomerular pathology described by Abramovici et al. (1999).^[14] The clinical presence of edema in 78.46% of preeclamptic participants further corroborates the vascular leak and volume overload associated with the condition.

The study found a significantly higher prevalence of vitamin D deficiency in pre-eclamptic women. Only 12.31% of women in Group A had sufficient vitamin D levels (>30 ng/mL), compared to 32.31% in Group B (p = 0.008). Notably, 58.46% of preeclamptic women had deficient levels (<20 ng/mL), and 13.84% had severe deficiency (<10 ng/mL). This distribution aligns closely with the findings of Gidlof et al. (2015),^[15] who reported that vitamin D deficiency was significantly associated with increased risk of pre-eclampsia in a Scandinavian cohort. Similarly, Wetta et al. (2014),^[16] identified low mid-trimester vitamin D levels as a predictor of pre-eclampsia and preterm birth. The potential mechanistic links include impaired angiogenesis, upregulation of inflammatory cytokines, and modulation of the renin-angiotensin system, all of which have been attributed to low vitamin D status. These physiological roles make vitamin D deficiency not just a marker but a potential modifiable contributor to the disease.

Biochemical markers in the present study revealed that serum vitamin D (18.2 \pm 6.5 ng/mL vs. 26.1 \pm 7.3 ng/mL, p < 0.001) and calcium (8.12 \pm 0.74 mg/dL vs. 9.01 \pm 0.68 mg/dL, p < 0.001) were significantly lower in pre-eclamptic women, supporting the hypothesis that both micronutrients are inversely related to hypertensive disorders in pregnancy. Khaing et al. (2017),^[17] in their network meta-analysis concluded that supplementation with calcium and vitamin D was protective against preeclampsia, especially in women with baseline deficiencies. Our study also found elevated phosphorus levels in pre-eclamptic women (4.2 \pm 0.6 mg/dL vs. 3.7 ± 0.5 mg/dL, p = 0.003), which reflect secondary hyperparathyroidism. may Alkaline phosphatase was significantly higher (152 \pm 38 IU/L) in Group A, possibly reflecting placental stress or increased bone turnover, a phenomenon previously observed by Teaema and Al Ansari (2010),^[18] in vitamin D-deficient pregnancies. Hypoalbuminemia was noted in Group A (3.1 ± 0.4) g/dL) compared to controls (3.4 \pm 0.3 g/dL, p = 0.001), consistent with proteinuria and systemic inflammation.

The multiple regression model identified serum vitamin D, serum calcium, sun exposure, and dietary calcium intake as independent and significant predictors of systolic blood pressure in preeclamptic women (adjusted $R^2 = 0.48$, p < 0.001). Specifically, for each 1 ng/mL decrease in vitamin D, systolic BP increased by 0.68 mmHg (p = 0.002), while for each 1 mg/dL decrease in calcium, systolic BP rose by 2.15 mmHg (p = 0.005). These associations are consistent with mechanisms proposed by Khaing et al. (2017),^[17] and Hofmeyr and Manyame (2017),^[19] wherein calcium and vitamin D influence vascular tone through suppression of parathyroid hormone, modulation of intracellular calcium, and endothelial nitric oxide synthesis. Moreover, the negative impact of limited sun exposure (p = 0.032) and low dietary calcium (p= 0.011) on blood pressure regulation reflects environmental and nutritional deficits as modifiable risk factors, as also stressed by Mehrotra et al. (2010),^[20] in the context of maternal and neonatal health outcomes. These findings collectively underscore the potential for early intervention through supplementation and lifestyle modification.

CONCLUSION

This study demonstrated a significant association between low serum levels of vitamin D and calcium and the development of pre-eclampsia in pregnant women. Deficiencies in both nutrients were more prevalent among pre-eclamptic women and were independently correlated with elevated systolic blood pressure. Limited sun exposure and inadequate dietary calcium further contributed to these deficiencies. These findings highlight the importance of early screening and nutritional optimization during pregnancy. Ensuring adequate vitamin D and calcium status may serve as a simple, cost-effective strategy to reduce the risk of preeclampsia.

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1345