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Micronutrient Intake and Preeclampsia: The Protective Role of Vitamins C and D

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Abstract

Preeclampsia is a major hypertensive disorder of pregnancy that contributes significantly to maternal and perinatal morbidity. This study aimed to examine the association between maternal micronutrient intake, particularly vitamin C and vitamin D, and the occurrence of preeclampsia among pregnant women. A case–control study was conducted in Padang, West Sumatra, involving 66 pregnant women in the third trimester: 33 with preeclampsia and 33 without. Micronutrient intake was assessed using a Semi-Quantitative Food Frequency Questionnaire. Data were analyzed using the Mann–Whitney test and logistic regression analysis. The results showed significant differences in vitamin C and vitamin D intake between the two groups. Multivariate analysis indicated that vitamin D intake and maternal education level were significantly associated with preeclampsia, whereas vitamin C intake was not significantly associated after adjustment for confounding variables. These findings suggest that adequate vitamin D intake during pregnancy may help reduce the risk of preeclampsia. Nutritional interventions during antenatal care may help improve maternal health outcomes.

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Introduction

Preeclampsia is widely recognized as one of the most serious hypertensive disorders occurring during pregnancy and remains a major contributor to maternal and perinatal morbidity and mortality worldwide. Clinically, this condition is defined by the onset of hypertension after 20

weeks of gestation, accompanied by proteinuria or signs of maternal organ dysfunction (Mészáros et al., 2024). Hypertensive disorders of pregnancy, including preeclampsia and eclampsia, are estimated to account for approximately 10–15% of maternal deaths globally, highlighting the substantial burden of this condition on maternal health systems (Mészáros et al., 2024). In addition to its effects on maternal health, preeclampsia is also strongly associated with adverse neonatal outcomes such as preterm delivery, fetal growth restriction, low birth weight, and increased neonatal mortality (Ushida et al., 2025).

The impact of preeclampsia is not limited to complications during pregnancy. Evidence suggests that women who experience preeclampsia are at higher risk of developing cardiovascular diseases later in life, including chronic hypertension, ischemic heart disease, and stroke (Ushida et al., 2025). These long-term consequences underscore the importance of identifying modifiable determinants that may contribute to the development of the condition, particularly those amenable to preventive strategies.

Optimal maternal nutrition is a key factor supporting healthy pregnancy outcomes. During pregnancy, adequate intake of both macro- and micronutrients is necessary to support maternal physiological adaptations, fetal growth, and placental development (Cristófalo et al., 2026). Micronutrients play essential roles in several biological processes, including immune regulation, antioxidant defense, and vascular function (Giourga et al., 2023). Adequate micronutrient status is therefore essential for maintaining metabolic balance and promoting normal placental implantation and development (AlSubai et al., 2023). In contrast, inadequate intake of essential micronutrients may increase the risk of pregnancy complications, including hypertensive disorders such as preeclampsia (Moghib et al., 2024).

Among the various micronutrients investigated in maternal health research, vitamins C and D have received considerable attention due to their biological roles in regulating oxidative stress and vascular function. Vitamin C is a powerful antioxidant that neutralizes reactive oxygen species and protects endothelial cells from oxidative damage (Chen et al., 2025). During pregnancy, oxidative stress has been identified as a key factor contributing to placental dysfunction and endothelial injury, which are central mechanisms involved in the development of preeclampsia (Chen et al., 2025).

Vitamin D also plays an important role in maintaining maternal and placental health. Functioning as a hormone-like micronutrient, vitamin D is involved in calcium metabolism, immune modulation, and vascular regulation (AlSubai et al., 2023). Recent evidence suggests that vitamin D contributes to normal placental development by influencing angiogenesis and inflammatory pathways that regulate trophoblast invasion and vascular remodeling (Kokkinari et al., 2025). Adequate vitamin D status is therefore considered important for maintaining proper placental function and reducing the risk of hypertensive complications during pregnancy (Giourga et al., 2023). Despite their recognized importance, deficiencies of these nutrients remain common among pregnant women worldwide. Vitamin D deficiency, for instance, is estimated to affect more than one billion people globally, including a large proportion of pregnant women (Cristófalo et al., 2026). Several epidemiological studies have reported that inadequate vitamin D levels during pregnancy are associated with an increased risk of gestational hypertension and preeclampsia (Giourga et al., 2023). In many regions, including Southeast Asia, vitamin D deficiency among pregnant women remains prevalent due to limited sun exposure, lifestyle factors, and insufficient dietary intake (Kokkinari et al., 2025). Similarly, inadequate intake of antioxidant nutrients, such as vitamin C, has been reported in many populations, often due to low consumption of fruits and vegetables (Chen et al., 2025). Insufficient antioxidant intake may weaken the body's ability to counteract oxidative stress during pregnancy. Increased oxidative stress can contribute to endothelial dysfunction and abnormal placental development, both of which are key mechanisms implicated in the pathogenesis of preeclampsia (Chen et al., 2025).

The development of preeclampsia is widely understood to involve complex and multifactorial mechanisms. One widely accepted theory suggests that abnormal placental development during early pregnancy leads to reduced uteroplacental blood flow and increased oxidative stress (Mészáros et al., 2024). This condition subsequently triggers systemic endothelial dysfunction and inflammatory responses within the maternal circulation, eventually leading to the clinical manifestations of preeclampsia (Mészáros et al., 2024). Within this context, micronutrients with antioxidant and immunomodulatory properties may play an important role in mitigating these pathological processes. Several studies have explored the relationship between micronutrient status and the occurrence of preeclampsia. A systematic review conducted by Giourga et al (2023) found that low maternal vitamin D levels were significantly associated with an increased risk of preeclampsia. Similarly, a meta-analysis by Moghib et al (2024) reported that vitamin D supplementation during pregnancy may reduce the incidence of preeclampsia in certain populations. Another study by Kokkinari et al (2025) also indicated that maternal vitamin D status plays a significant role in pregnancy outcomes, including gestational hypertension and preeclampsia.

Research has also highlighted the potential protective role of vitamin C. Chen et al (2025) reported that lower maternal vitamin C levels were associated with increased oxidative stress and a higher risk of preeclampsia. In addition, Ibrahim et al (2026) emphasized the importance of adequate maternal vitamin D levels in preventing adverse pregnancy outcomes, including hypertensive disorders and fetal growth restriction. Although these studies provide valuable insights, several gaps remain in the existing literature. Many previous investigations have focused primarily on serum micronutrient concentrations rather than on dietary intake patterns during pregnancy (Giourga et al., 2023). While biochemical measurements provide important clinical information, dietary intake assessments may offer a broader perspective on maternal nutritional status and long-term nutrient exposure. In addition, most studies have examined individual micronutrients separately, whereas the potential combined effects of multiple nutrients have received limited attention (Moghib et al., 2024). Considering that vitamins C and D influence interconnected biological pathways—such as antioxidant defense, immune regulation, and endothelial function—their combined intake may provide synergistic protective effects against preeclampsia.

Another important limitation in the current literature is the relatively limited evidence from developing countries, including Indonesia, where maternal nutritional deficiencies and hypertensive disorders of pregnancy remain major contributors to maternal morbidity and mortality (Ministry of Health of the Republic of Indonesia, 2022; World Health Organization, 2023). In many low- and middle-income countries, inadequate dietary diversity, limited access to micronutrient supplementation, and disparities in antenatal care may increase the risk of adverse pregnancy outcomes, including preeclampsia (Keats et al., 2021). Recent evidence has highlighted that maternal malnutrition and micronutrient deficiencies continue to be highly prevalent in resource-limited settings and are associated with poor maternal and neonatal outcomes (Stevens et al., 2022). Although global evidence regarding maternal nutrition and preeclampsia has expanded, data from Southeast Asia and Indonesia remain limited, restricting the development of context-specific nutritional interventions and maternal health strategies (World Health Organization, 2021). Therefore, examining the relationship between micronutrient intake and preeclampsia in local populations is essential for generating population-relevant evidence to guide effective antenatal nutrition policies. Based on these considerations, this study aimed to analyze the association between maternal intake of vitamin C and vitamin D and the occurrence of preeclampsia among pregnant women. By examining dietary micronutrient intake in relation to pregnancy outcomes, this research sought to contribute to the growing body of evidence on nutritional determinants of

hypertensive disorders of pregnancy and to support the development of targeted maternal nutrition interventions in developing-country settings.

This study is grounded in the theoretical framework of preeclampsia pathophysiology, which emphasizes the roles of oxidative stress, endothelial dysfunction, and impaired placental development in the onset of the disease (Mészáros et al., 2024). Within this framework, adequate intake of antioxidant and immunomodulatory micronutrients such as vitamins C and D may help reduce oxidative damage, improve vascular function, and support placental health. By integrating nutritional and physiological perspectives, this research aims to provide a more comprehensive understanding of the mechanisms linking micronutrient intake with the risk of preeclampsia.

This study provides novel evidence by examining dietary micronutrient intake (rather than serum levels) in an Indonesian population, where evidence remains limited. Additionally, this study simultaneously evaluates vitamin C and vitamin D intake, offering a more comprehensive understanding of their combined role in preeclampsia risk within a developing country context.

Materials and Methods

This study employed an analytical observational design using a case–control approach to analyze the association between micronutrient intake, specifically vitamins C and D, and the occurrence of preeclampsia among pregnant women. The case–control approach was chosen because it allows comparison between pregnant women with preeclampsia and those without the condition to identify potential risk or protective factors associated with micronutrient intake.

The study was conducted in Padang, West Sumatra, Indonesia, at several hospitals and maternal health facilities that provide antenatal care services. The study population consisted of pregnant women attending antenatal care at these health facilities during the study period. The respondents included in this study were pregnant women in the third trimester, since preeclampsia is generally diagnosed clinically during this stage of pregnancy. A total of 66 respondents participated in the study, comprising 33 pregnant women with preeclampsia (case group) and 33 pregnant women without preeclampsia (control group). The sample size was determined based on feasibility considerations and the availability of eligible participants during the study period. Although relatively small, the sample size was considered adequate for detecting associations in this exploratory case–control study.

Participants were selected using a purposive sampling technique based on predetermined inclusion and exclusion criteria. Participants were selected using a purposive sampling technique to ensure that all respondents met specific clinical and inclusion criteria relevant to the study objectives. However, this sampling method may introduce selection bias and limit the generalizability of the findings, a limitation acknowledged in this study.

The inclusion criteria were pregnant women in the third trimester of pregnancy who were willing to participate in the study and had complete medical records. The exclusion criteria included pregnant women with a history of chronic diseases such as chronic hypertension, kidney disease, diabetes mellitus, or other systemic conditions that could influence pregnancy outcomes, as well as respondents with incomplete dietary intake data.

This study used both primary and secondary data sources. Primary data were collected through direct interviews with respondents using a structured questionnaire to obtain information regarding maternal characteristics and dietary patterns. Micronutrient intake, particularly vitamin C and vitamin D, was assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) to identify the frequency and portion size of foods consumed during pregnancy. Although SQ-FFQ is useful for estimating habitual intake, it relies on self-reported data and may be subject to recall bias and measurement error. Secondary data were obtained from medical records at the health facilities, including blood pressure measurements, obstetric history, and clinical diagnoses of preeclampsia.

The diagnosis of preeclampsia in this study was based on clinical criteria: systolic blood pressure ≥140 mmHg and diastolic blood pressure ≥90 mmHg after 20 weeks of gestation, accompanied by proteinuria or other signs of organ dysfunction. The dependent variable in this study was the occurrence of preeclampsia. In contrast, the independent variables were maternal intake of vitamin C and vitamin D. Several potential confounding variables were also considered, including maternal age, body mass index (BMI), parity, and education level.

Data analysis was performed using statistical software. Descriptive (univariate) analysis was used to describe the distributions of respondent characteristics, including maternal age, parity, body mass index, and micronutrient intake levels. Bivariate analysis using the Mann-Whitney test was conducted to assess the association between vitamin C and vitamin D intake and the occurrence of preeclampsia. Variables showing potential associations were further analyzed using multivariate logistic regression analysis to estimate the Odds Ratio (OR) and determine the strength of the association between micronutrient intake and preeclampsia after controlling for potential confounding variables. A p-value < 0.05 was considered statistically significant.

To ensure data validity and reliability, the SQ-FFQ instrument used in this study was adapted from previously validated dietary assessment tools and pre-tested prior to data collection. Data obtained through interviews were cross-checked with medical records to minimize reporting bias and improve accuracy. Data processing and statistical analysis were carefully conducted to ensure the consistency and reliability of the results. Ethical approval for this study was obtained from the relevant health research ethics committee NO: 019/IKES PN/KEPK/I/2025, and written informed consent was obtained from all participants before they participated in the study (Aldi et al., 2023).

Results and Discussions

This section presents the study's key findings and their interpretation in relation to existing evidence on maternal nutrition and preeclampsia. These findings provide important insights into potential risk factors associated with preeclampsia among pregnant women. The discussion further interprets the results by comparing them with existing literature to understand better the role of maternal characteristics in the development of hypertensive disorders during pregnancy.

Table 1. The Characteristics Of The Respondents

Variable	Category	n	%
Age	18–35 years	57	86.4
	>35 years	9	13.6
Parity	Primigravida	31	47
	Multigravida	35	53
Education	Elementary School	2	3
	Junior High School	7	10.6
	Senior High School	22	33.3
	Diploma (D3)	7	10.6
	Bachelor's Degree (S1)	25	37.9
	Master's Degree (S2)	3	4.5
Body Mass Index (BMI)	18.5–22.9	21	31.8
	23.0–29.9	35	53
	>30	10	15.2

Table 1 presents the distribution of respondents based on maternal characteristics, including age, parity, education level, and body mass index (BMI). The majority of respondents were aged 18–

35 years (86.4%), while only a small proportion were aged 36 or older (13.6%). This age range represents the reproductive age group that is generally considered safer for pregnancy. However, advanced maternal age remains an important factor associated with increased risk of pregnancy complications, including hypertensive disorders such as preeclampsia.

In terms of parity, slightly more than half of the respondents were multigravida (53.0%), while 47.0% were primigravida. Parity has been widely discussed as an important determinant in pregnancy outcomes. Previous studies have reported that both primigravida and multigravida mothers may experience different levels of risk related to preeclampsia due to physiological adaptation during pregnancy and maternal immunological responses to placental development.

The distribution of respondents based on educational level shows that most participants had completed a bachelor's degree (37.9%), followed by senior high school (33.3%). Educational level may influence maternal knowledge and awareness regarding pregnancy care, nutritional intake, and early detection of pregnancy complications. Higher educational attainment is often associated with better health literacy and greater access to health information, which may contribute to improved maternal health outcomes.

Regarding nutritional status, more than half of the respondents had a BMI between 23.0 and 29.9 (53.0%), suggesting a tendency toward overweight. Meanwhile, 31.8% of respondents were in the normal BMI category (18.5–22.9), and 15.2% had a BMI greater than 30, which falls within the obesity category. Maternal BMI is considered an important risk factor in pregnancy, as overweight and obesity have been linked to metabolic disturbances, inflammation, and endothelial dysfunction that may increase the risk of preeclampsia. Overall, these maternal characteristics provide an important overview of the study population and highlight several factors that may potentially influence the occurrence of preeclampsia during pregnancy.

The normality tests using the Kolmogorov–Smirnov and Shapiro–Wilk tests indicated that the vitamin C and vitamin D intake data were not normally distributed ($p < 0.05$). Therefore, the bivariate analysis between micronutrient intake and preeclampsia was performed using the non-parametric Mann–Whitney test.

Table 2. Differences in Vitamin C Intake Between Pregnant Women With and Without Preeclampsia

Variable	Preeclampsia Status	n	Mean Rank	Mann–Whitney U	Z	p-value
Vitamin C	No Preeclampsia	33	42.97	232	-4.008	<0.001
	Preeclampsia	33	24.03			

There was a significant difference in vitamin C intake between pregnant women with and without preeclampsia. The Mann–Whitney test showed that the mean rank of vitamin C intake in the non-preeclampsia group (42.97) was higher than that in the preeclampsia group (24.03), indicating lower vitamin C intake among women with preeclampsia ($U = 232.000$; $Z = -4.008$; $p < 0.001$).

Table 3. Differences in Vitamin D Intake Between Pregnant Women With and Without Preeclampsia

Variable	Preeclampsia Status	n	Mean Rank	Mann–Whitney U	Z	p-value
Vitamin D Intake	No Preeclampsia	33	43.91	201	-4.405	<0.001
	Preeclampsia	33	23.09			

The Mann–Whitney test showed a significant difference in vitamin D intake between pregnant women with and without preeclampsia. The mean rank for vitamin D intake in the non-preeclampsia group was 43.91, higher than that in the preeclampsia group (23.09). This finding indicates that pregnant women without preeclampsia tended to have higher vitamin D intake compared to those diagnosed with preeclampsia. Statistical analysis showed that the difference was

statistically significant (U = 201.000; Z = -4.405; p < 0.001). These results suggest that lower vitamin D intake may be associated with an increased risk of preeclampsia among pregnant women.

Table 4. Logistic Regression Analysis of Factors Associated with Preeclampsia

Variable	B	SE	OR (Exp(B))	p-value
Maternal Age	0.062	1.421	1.064	0.965
Parity	1.851	0.972	6.363	0.057
Education	-1.038	0.400	0.354	0.01
BMI	1.284	0.741	3.611	0.083
Vitamin C Intake	-0.048	0.047	0.953	0.306
Vitamin D Intake	-0.358	0.158	0.699	0.024

A logistic regression analysis was performed to determine factors associated with preeclampsia among pregnant women. The results showed that education level and vitamin D intake were significantly associated with preeclampsia. Education level had a significant protective effect against preeclampsia (OR = 0.354; p = 0.010), indicating that pregnant women with higher levels of education had a lower risk of preeclampsia than those with lower levels. Vitamin D intake was also significantly associated with preeclampsia (OR = 0.699; p = 0.024). This finding suggests that higher vitamin D intake was associated with a reduced risk of preeclampsia among pregnant women. Meanwhile, maternal age (p = 0.965), parity (p = 0.057), body mass index (BMI) (p = 0.083), and vitamin C intake (p = 0.306) were not significantly associated with preeclampsia in the multivariate analysis.

This study examined the association between maternal intake of micronutrients, particularly vitamins C and D, and the risk of preeclampsia. The findings showed significant differences in vitamin C and vitamin D intake between pregnant women with and without preeclampsia, as determined by the Mann–Whitney test. Pregnant women without preeclampsia had higher mean ranks of vitamin C and vitamin D intake compared to those diagnosed with preeclampsia. These results indicate that lower micronutrient intake may be associated with an increased risk of hypertensive disorders during pregnancy.

The role of micronutrients in the development of preeclampsia has been widely discussed in the literature, particularly in relation to oxidative stress and endothelial dysfunction. Preeclampsia is characterized by abnormal placentation, systemic inflammation, and increased oxidative stress, which can lead to endothelial damage and impaired uteroplacental blood flow. Antioxidant nutrients such as vitamin C are known to play an important role in protecting endothelial cells from oxidative damage. Vitamin C functions as a potent antioxidant that can neutralize reactive oxygen species (ROS) and help maintain vascular integrity during pregnancy. Previous studies have reported that low vitamin C levels are associated with increased oxidative stress markers and a higher risk of preeclampsia (Chen et al., 2025).

Vitamin C, as an antioxidant, helps reduce oxidative stress and protect endothelial function. Oxidative stress is a central mechanism in the development of preeclampsia, contributing to endothelial dysfunction and abnormal placental development (Burton et al., 2021). However, inconsistent findings have been reported regarding the independent role of vitamin C intake in reducing the risk of hypertensive disorders during pregnancy (Chen et al., 2025; Rumbold et al., 2022).

In contrast, vitamin D intake was significantly associated with preeclampsia in the multivariate model. The results indicated that higher vitamin D intake was associated with a lower risk of preeclampsia, suggesting a protective effect of this micronutrient. These findings are consistent with previous studies that identified vitamin D deficiency as an important risk factor for hypertensive disorders during pregnancy (Giourga et al., 2023). Vitamin D plays multiple biological

roles that are relevant to the development of preeclampsia. It functions as a hormone-like nutrient involved in immune modulation, angiogenesis, and vascular regulation. Adequate vitamin D levels are important for proper trophoblast invasion and placental vascularization during early pregnancy. Insufficient vitamin D may impair placental development, increase inflammatory responses, and cause endothelial dysfunction, key mechanisms in the pathogenesis of preeclampsia (AlSubai et al., 2023). Several systematic reviews and meta-analyses have also highlighted the potential role of vitamin D supplementation in reducing the risk of preeclampsia. A meta-analysis by Moghib et al (2024) reported that vitamin D supplementation during pregnancy was associated with a reduced risk of hypertensive disorders in certain populations.

These findings support the hypothesis that adequate vitamin D status during pregnancy may contribute to improved placental development and vascular function, thereby reducing the likelihood of developing preeclampsia. Recent evidence has consistently shown that low maternal vitamin D levels during early and mid-pregnancy are significantly associated with an increased risk of preeclampsia (Hu et al., 2022). Vitamin D plays an essential role in placental implantation, angiogenesis, immune modulation, and endothelial stability, all of which are critical biological pathways for maintaining healthy pregnancy progression (Purswani et al., 2017). Furthermore, a recent systematic review highlighted that vitamin D deficiency may contribute to placental dysfunction by impairing trophoblast invasion, disrupting placental vascular remodeling, and increasing inflammatory responses, thereby exacerbating the pathophysiological mechanisms underlying preeclampsia (Gerovasili et al., 2025). Longitudinal evidence has also demonstrated that persistently low vitamin D status throughout pregnancy is associated with a greater risk of hypertensive disorders, particularly preeclampsia (Wei et al., 2012). Supporting these findings, a more recent case-control study conducted in Southern Sweden reported that lower maternal serum vitamin D concentrations in early pregnancy were significantly associated with an increased risk of preeclampsia later in pregnancy (Malm et al., 2023). Collectively, these findings reinforce the importance of adequate vitamin D intake and status during pregnancy as a potentially modifiable protective factor against preeclampsia.

Another important finding in this study was a significant association between maternal education level and preeclampsia. Women with higher educational levels had a lower risk of developing preeclampsia compared to those with lower education levels. The influence of education on health literacy, nutritional awareness, and access to health information may explain this result. Women with higher educational attainment are generally more likely to adopt healthier lifestyles, maintain better dietary habits, and utilize antenatal care services more effectively. Socioeconomic factors, including maternal education, have been widely recognized as determinants of maternal nutritional status and pregnancy outcomes. Previous studies have reported that women with higher levels of education tend to have greater dietary diversity and higher micronutrient intake during pregnancy (Cristófalo et al., 2026).

Micronutrient deficiencies during pregnancy remain a global concern as they contribute to various pregnancy complications, including preeclampsia, and adversely affect both maternal and neonatal health (Gernand et al., 2016). Preeclampsia itself is one of the hypertensive disorders of pregnancy that occurs after 20 weeks of gestation and may be accompanied by organ dysfunction, making it a leading cause of maternal and perinatal morbidity and mortality (Chalas, 2020). In addition, evidence from systematic reviews and meta-analyses has shown that low vitamin D levels are associated with an increased risk of preeclampsia (Serrano-Díaz et al., 2018). Therefore, adequate nutritional intake during pregnancy, including essential micronutrients, is a critical component of antenatal care recommended to support a healthy pregnancy and prevent complications (WHO, 2021). In Indonesia, maternal nutritional problems remain a challenge, as reported in the Indonesian Health Profile, which indicates the persistence of micronutrient

deficiencies that may increase the risk of pregnancy complications (Ministry of Health, Republic of Indonesia, 2023).

Recent evidence also suggests that vitamin D supplementation during pregnancy may reduce the risk of preeclampsia, although the magnitude of the effect may vary depending on dosage, baseline nutritional status, and population characteristics (Moghib et al., 2024; Roth et al., 2023). Maternal nutrition remains a key determinant of pregnancy outcomes globally, particularly in low and middle-income countries, where micronutrient deficiencies are still prevalent and contribute significantly to maternal morbidity (Keats et al., 2021; UNICEF, 2023).

In this study, maternal age, parity, and body mass index did not show statistically significant associations with preeclampsia in the multivariate model. Although these variables are commonly reported as risk factors for preeclampsia, the results suggest that nutritional factors and socioeconomic characteristics may play a more prominent role within the studied population. Overall, this study's findings emphasize the importance of maternal nutrition in preventing pregnancy complications. Adequate intake of essential micronutrients, particularly vitamin D, may help improve placental function and reduce the risk of hypertensive disorders during pregnancy. These findings highlight the potential value of nutritional interventions and dietary counseling within comprehensive antenatal care programs to improve maternal and fetal health outcomes.

This study has several strengths. First, it used a case–control design that allowed the comparison of micronutrient intake between pregnant women with and without preeclampsia. Second, dietary intake was assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), which enabled the estimation of habitual micronutrient intake during pregnancy. However, several limitations should also be considered. The sample size was relatively small, which may limit the generalizability of the findings. In addition, dietary intake data were obtained through self-reported questionnaires, which may introduce recall bias.

Furthermore, the study focused on dietary intake rather than biochemical measurements of micronutrient status, which could provide more precise information regarding maternal nutritional status. Future research with larger sample sizes and prospective study designs is recommended to explore further the relationship between micronutrient intake and hypertensive disorders of pregnancy. In addition, combining dietary assessment with biochemical markers of vitamin status may provide a more comprehensive understanding of the role of micronutrients in preventing preeclampsia.

Conclusion

This study investigated the association between maternal intake of micronutrients, particularly vitamins C and D, and the risk of preeclampsia. The findings revealed significant differences in vitamin C and vitamin D intake between pregnant women with and without preeclampsia. However, multivariate analysis demonstrated that vitamin D intake and maternal education level were significantly associated with the risk of preeclampsia, while vitamin C intake was not significantly associated after adjusting for other variables. These findings suggest that adequate vitamin D intake during pregnancy may protect against the development of preeclampsia.

From a scientific perspective, this study contributes to the growing body of evidence highlighting the importance of maternal micronutrient status in the pathophysiology of hypertensive disorders of pregnancy. Vitamin D may influence preeclampsia development through several biological mechanisms, including immune modulation, regulation of angiogenesis, and maintenance of endothelial function, which are essential for normal placental development.

From a practical perspective, the findings emphasize the importance of improving maternal nutrition during pregnancy, particularly ensuring adequate vitamin D intake through balanced diets, nutritional counseling, and appropriate supplementation during antenatal care. Strengthening

nutritional education for pregnant women may also help reduce the risk of pregnancy complications. Future studies with larger sample sizes and prospective designs are recommended to explore further the role of micronutrients in preventing preeclampsia and to support the development of evidence-based maternal nutrition interventions.

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References

Aldi, Y., Afriwardi, Badriyya, E., Azukhruf, W. S., & Alianta, A. A. (2023). Effects of Pegagan Embun (Hydrocotyle sibthorpioides Lam) Extract on Renal Function in Male Wistar Rats as Assessed by Creatinine Clearance. *Tropical Journal of Natural Product Research, 7*(3), 2547–2550. https://doi.org/10.26538/tjnpr/v7i3.13

AlSubai, A., Baqai, M. H., Agha, H., Shankarlal, N., Javaid, S. S., Jesrani, E. K., Golani, S., Akram, A., Qureshi, F., Ahmed, S., & Saran, S. (2023). Vitamin D and preeclampsia: A systematic review and meta-analysis. *Sage Open Medicine, 11*. https://doi.org/10.1177/20503121231212093

Chalas, E. (2020). The American College of Obstetricians and Gynecologists in 2020: A Clear Vision for the Future. *Obstetrics and Gynecology, 135*(6), 1251–1254. https://doi.org/10.1097/AOG.0000000000003899

Chen, S., Huang, D., & Cheng, W. (2025). Analysis of serological risk factors for preeclampsia and the predictive role of high homocysteine levels. *American Journal of Translational Research, 17*(5), 3465–3475. https://doi.org/10.62347/IKIP3300

Cristófalo, M. M., de Almeida Garcia, J. O., Aldrighi, J. F. S., Cristófalo, R. M., França, M. L. M., Luzia, L. A., Vasconcelos, S. P., & Aldrighi, J. M. (2026). Prevalence of Vitamin D Deficiency in Pregnant Women: Systematic Review and Meta-analysis. *Nutrition Reviews, 84*(3), 600–614. https://doi.org/10.1093/nutrit/nuaf168

Gernand, A. D., Schulze, K. J., Stewart, C. P., West, K. P. J., & Christian, P. (2016). Micronutrient deficiencies in pregnancy worldwide: health effects and prevention. Nature Reviews. *Endocrinology, 12*(5), 274–289. https://doi.org/10.1038/nrendo.2016.37

Gerovasili, E., Sarantaki, A., Bothou, A., Deltsidou, A., Dimitrakopoulou, A., & Diamanti, A. (2025). The role of vitamin D deficiency in placental dysfunction: A systematic review. *Metabolism Open, 25*, 100350.

Giourga, C., Papadopoulou, S. K., Voulgaridou, G., Karastogiannidou, C., Giaginis, C., & Pritsa, A. (2023). Vitamin D Deficiency as a Risk Factor of Preeclampsia during Pregnancy. *Diseases (Basel, Switzerland), 11*(4). https://doi.org/10.3390/diseases11040158

Hu, K., Zhang, C., & Chen, P. (2022). Vitamin D Levels in Early and Middle Pregnancy and Preeclampsia: A Systematic Review and Meta-Analysis. *Frontiers In Nutrition, 9*, 863428. https://doi.org/10.3389/fnut.2022.863428

Ibrahim, Y., Mohd Jamil, A. A., Nordin, N., Loh, S. P., & Basri, N. I. (2026). Maternal Vitamin D Deficiency and Its Effects on Pregnancy Outcomes. *Food Science & Nutrition, 14*(1). https://doi.org/10.1002/fsn3.71377

Keats, E. C., Haider, B. A., Tam, E., & Bhutta, Z. A. (2021). Multiple-Micronutrient Supplementation for Women During Pregnancy. *Cochrane Database Of Systematic Reviews, 11*. https://doi.org/10.1002/14651858.CD004905.pub6

Kokkinari, A., Gourounti, K., Dagla, M., Tsinisizeli, N., & Iatrakis, G. (2025). Maternal Vitamin D Status, Gestational Hypertension, and Preeclampsia: A Cross-Sectional Study in Urban Greece. *Biomedicines, 13*(11). https://doi.org/10.3390/biomedicines13112624

Malm, G., Lindh, C., & Hansson, S. (2023). Maternal Serum Vitamin D Level in Early Pregnancy and Risk for Preeclampsia: A Case-Control Study in Southern Sweden. *PLOS ONE, 18*(2), e0281234.

Mészáros, B., Veres, D. S., Nagyistók, L., Kovács, B. G., Kukor, Z., & Valent, S. (2024). A meta-analysis on first-trimester blood count parameters: Is the neutrophil-to-lymphocyte ratio a potentially novel method for first-trimester preeclampsia screening? *Frontiers in Medicine, 11*, 1336764. https://doi.org/10.3389/fmed.2024.1336764

Ministry of Health, Republic of Indonesia. (2023). *Indonesia Health Profile 2022*. Ministry of Health, Republic of Indonesia. https://www.kemkes.go.id

Moghib, K., Ghanm, T. I., Abunamoos, A., Rajabi, M., Moawad, S. M., Mohsen, A., Kasem, S., Elsayed, K., Sayed, M., Dawoud, A. I., Salomon, I., Elmaghreby, A., Ismail, M., & Amer, A. (2024). Efficacy of vitamin D supplementation on the incidence of preeclampsia: a systematic review and meta-analysis. *BMC Pregnancy and Childbirth, 24*(1), 852. https://doi.org/10.1186/s12884-024-07081-y

Purswani, J., Gala, P., Dwarkanath, P., Larkin, H. M., Kurpad, A., & Mehta, S. (2017). The Role of Vitamin D in Preeclampsia: A Systematic Review. *BMC Pregnancy And Childbirth, 17*, 231. https://doi.org/10.1186/s12884-017-1408-3

Serrano-Díaz, N. C., Gamboa-Delgado, E. M., Domínguez-Urrego, C. L., Vesga-Varela, A. L., Serrano-Gómez, S. E., & Quintero-Lesmes, D. C. (2018). Vitamin D and risk of preeclampsia: A systematic review and meta-analysis. *Biomedica, 38*(1), 43–53. https://doi.org/10.7705/biomedica.v38i0.3683

Stevens, G. A., Beal, T., Mbuya, M. N. N., Luo, H., Neufeld, L. M., & Group, G. M. D. R. (2022). Micronutrient Deficiencies Among Preschool-Aged Children and Women of Reproductive Age Worldwide: A Pooled Analysis of Individual-Level Data from Population-Representative Surveys. *The Lancet Global Health, 10*(11), e1590–e1599. https://doi.org/10.1016/S2214-109X(22)00367-9

Ushida, T., Tano, S., Matsuo, S., Fuma, K., Imai, K., Kajiyama, H., & Kotani, T. (2025). Dietary supplements and prevention of preeclampsia. *Hypertension Research, 48*(4), 1444–1457. https://doi.org/10.1038/s41440-025-02144-9

Wei, S. Q., Audibert, F., & Hidiroglou, N. (2012). Longitudinal Vitamin D Status in Pregnancy and the Risk of Preeclampsia. *BJOG: An International Journal Of Obstetrics & Gynaecology, 119*(7), 832–839. https://doi.org/10.1111/j.1471-0528.2012.03307.x

World Health Organization. (2021). *WHO recommendations on antenatal care for a positive pregnancy experience*. https://www.who.int/publications/i/item/9789241549912

World Health Organization. (2023). *Trends in maternal mortality 2000 to 2020: Estimates by WHO, UNICEF, UNFPA, World Bank Group and UNDESA/Population Division*. https://www.who.int/publications/i/item/9789240068759