

The Role of Maternal Vitamin D in the Prevention of Preeclampsia: A Literature Review

Lalu Maji'urriszki Muharzami¹, M. Andiffa Arifianto²

Fakultas Kedokteran dan Ilmu Kesehatan, Universitas Mataram

Article Info

Article history:

Accepted: 20 September 2026

Publish: 25 September 2026

Keywords:

25-hydroxyvitamin D;

Hypertensive;

Preeclampsia;

Pregnancy;

Vitamin D;

Vitamin D supplementation.

Abstract

Preeclampsia remains an important complication of pregnancy and is associated with substantial maternal and perinatal morbidity and mortality. Maternal vitamin D has been proposed to have a preventive role in preeclampsia due to its involvement in placental development, trophoblast invasion, angiogenesis, immune responses, oxidative balance, and vascular regulation. This literature review aimed to evaluate the potential role of maternal vitamin D in preventing preeclampsia by examining the relationship between maternal 25-hydroxyvitamin D [25(OH)D] concentrations and preeclampsia risk, exploring possible underlying mechanisms, and assessing the effects of vitamin D supplementation during pregnancy. A narrative literature review was performed using PubMed, ScienceDirect, and Google Scholar to identify relevant publications from January 2016 through September 2026. Studies involving pregnant women that evaluated maternal vitamin D status or vitamin D supplementation in relation to preeclampsia were considered, including original research, randomized controlled trials, systematic reviews, and meta-analyses. Overall, the reviewed evidence suggests that insufficient maternal 25(OH)D concentrations may be associated with a greater risk of preeclampsia, although the findings vary depending on the timing of vitamin D assessment, criteria used to define vitamin D status, characteristics of the study population, and potential confounding variables. Vitamin D may affect the pathogenesis of preeclampsia by modulating trophoblast invasion, angiogenic processes, antiangiogenic factors, immune regulation, oxidative stress, and vascular function. Evidence from several meta-analyses of randomized controlled trials also indicates that vitamin D supplementation during pregnancy could lower the occurrence of preeclampsia; however, considerable variation among studies remains, and a definitive dose and timing of supplementation have yet to be established. In conclusion, maternal vitamin D appears to have potential as a preventive factor for preeclampsia, although further rigorous research is required to establish the most appropriate supplementation regimen.

This is an open access article under the [Lisensi Creative Commons Atribusi-BerbagiSerupa 4.0 Internasional](https://creativecommons.org/licenses/by-sa/4.0/)



Corresponding Author:

Lalu Maji'urriszki Muharzami

Universitas Mataram

Email: lalumajiurriszki@gmail.com

1. INTRODUCTION

Preeclampsia is one of the major hypertensive complications of pregnancy and is generally diagnosed by the development of new-onset hypertension after 20 weeks of gestation accompanied by proteinuria and/or evidence of maternal organ dysfunction. The condition can affect multiple maternal organ systems and may result in serious complications, including eclampsia, renal and hepatic impairment, pulmonary edema, preterm delivery, and fetal growth restriction. Affecting approximately 2–8% of

pregnancies worldwide, preeclampsia remains an important contributor to maternal and perinatal morbidity and mortality [1]. Its considerable clinical burden emphasizes the need to identify potentially modifiable factors and develop effective preventive approaches.

The development of preeclampsia is thought to involve abnormalities in placental development followed by widespread maternal vascular dysfunction. Inadequate trophoblastic invasion and incomplete remodeling of the spiral arteries during early pregnancy can impair uteroplacental circulation and lead to placental hypoperfusion. Subsequent oxidative and inflammatory processes may stimulate the release of antiangiogenic mediators, particularly soluble fms-like tyrosine kinase-1 (sFlt-1) and soluble endoglin (sEng). An imbalance between angiogenic and antiangiogenic factors contributes to maternal endothelial dysfunction and vascular abnormalities, which ultimately underlie many of the clinical manifestations of preeclampsia [1]. This complex pathophysiology has also prompted interest in nutritional factors that may influence placental development and maternal vascular health.

Vitamin D has functions in pregnancy that extend beyond its established role in calcium and phosphorus regulation. Maternal vitamin D status is commonly evaluated using circulating 25-hydroxyvitamin D [25(OH)D], whereas 1,25-dihydroxyvitamin D [1,25(OH)₂D] represents the biologically active form. Both the placenta and decidua express the vitamin D receptor (VDR) and enzymes involved in vitamin D metabolism, suggesting that vitamin D signaling may contribute to placental development, trophoblastic function, and maternal–fetal immune regulation [2]. In addition, vitamin D has been implicated in the regulation of inflammatory responses, angiogenesis, and vascular function, all of which are relevant to the pathophysiological processes involved in preeclampsia.

Evidence from observational studies has suggested a potential relationship between maternal vitamin D status and preeclampsia. A systematic review and dose-response meta-analysis by Mehrnabi et al. reported that higher circulating 25(OH)D concentrations were associated with a lower risk of preeclampsia [3]. Similarly, Li et al. found an association between vitamin D insufficiency or deficiency during pregnancy and an increased risk of preeclampsia [4]. Nevertheless, the available evidence remains inconsistent. A subsequent meta-analysis by Zakerinasab et al. reported lower overall vitamin D concentrations among women with preeclampsia, while the associations observed when participants were categorized according to vitamin D insufficiency or deficiency did not reach statistical significance [5]. Differences in the timing of vitamin D assessment, definitions of vitamin D status, study populations, and potential confounding variables may partly account for these inconsistent findings.

Beyond observational evidence, randomized controlled trials have investigated whether vitamin D supplementation could contribute to the prevention of preeclampsia. A meta-analysis involving 27 randomized controlled trials found that vitamin D supplementation during pregnancy was associated with a lower risk of preeclampsia [6]. Similar findings were reported in a more recent meta-analysis of randomized controlled trials, which observed a lower incidence of preeclampsia among women receiving vitamin D supplementation [7]. However, the results across individual studies remain heterogeneous, particularly with respect to supplementation dose and timing, baseline vitamin D status, and maternal characteristics. Therefore, further evaluation of the biological mechanisms and clinical evidence linking maternal vitamin D status and supplementation with preeclampsia prevention is warranted.

This literature review aims to examine the potential role of maternal vitamin D in the prevention of preeclampsia by discussing its biological functions during pregnancy, the

mechanisms through which vitamin D may influence the pathophysiology of preeclampsia, the association between maternal vitamin D status and preeclampsia risk, and the available evidence regarding vitamin D supplementation as a preventive strategy.

2. METHODS

This review employed a narrative literature review approach to assess the potential role of maternal vitamin D in the prevention of preeclampsia. Relevant literature was identified through searches of PubMed, ScienceDirect, and Google Scholar. The search strategy incorporated keywords and Medical Subject Headings (MeSH) related to vitamin D and preeclampsia, including “vitamin D,” “25-hydroxyvitamin D,” “maternal vitamin D,” “vitamin D deficiency,” “vitamin D supplementation,” “pregnancy,” and “preeclampsia.” Boolean operators “AND” and “OR” were applied to combine the search terms and broaden or refine the retrieved literature.

The search covered publications from January 2016 to September 2026. Studies were considered eligible when they included pregnant women and investigated maternal vitamin D status, vitamin D deficiency or insufficiency, or vitamin D supplementation in relation to the risk or occurrence of preeclampsia. Original research studies, randomized controlled trials, systematic reviews, and meta-analyses published in peer-reviewed journals and available in English were considered for inclusion.

Studies were excluded when they did not involve pregnant women, did not assess maternal vitamin D status or supplementation, or did not report preeclampsia or other relevant maternal outcomes. Case reports, conference abstracts, editorials, letters, and duplicate publications were also excluded. Reference lists of relevant publications were additionally reviewed to identify potentially eligible studies that might not have been retrieved through the database search.

Study selection involved an initial screening of titles and abstracts, followed by assessment of the full text of potentially relevant articles. Information extracted from eligible studies included study characteristics, maternal population, the timing and method of vitamin D assessment or supplementation, maternal vitamin D status, the incidence or risk of preeclampsia, and the principal findings. The findings were subsequently synthesized narratively, with emphasis on the biological role of vitamin D, potential mechanisms connecting vitamin D with preeclampsia, the relationship between maternal vitamin D status and preeclampsia, and evidence concerning vitamin D supplementation.

3. RESULTS AND DISCUSSION

3.1 Maternal Vitamin D Status and Preeclampsia

The potential relationship between maternal vitamin D status and preeclampsia has been evaluated in a substantial number of observational studies. Overall, the available evidence tends to indicate that inadequate maternal vitamin D status is associated with a higher likelihood of preeclampsia, although the magnitude and statistical significance of this association vary among studies. Li et al. synthesized evidence from 22 studies involving 25,530 participants and reported that women with vitamin D insufficiency or deficiency had higher odds of developing preeclampsia, with a pooled OR of 1.58 (95% CI: 1.39–1.79). When the two categories were analyzed separately, the OR was 1.35 (95% CI: 1.10–1.66) for vitamin D deficiency and 1.44 (95% CI: 1.24–1.66) for vitamin D insufficiency [4].

Evidence suggesting a concentration-dependent association has also been reported. Mehrnabi et al. conducted a dose-response meta-analysis involving 65 observational studies and 76,394 participants, including 32 prospective studies. Their analysis showed

that women with the highest circulating 25(OH)D concentrations had a lower risk of preeclampsia than those in the lowest concentration group (RR 0.67, 95% CI: 0.54–0.83). Furthermore, the dose-response analysis estimated that every 10 ng/mL increase in 25(OH)D concentration was associated with an RR of 0.86 (95% CI: 0.83–0.90) for preeclampsia [3]. Thus, the association may involve not only categorical differences in vitamin D status but also variation in circulating 25(OH)D concentrations.

The findings reported by Yang et al. provide additional support for this association. In their nested case-control study, 65.6% of women with preeclampsia had serum 25(OH)D concentrations below 50 nmol/L, compared with 55.3% of women in the control group. The authors subsequently combined their findings with those from 20 other studies, resulting in a meta-analysis comprising 39,031 participants and 3,305 preeclampsia cases. The pooled analysis indicated that lower maternal vitamin D concentrations were associated with increased odds of preeclampsia (OR 1.62, 95% CI: 1.36–1.94) [8].

Despite these findings, the association between vitamin D status and preeclampsia has not been demonstrated consistently across all analyses. Zakerinasab et al. evaluated 29 observational studies involving 74,061 participants and found that women with preeclampsia had lower vitamin D concentrations than those without preeclampsia. The pooled standardized mean difference was -0.28 (95% CI: -0.39 to -0.17). However, when vitamin D status was examined using predefined categories, the results did not show statistically significant associations. The pooled OR was 1.05 (95% CI: 0.78–1.42) for vitamin D insufficiency and 1.25 (95% CI: 0.89–1.76) for vitamin D deficiency [5].

Several methodological and population-related factors may contribute to these differences. The gestational age at which maternal vitamin D was assessed, the criteria used to classify deficiency or insufficiency, and the laboratory methods used to determine 25(OH)D concentrations can influence the results. Differences in maternal age, body mass index, socioeconomic conditions, sunlight exposure, dietary intake, and vitamin D supplementation may also act as potential confounding factors. In addition, the predominance of observational evidence limits the interpretation of these findings. An observed association between low maternal vitamin D status and preeclampsia does not necessarily indicate a direct causal relationship. Low vitamin D concentrations may coexist with other maternal, behavioral, or environmental factors that are themselves related to preeclampsia. Therefore, although the existing evidence supports an association between maternal vitamin D status and preeclampsia, the extent to which vitamin D itself has a causal role remains uncertain.

3.2 Mechanisms Linking Vitamin D to Preeclampsia

The possible involvement of vitamin D in preeclampsia can be understood through several interconnected biological processes, particularly those related to placental development, angiogenesis, immune regulation, oxidative balance, and vascular function. The placenta and decidua contain both the vitamin D receptor (VDR) and CYP27B1, an enzyme involved in the local conversion of vitamin D into its active form. The presence of these components at the maternal-fetal interface indicates that vitamin D metabolism can occur locally and may influence placental processes during pregnancy [2].

Normal placentation depends on adequate trophoblast activity and remodeling of the maternal spiral arteries. In early pregnancy, trophoblasts migrate into the maternal decidua and contribute to the transformation of spiral arteries into vessels with lower resistance and greater capacity to accommodate blood flow. Failure of this process may result in inadequate placental perfusion and is considered an important feature in the development of preeclampsia. Vitamin D signaling through VDR may affect trophoblast migration and

function, providing a possible explanation for how inadequate vitamin D status could be associated with abnormal placentation [2].

Another pathway that may connect vitamin D with preeclampsia is placental angiogenesis. Appropriate vascular development within the placenta depends on a coordinated balance between proangiogenic mediators, including vascular endothelial growth factor (VEGF) and placental growth factor (PlGF), and antiangiogenic mediators such as soluble fms-like tyrosine kinase-1 (sFlt-1) and soluble endoglin (sEng). In preeclampsia, this balance is disrupted toward an antiangiogenic state. Vitamin D has been implicated in the regulation of angiogenic processes, suggesting that inadequate vitamin D availability may be related to impaired placental vascular development [9]. Consistent with this possibility, case-control evidence has demonstrated lower vitamin D concentrations in women with preeclampsia alongside higher levels of antiangiogenic factors, including sFlt-1 and endoglin [10].

The immunological effects of vitamin D may provide another link to the pathogenesis of preeclampsia. Maternal immune adaptation during pregnancy must be sufficiently controlled to support tolerance of the developing fetus without compromising protective immune responses. Excessive inflammation or inappropriate immune activation may interfere with placental function and contribute to maternal endothelial injury. Activation of VDR can modulate multiple immune and inflammatory pathways, indicating that vitamin D may participate in maintaining the immunological balance required during pregnancy [2].

Oxidative imbalance may further connect abnormal placentation with the vascular abnormalities characteristic of preeclampsia. Reduced placental perfusion can promote the generation of reactive oxygen species (ROS), which may cause oxidative injury and aggravate endothelial dysfunction. Experimental findings have provided additional biological support for a potential role of vitamin D in this process. In an animal model of preeclampsia-like disease, vitamin D supplementation was associated with improved placental angiogenesis and reduced blood pressure [11]. Nevertheless, because these observations originate from experimental animal research, they cannot be interpreted as direct evidence of a causal effect in pregnant women.

Vitamin D has also been proposed to interact with the renin-angiotensin-aldosterone system (RAAS), which is involved in the regulation of blood pressure and vascular homeostasis. VDR signaling has been linked to the regulation of renin expression, while abnormalities in RAAS activity may contribute to elevated blood pressure. In addition, vitamin D may affect vascular endothelial function and inflammatory processes within the vasculature. However, evidence directly establishing the relationship among vitamin D, RAAS activity, and preeclampsia in humans remains limited and inconsistent.

Taken together, the potential relationship between vitamin D and preeclampsia does not appear to depend on a single biological pathway. Instead, vitamin D may interact with several processes involved in placental development and maternal vascular adaptation, including trophoblast invasion, spiral artery remodeling, angiogenesis, immune regulation, oxidative stress, and vascular function. These mechanisms provide biological plausibility for an association between vitamin D status and preeclampsia. Nevertheless, because part of the mechanistic evidence is based on experimental studies, the existence of a direct causal relationship in humans remains unconfirmed.

3.3 Effect of Vitamin D Supplementation on Preeclampsia

Beyond the observational relationship between maternal vitamin D status and preeclampsia, research has also examined whether supplementation during pregnancy can

modify the risk of developing the condition. Several systematic reviews and meta-analyses have reported a protective association, although the magnitude of the effect has varied across studies. AlSubai et al. analyzed 34 studies comprising both randomized controlled trials and observational studies and found that vitamin D supplementation was associated with lower odds of preeclampsia (OR 0.50, 95% CI: 0.40–0.63) [12].

Evidence from randomized trials has produced similar findings. Fogacci et al. pooled 27 randomized controlled trials involving 4,777 participants and reported an OR of 0.37 (95% CI: 0.26–0.52) for preeclampsia among women receiving vitamin D supplementation. Their analysis also considered the timing of treatment and found a lower risk when supplementation was started at or before 20 weeks of gestation (OR 0.35, 95% CI: 0.24–0.50) [6]. These results raise the possibility that the gestational age at which supplementation begins may affect its potential preventive effect.

Further evidence was reported in a more recent meta-analysis that included 33 randomized controlled trials and 10,613 participants. Vitamin D supplementation was associated with a lower incidence of preeclampsia, with a pooled RR of 0.55 (95% CI: 0.43–0.71) [7]. Although this finding is consistent with a potential preventive effect, differences between individual trials should be considered. The studies varied in supplementation dose and duration, gestational age at initiation, baseline vitamin D status, and participant characteristics, all of which may contribute to variation in treatment effects.

Baseline vitamin D status may also influence the response to supplementation. A meta-analysis of five randomized controlled trials involving 2,461 participants reported an RR of 0.61 (95% CI: 0.50–0.75) for preeclampsia among women receiving vitamin D supplementation. The reduction appeared to be more pronounced in women whose baseline 25(OH)D concentration was below 20 ng/mL [13]. This observation suggests that the effect of supplementation may not be uniform across all pregnant women and could depend partly on their vitamin D status before treatment.

The timing of supplementation has received particular attention because important placental developmental processes occur during early pregnancy. A systematic review examining supplementation initiated during early pregnancy reported potential reductions in preeclampsia risk, with OR estimates ranging from approximately 0.26 to 0.31 [14]. From a biological perspective, administration during this period could potentially influence processes such as trophoblast invasion and spiral artery remodeling. However, the clinical significance of this proposed mechanism requires confirmation through appropriately designed human studies.

The amount of vitamin D administered represents another variable that may affect outcomes. A dose-related meta-analysis found that supplementation at doses of $\leq 2,000$ IU/day was associated with a lower risk of preeclampsia (RR 0.29, 95% CI: 0.09–0.95). In contrast, a direct comparison between higher and lower doses did not demonstrate a statistically significant difference [15]. These findings indicate that a higher supplementation dose cannot automatically be assumed to provide greater protection against preeclampsia. The effect of supplementation should therefore be considered in relation to baseline vitamin D status and other maternal characteristics.

Despite the generally favorable results reported in several analyses, evidence from randomized studies remains heterogeneous. A separate systematic review and meta-analysis assessing vitamin D supplementation during pregnancy found no statistically significant reduction in preeclampsia risk, with an RR of 0.81 (95% CI: 0.43–1.53). This analysis included six trials involving 1,483 participants and reported substantial heterogeneity together with a high risk of bias in several of the included studies [16]. The differing results across reviews may reflect variations in baseline vitamin D concentrations,

supplementation dose, timing and duration of treatment, adherence, participant characteristics, and study methodology.

Overall, available evidence indicates that vitamin D supplementation during pregnancy may reduce the risk of preeclampsia, but the findings are not sufficiently consistent to define a single preventive strategy applicable to all pregnant women. Differences in baseline vitamin D status, dose, timing of initiation, and population characteristics appear to be important considerations when interpreting the observed effects. Further well-designed randomized controlled trials are required to clarify which groups are most likely to benefit and to establish the appropriate timing and dosage of vitamin D supplementation for preeclampsia prevention.

4. CONCLUSION

Maternal vitamin D may contribute to reducing the risk of preeclampsia by influencing several biological processes, including placental development, trophoblast invasion, angiogenesis, immune responses, oxidative balance, and vascular function. Findings from observational studies predominantly show an association between inadequate maternal 25(OH)D levels and an increased likelihood of preeclampsia, although the magnitude and statistical significance of this relationship differ across studies. Evidence from meta-analyses of randomized controlled trials further indicates that vitamin D supplementation during pregnancy may have a protective effect against the development of preeclampsia. Nevertheless, considerable variation in baseline vitamin D status, supplementation dosage, initiation time, participant characteristics, and methodological quality may explain the heterogeneity observed among studies. Thus, although vitamin D supplementation has potential as an approach to preventing preeclampsia, the available evidence does not yet support a standardized dose or supplementation schedule specifically for this purpose. Additional high-quality randomized controlled trials are required to clarify the most appropriate supplementation regimen and to determine which maternal populations are most likely to benefit.

5. ACKNOWLEDGEMENT

The authors gratefully acknowledge the support and assistance provided by all individuals and institutions involved in the preparation of this literature review. Appreciation is also extended to the academic community and researchers whose scientific publications provided valuable information and evidence for this review. The support, contributions, and scholarly work of these parties greatly facilitated the completion of this manuscript.

6. REFERENCES

- [1] C. W. Ives, R. Sinkey, I. Rajapreyar, A. T. N. Tita, and S. Oparil, "Preeclampsia—Pathophysiology and clinical presentations: JACC state-of-the-art review," *Journal of the American College of Cardiology*, vol. 76, no. 14, pp. 1690–1702, 2020, doi: 10.1016/j.jacc.2020.08.014.
- [2] A. Ganguly, J. A. Tamblyn, S. Finn-Sell, S.-Y. Chan, M. Westwood, J. Gupta, M. D. Kilby, S. R. Gross, and M. Hewison, "Vitamin D, the placenta and early pregnancy: Effects on trophoblast function," *Journal of Endocrinology*, vol. 236, no. 2, pp. R93–R103, 2018, doi: 10.1530/JOE-17-0491.
- [3] P. Rouhani, E. Mokhtari, K. Lotfi, and P. Saneai, "The association between circulating 25-hydroxyvitamin D levels and preeclampsia: A systematic review and dose-

- response meta-analysis of epidemiologic studies with GRADE assessment,” *Nutrition Reviews*, vol. 81, no. 10, pp. 1267–1289, 2023, doi: 10.1093/nutrit/nuad006.
- [4] K.-L. Hu, C.-X. Zhang, P. Chen, D. Zhang, and S. Hunt, “Vitamin D levels in early and middle pregnancy and preeclampsia, a systematic review and meta-analysis,” *Nutrients*, vol. 14, no. 5, p. 999, 2022, doi: 10.3390/nu14050999.
- [5] F. Zakerinasab, Q. Behfar, H. Daghistani, A. Ansari, R. H. Zadeh, R. H. Zadeh, and A. Amirbeik, “Vitamin D levels in early and middle pregnancy and preeclampsia: A systematic review and meta-analysis,” *Frontiers in Medicine*, vol. 12, p. 1535359, 2025, doi: 10.3389/fmed.2025.1535359.
- [6] S. Fogacci, F. Fogacci, M. Banach, E. D. Michos, A. V. Hernandez, G. Y. H. Lip, M. J. Blaha, P. P. Toth, C. Borghi, and A. F. G. Cicero, “Vitamin D supplementation and incident preeclampsia: A systematic review and meta-analysis of randomized clinical trials,” *Clinical Nutrition*, vol. 39, no. 6, pp. 1742–1752, 2020, doi: 10.1016/j.clnu.2019.08.015.
- [7] K. Moghib, T. I. Ghanm, A. Abunamoos, M. Rajabi, S. M. Moawad, A. Mohsen, S. Kasem, K. Elsayed, M. Sayed, A. I. Dawoud, I. Salomon, A. Elmaghreby, M. Ismail, and A. Amer, “Efficacy of vitamin D supplementation on the incidence of preeclampsia: A systematic review and meta-analysis,” *BMC Pregnancy and Childbirth*, vol. 24, p. 852, 2024, doi: 10.1186/s12884-024-07081-y.
- [8] X. Yang, J. Zhang, Y. Xu, et al., “Association of maternal serum 25-hydroxyvitamin D concentrations with risk of preeclampsia: A nested case-control study and meta-analysis,” *Journal of Maternal-Fetal & Neonatal Medicine*, vol. 33, no. 15, pp. 2586–2594, 2020, doi: 10.1080/14767058.2019.1640675.
- [9] J. Nema, D. Sundrani, and S. Joshi, “Role of vitamin D in influencing angiogenesis in preeclampsia,” *Hypertension in Pregnancy*, vol. 38, no. 4, pp. 201–207, 2019, doi: 10.1080/10641955.2019.1647231.
- [10] D. B. Seifer, G. Lambert-Messerlian, G. E. Palomaki, R. M. Silver, C. Parker, C. J. Rowland Hogue, B. J. Stoll, G. R. Saade, R. L. Goldenberg, D. J. Dudley, R. Bukowski, H. Pinar, and U. M. Reddy, “Preeclampsia at delivery is associated with lower serum vitamin D and higher antiangiogenic factors: A case control study,” *Reproductive Biology and Endocrinology*, vol. 20, no. 1, p. 8, 2022, doi: 10.1186/s12958-021-00885-z.
- [11] J. Nema, D. Sundrani, and S. Joshi, “Prenatal vitamin D supplementation reduces blood pressure and improves placental angiogenesis in an animal model of preeclampsia,” *Food & Function*, vol. 11, no. 12, pp. 10413–10422, 2020, doi: 10.1039/D0FO01782E.
- [12] A. AlSubai, M. H. Baqai, H. Agha, N. Shankarlal, S. S. Javaid, E. K. Jesrani, S. Golani, A. Akram, F. Qureshi, S. Ahmed, and S. Saran, “Vitamin D and preeclampsia: A systematic review and meta-analysis,” *SAGE Open Medicine*, vol. 11, p. 20503121231212093, 2023, doi: 10.1177/20503121231212093.
- [13] A. Kokkinari, E. Antoniou, E. Orovou, P. E. Andronikidi, M. Tzitziridou-Chatzopoulou, A. Sarantaki, K. Gourounti, and G. Iatrakis, “The role of vitamin D supplementation in preventing pre-eclampsia: A review of randomized controlled trials with meta-analysis,” *Healthcare*, vol. 13, no. 11, p. 1221, 2025, doi: 10.3390/healthcare13111221.
- [14] G. Dahma, G. Reddy, M. Craina, C. Dumitru, A. Popescu, L. Stelea, R. Neamtu, A. Gluhovschi, R. Nitu, A. L. Maghiari, G. Tapalaga, D. A. Arnautu, A. Nelluri, R. K. Maganti, and E. Bernad, “The effects of vitamin D supplementation before 20 weeks

- of gestation on preeclampsia: A systematic review,” *Journal of Personalized Medicine*, vol. 13, no. 6, p. 996, 2023, doi: 10.3390/jpm13060996.
- [15] R. Irwinda, R. Hiksas, A. W. Lokeswara, and N. Wibowo, “Vitamin D supplementation higher than 2000 IU/day compared to lower dose on maternal-fetal outcome: Systematic review and meta-analysis,” *Women’s Health*, vol. 18, p. 17455057221111066, 2022, doi: 10.1177/17455057221111066.
- [16] W.-C. Yang, R. Chitale, K. M. O’Callaghan, C. R. Sudfeld, and E. R. Smith, “The effects of vitamin D supplementation during pregnancy on maternal, neonatal, and infant health: A systematic review and meta-analysis,” *Nutrition Reviews*, vol. 83, no. 3, pp. e892–e903, 2024, doi: 10.1093/nutrit/nuae065.