

ASSOCIATION BETWEEN FIRST-TRIMESTER SERUM 25-HYDROXYVITAMIN D LEVELS AND ADVERSE MATERNAL AND PREGNANCY OUTCOMES

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Abstract. Vitamin D deficiency is a widespread public health problem, particularly among pregnant women, and may be associated with an increased risk of adverse pregnancy outcomes. The aim of this systematic review was to evaluate the association between first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels and adverse maternal and pregnancy outcomes.

A systematic literature review was conducted using PubMed, Scopus, Web of Science, and Google Scholar databases. A total of 27 studies that met the inclusion criteria were analyzed. The prevalence of vitamin D deficiency among pregnant women ranged from 52.8% to 84%, depending on the population, geographic region, and diagnostic threshold used. Several included studies reported an association between low first-trimester 25(OH)D levels and an increased risk of preeclampsia, gestational diabetes mellitus, and preterm birth. Vitamin D deficiency below 20 ng/mL was associated with a higher risk of preeclampsia in some studies, while adjusted analyses also indicated an increased risk of gestational diabetes mellitus. Low vitamin D levels were additionally associated with shorter gestational duration and a higher probability of preterm birth.

The findings suggest that vitamin D deficiency in early pregnancy may be considered a potentially modifiable factor associated with adverse maternal and pregnancy outcomes. Early assessment of vitamin D status may help identify women at increased obstetric risk. However, further well-designed prospective studies and randomized controlled trials are needed to confirm the effectiveness of early correction strategies.

Keywords: vitamin D deficiency, 25(OH)D, pregnancy, preeclampsia, gestational diabetes mellitus, preterm birth

ЖҮКТІЛІКТІҢ БІРІНШІ ТРИМЕСТРІНДЕГІ 25-ГИДРОКСИВИТАМИН D ДЕҢГЕЙІ МЕН ЖАҒЫМСЫЗ АНАЛЫҚ ЖӘНЕ ЖҮКТІЛІК НӘТИЖЕЛЕРІ АРАСЫНДАҒЫ БАЙЛАНЫС

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Аңдатпа. D дәруменінің тапшылығы қоғамдық денсаулық сақтаудың кең таралған мәселелерінің бірі болып табылады және әсіресе жүкті әйелдер арасында жиі кездеседі. Бұл жағдай жүктіліктің жағымсыз нәтижелерінің даму қаупімен байланысты болуы мүмкін.

Осы жүйелі шолудың мақсаты — жүктіліктің бірінші триместріндегі қан сарысуындағы 25-гидроксивитамин D [25(OH)D] деңгейі мен жағымсыз аналық және жүктілік нәтижелері арасындағы байланысты бағалау.

PubMed, Scopus, Web of Science және Google Scholar дерекқорлары бойынша жүйелі әдеби шолу жүргізілді. Қосу критерийлеріне сәйкес келген 27 зерттеу талданды. Жүкті әйелдер арасында D дәрумені тапшылығының таралуы зерттелген популяцияға, географиялық аймаққа және қолданылған диагностикалық шекке байланысты 52,8%-дан 84%-ға дейін өзгерді. Бірқатар зерттеулерде бірінші триместрдегі 25(OH)D деңгейінің төмен болуы преэклампсия, гестациялық қант диабеті және мерзімінен бұрын босану қаупінің жоғарылауымен байланысты екені көрсетілген. 25(OH)D деңгейінің 20 нг/мл-ден төмен болуы кейбір зерттеулерде преэклампсия қаупінің артуымен байланысты болды, ал түзетілген талдаулар гестациялық қант диабеті қаупінің жоғарылауын да көрсетті. Сонымен қатар, D дәруменінің төмен деңгейі жүктілік мерзімінің қысқаруымен және мерзімінен бұрын босану ықтималдығының артуымен байланысты болды.

Алынған нәтижелер ерте жүктілік кезеңіндегі D дәрумені тапшылығын жағымсыз аналық және жүктілік нәтижелерімен байланысты ықтимал өзгертілетін фактор ретінде қарастыруға болатынын көрсетеді. D дәрумені деңгейін ерте бағалау акушерлік қауіп жоғары әйелдерді анықтауға мүмкіндік беруі мүмкін. Дегенмен, ерте түзету шараларының тиімділігін нақтылау үшін жақсы жоспарланған проспективті зерттеулер мен рандомизацияланған бақыланатын зерттеулер қажет.

Түйін сөздер: D дәрумені тапшылығы, 25(OH)D, жүктілік, преэклампсия, гестациялық қант диабеті, мерзімінен бұрын босану

СВЯЗЬ МЕЖДУ УРОВНЕМ 25-ГИДРОКСИВИТАМИНА D В ПЕРВОМ ТРИМЕСТРЕ И НЕБЛАГОПРИЯТНЫМИ МАТЕРИНСКИМИ И АКУШЕРСКИМИ ИСХОДАМИ

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Аннотация. Дефицит витамина D является широко распространённой проблемой общественного здравоохранения и особенно часто встречается среди беременных женщин. Данное состояние может быть связано с повышенным риском неблагоприятных исходов беременности. Целью настоящего систематического обзора было оценить связь между уровнем 25-гидроксивитамина D [25(OH)D] в первом триместре беременности и неблагоприятными материнскими и акушерскими исходами.

Проведён систематический обзор литературы с использованием баз данных PubMed, Scopus, Web of Science и Google Scholar. В анализ были включены 27 исследований, соответствующих критериям отбора. Распространённость дефицита витамина D среди беременных женщин варьировала от 52,8% до 84% в зависимости от исследуемой популяции, географического региона и применяемого диагностического порога. В ряде

включённых исследований низкий уровень 25(OH)D в первом триместре ассоциировался с повышенным риском преэклампсии, гестационного сахарного диабета и преждевременных родов. Дефицит витамина D ниже 20 нг/мл в отдельных исследованиях был связан с более высоким риском преэклампсии, а скорректированный анализ также указывал на увеличение риска гестационного сахарного диабета. Низкий уровень витамина D дополнительно ассоциировался с сокращением срока гестации и повышенной вероятностью преждевременных родов.

Полученные данные позволяют рассматривать дефицит витамина D на ранних сроках беременности как потенциально модифицируемый фактор, связанный с неблагоприятными материнскими и акушерскими исходами. Ранняя оценка статуса витамина D может способствовать выявлению женщин с повышенным акушерским риском. Вместе с тем для подтверждения эффективности ранних корректирующих мероприятий необходимы хорошо спланированные проспективные и рандомизированные контролируемые исследования.

Ключевые слова: дефицит витамина D, 25(OH)D, беременность, преэклампсия, гестационный сахарный диабет, преждевременные роды.

Introduction. Vitamin D deficiency is widely recognized as a global public health problem and remains particularly relevant during pregnancy. Pregnant women are considered a vulnerable group because maternal vitamin D status influences not only calcium and phosphorus metabolism, but also immune regulation, placental development, vascular function, and metabolic homeostasis. According to recent studies, the prevalence of 25-hydroxyvitamin D [25(OH)D] insufficiency and deficiency among pregnant women remains high in many regions of the world and may vary depending on geographic latitude, season, ethnicity, nutritional habits, clothing style, sun exposure, and socioeconomic factors (Abbasalizadeh et al., 2025; Ku et al., 2024; Varthaliti et al., 2025).

During pregnancy, vitamin D plays an important role in maintaining maternal and fetal health. Its biological effects are mediated through vitamin D receptors and the enzyme 1 α -hydroxylase, which are expressed in placental and decidual tissues. These mechanisms are especially important in early pregnancy, when implantation, trophoblast invasion, spiral artery remodeling, and placental vascular development take place. Adequate vitamin D status may contribute to immune tolerance at the maternal–fetal interface, regulation of inflammatory responses, and normal angiogenesis. Therefore, vitamin D deficiency during the first trimester may theoretically affect key processes involved in the development of adverse pregnancy outcomes, including preeclampsia, gestational diabetes mellitus, and preterm birth (Mansur et al., 2022; Giourga et al., 2023; Al Balawi et al., 2024; Chen et al., 2024).

The association between low maternal 25(OH)D levels and adverse obstetric outcomes has been widely discussed in the literature. Several observational studies have reported that vitamin D deficiency is associated with an increased risk of preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth (Das et al., 2021; Reverzani et al., 2025). However, the available evidence remains inconsistent. Some randomized controlled trials and intervention studies have not demonstrated clear or uniform benefits of vitamin D supplementation in preventing pregnancy complications. These discrepancies may be explained by differences in

study design, baseline vitamin D status, supplementation dose, timing of intervention, population characteristics, and adjustment for confounding factors such as body mass index, seasonality, diet, and ethnicity (Dahma et al., 2023; Ibrahim et al., 2022; Ku et al., 2024).

An important methodological issue is that many studies assess vitamin D status in the second or third trimester, when pathological processes leading to adverse outcomes may already be established. This limits the ability to determine whether low vitamin D levels are a contributing factor or a consequence of ongoing pregnancy complications. In this regard, the first trimester represents a critical window for investigation, as placentation, vascular adaptation, and early metabolic changes occur during this period. Assessment of 25(OH)D levels in early pregnancy may therefore provide more clinically meaningful information for identifying women at increased obstetric risk (Malm et al., 2023; Alkhalaf et al., 2026; Beck et al., 2025).

Despite the growing number of studies on vitamin D and pregnancy outcomes, evidence on first-trimester vitamin D status remains limited and heterogeneous, particularly in relation to region-specific populations. This is especially relevant for Central Asian countries, including Kazakhstan, where local epidemiological data on vitamin D deficiency among pregnant women and its association with maternal outcomes remain insufficient. A better understanding of this association may contribute to the development of more targeted antenatal screening and prevention strategies.

Objective. The objective of this systematic review was to evaluate the association between first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels and the risk of adverse maternal and pregnancy outcomes, with a particular focus on preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth.

Materials and Methods

Study Design. This study was designed as a systematic review with elements of qualitative evidence synthesis. The review focused on studies investigating the relationship between maternal serum 25-hydroxyvitamin D [25(OH)D] levels measured during the first trimester of pregnancy and the subsequent development of adverse maternal and pregnancy outcomes.

The methodological approach was developed in accordance with the PRISMA 2020 statement for reporting systematic reviews. Given the heterogeneity of the included studies in terms of design, population characteristics, definitions of vitamin D deficiency, outcome measures, and statistical reporting, a quantitative meta-analysis was not performed. Instead, the findings were summarized using a narrative synthesis approach.

This design was selected to provide a structured and clinically meaningful overview of the available evidence, while taking into account methodological differences between the included studies.

Literature Search Strategy. A comprehensive literature search was conducted in the electronic databases PubMed, Scopus, Web of Science, and Google Scholar. The search was performed from April 13 to April 25, 2026.

The search strategy included combinations of keywords and Boolean operators related to vitamin D status, early pregnancy, and adverse maternal outcomes. The following terms and their combinations were used: “vitamin D,” “25-hydroxyvitamin D,” “25(OH)D,” “pregnancy,” “first trimester,” “early pregnancy,” “maternal outcomes,” “adverse pregnancy outcomes,”

“preeclampsia,” “gestational diabetes mellitus,” “hypertensive disorders of pregnancy,” and “preterm birth.”

The search was limited to studies published in English and conducted in human populations. Additional relevant articles were identified through manual screening of reference lists of selected publications where appropriate.

Inclusion and Exclusion Criteria. Studies were included in the review if they met the following criteria:

1. original research articles, including cohort studies, case-control studies, cross-sectional studies, and randomized controlled trials;
2. assessment of maternal serum 25(OH)D levels during the first trimester of pregnancy or early pregnancy;
3. analysis of adverse maternal or pregnancy outcomes, including preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, preterm birth, or related obstetric complications;
4. availability of full-text articles;
5. clear description of vitamin D status or diagnostic thresholds used to define deficiency or insufficiency.

Studies were excluded if they met any of the following criteria:

1. review articles, systematic reviews, meta-analyses, editorials, letters, comments, or case reports;
2. studies that did not clearly define vitamin D status or did not report serum 25(OH)D levels;
3. studies in which vitamin D levels were assessed only in the second or third trimester without separate first-trimester data;
4. studies with insufficient information on maternal or pregnancy outcomes;
5. duplicate publications or studies reporting overlapping data from the same population.

Original studies were included in the synthesis; review articles were used only for background context where relevant.

Study Selection. The study selection process was conducted in accordance with the PRISMA 2020 flow approach. The initial search identified 140 publications. After removing duplicates, 128 records remained. During title and abstract screening, 52 studies were excluded because they did not meet the inclusion criteria. Full-text assessment was conducted for 76 articles, of which 49 were excluded due to methodological limitations, absence of relevant first-trimester data, insufficient outcome information, or lack of clear definition of vitamin D status. Finally, 27 studies were included in the qualitative synthesis.

Table 1. PRISMA-based study selection process

Stage of selection	Number of records
Records identified through database search	140
Records after duplicate removal	128
Records excluded after title/abstract screening	52
Full-text articles assessed for eligibility	76
Full-text articles excluded	49
Studies included in qualitative synthesis	27

Data Extraction. Data extraction was performed using a structured approach. For each included study, the following information was collected:

- author and year of publication;
- country and study setting;
- study design;
- sample size and main characteristics of participants;
- gestational age at the time of 25(OH)D assessment;
- serum 25(OH)D levels;
- cut-off values used to define vitamin D deficiency or insufficiency;
- maternal and pregnancy outcomes assessed;
- statistical measures of association, including odds ratios, adjusted odds ratios, confidence intervals, and p-values where available;
- key findings and conclusions of the study.

Data extraction was performed independently by two reviewers. Any inconsistencies were checked and resolved through discussion and verification of the original full-text articles. This approach was used to minimize selection bias and improve the reliability of the extracted data.

Quality Assessment. The methodological quality of the included studies was assessed using validated appraisal tools appropriate for each study design. For observational studies, the Newcastle–Ottawa Scale was used to evaluate the quality of cohort and case-control studies.

The assessment focused on the following domains:

- selection of study participants;
- comparability of study groups;
- adequacy of exposure assessment;
- clarity and validity of outcome measurement;
- adjustment for potential confounding factors;
- completeness of follow-up or outcome data.

Particular attention was given to whether the included studies adjusted for clinically relevant confounders such as maternal age, body mass index, ethnicity, season of blood sampling, dietary intake, vitamin D supplementation, socioeconomic status, and comorbid conditions.

The risk of bias was considered when interpreting the findings, especially in studies with small sample sizes, retrospective design, incomplete adjustment for confounding variables, or inconsistent definitions of vitamin D deficiency.

Data Synthesis. Due to substantial heterogeneity among the included studies, a qualitative narrative synthesis was conducted. The included studies differed in terms of population characteristics, geographic regions, cut-off values for vitamin D deficiency, timing of blood sampling, outcome definitions, and statistical methods. Therefore, pooling of results in a meta-analysis was not considered appropriate.

The findings were grouped according to the main categories of adverse outcomes:

1. preeclampsia and hypertensive disorders of pregnancy;
2. gestational diabetes mellitus;
3. preterm birth and gestational duration;

4. other reported maternal or pregnancy-related outcomes.

Where available, measures of association such as odds ratios, adjusted odds ratios, confidence intervals, and levels of statistical significance were considered. Greater emphasis was placed on studies that assessed vitamin D status in the first trimester and adjusted for major confounding factors.

The synthesis aimed to identify the direction, consistency, and clinical relevance of the association between early pregnancy vitamin D status and adverse outcomes, rather than to establish direct causality.

Results. The included studies analyzed pregnant women assessed during early pregnancy, with first-trimester serum 25-hydroxyvitamin D [25(OH)D] levels reported as the main exposure variable. Across the studied populations, the mean age of pregnant women ranged from 27.9 to 31.27 years (Abbasalizadeh et al., 2025; Beck et al., 2025). The mean body mass index (BMI) ranged from 22.16 to 26.6 kg/m², and in some cohorts a substantial proportion of participants had normal body weight at the time of registration, reaching up to 71% (Abbasalizadeh et al., 2025; Beck et al., 2025). The mean gestational age at the initial assessment varied from 9.4 to 11.7 weeks, indicating that vitamin D status was evaluated during the first trimester, which was the key period of interest in this review (Abbasalizadeh et al., 2025; Ku et al., 2024).

The prevalence of low vitamin D status among pregnant women was high across the included studies, although the reported rates differed depending on the population, geographic region, and cut-off values used to define deficiency or insufficiency. Hypovitaminosis D, defined as serum 25(OH)D levels below 30 ng/mL, reached 52.8% (95% CI: 46.98–58.54) in the Iranian cohort and up to 84% in the Chinese population (Abbasalizadeh et al., 2025; Wu et al., 2025). Vitamin D deficiency, defined as serum 25(OH)D levels below 20 ng/mL, was reported in 40.5% of pregnant women in the Mexican cohort (Arce-Sánchez et al., 2025). The proportion of women with sufficient vitamin D levels, defined as 25(OH)D $\geq$ 30 ng/mL, varied from 12.1% to 47.2% during the first trimester (Abbasalizadeh et al., 2025; Polanek et al., 2024). These findings indicate that insufficient vitamin D status was common in early pregnancy among the populations included in the review.

Table 2. Summary of key findings on first-trimester vitamin D status and adverse outcomes

Outcome	Reported finding	Measure of association	Source
Preeclampsia	More frequent among women with vitamin D deficiency: 16.9% vs. 9.6%	Not reported in this row	Alkhalaf et al., 2026
Preeclampsia	Higher risk among women with serum 25(OH)D levels < 20 ng/mL	OR: 11.31; 95% CI: 7.60–14.01; p < 0.001	Das et al., 2021
Gestational diabetes mellitus	Diagnosed in 14.4%–24.3% of cases	Not reported in this row	Arce-Sánchez et al., 2025; Aslan Çin et al., 2022
Gestational diabetes mellitus	Increased odds among women with vitamin D deficiency after adjustment for age and BMI	aOR: 2.04; 95% CI: 1.14–3.65; p = 0.01	Arce-Sánchez et al., 2025
Gestational diabetes mellitus	Higher risk among women with vitamin D deficiency	OR: 10.60; 95% CI: 2.82–39.76; p < 0.001	Aslan Çin et al., 2022

Preterm birth	Preterm birth before 37 weeks occurred in 8.3% of cases	Not reported in this row	Beck et al., 2025
Preterm birth	Low first-trimester 25(OH)D levels < 40 nmol/L were associated with increased risk	OR: 4.35; 95% CI: 1.14–16.55	Beck et al., 2025
Delivery at ≤ 38 weeks	Associated with serum 25(OH)D levels ≤ 14.7 ng/mL	OR: 1.611; 95% CI: 1.120–2.318; $p = 0.010$	Chen et al., 2024
Severe hypertensive disorders	Increased odds among women with vitamin D deficiency	aOR: 2.86; 95% CI: 1.45–6.08; $p = 0.003$	Reverzani et al., 2025

Adverse maternal and pregnancy outcomes were reported with varying frequency across the included studies. Preeclampsia was observed in 10% of cases in the analyzed cohort and occurred more frequently among women with vitamin D deficiency than among women with normal vitamin D levels: 16.9% versus 9.6%, respectively (Alkhalaf et al., 2026). Gestational diabetes mellitus (GDM) was diagnosed in 14.4%–24.3% of cases, depending on the study population and diagnostic criteria used (Arce-Sánchez et al., 2025; Aslan Çin et al., 2022). Preterm birth before 37 weeks of gestation was reported in 8.3% of cases (Beck et al., 2025).

The analysis of reported associations showed that low first-trimester 25(OH)D levels were associated with a higher risk of several adverse outcomes. In relation to preeclampsia, women with serum 25(OH)D levels below 20 ng/mL had an 11.3-fold higher risk compared with women with normal vitamin D levels (OR: 11.31; 95% CI: 7.60–14.01; $p < 0.001$) (Das et al., 2021). This finding suggests a strong association between vitamin D deficiency and preeclampsia in the cited study; however, given the review design and heterogeneity of the included studies, this result should be interpreted as evidence of association rather than proof of direct causality.

For gestational diabetes mellitus, adjusted analysis also indicated an association with vitamin D deficiency. In a multivariate logistic regression model adjusted for maternal age and BMI, vitamin D deficiency was associated with a twofold increase in the odds of GDM (aOR: 2.04; 95% CI: 1.14–3.65; $p = 0.01$) (Arce-Sánchez et al., 2025). In another prospective cohort study conducted in Turkey, women with vitamin D deficiency had a more than tenfold increased risk of developing GDM (OR: 10.60; 95% CI: 2.82–39.76; $p < 0.001$) (Aslan Çin et al., 2022). The difference in the magnitude of association between studies may reflect variations in study design, population characteristics, diagnostic thresholds, and adjustment for confounding factors.

Regarding delivery outcomes, low first-trimester 25(OH)D levels were also associated with shorter gestational duration and a higher risk of preterm birth. Serum 25(OH)D levels below 40 nmol/L were associated with a 4.35-fold increase in the risk of preterm birth (95% CI: 1.14–16.55) and with a reduction in gestational duration by an average of 1.17 weeks (Beck et al., 2025). In addition, serum 25(OH)D levels ≤ 14.7 ng/mL were identified as an independent factor associated with delivery at ≤ 38 weeks of gestation (OR: 1.611; 95% CI: 1.120–2.318; $p = 0.010$) (Chen et al., 2024).

The included studies also reported an association between vitamin D deficiency and hypertensive disorders of pregnancy. Adjusted analysis demonstrated that vitamin D deficiency was associated with increased odds of severe hypertensive disorders (aOR: 2.86; 95% CI: 1.45–6.08; $p = 0.003$) (Reverzani et al., 2025). This supports the possible role of early pregnancy vitamin D status as a marker of increased obstetric risk, particularly for hypertensive complications.

Overall, the findings of the included studies consistently suggest that low serum 25(OH)D levels in the first trimester are associated with an increased risk of preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth. However, the strength of these associations varied across studies. Therefore, the results should be interpreted with caution, taking into account differences in study design, sample size, definitions of vitamin D deficiency, timing of assessment, and the extent of adjustment for potential confounding factors.

Limitations. This review has several limitations. First, due to heterogeneity in study designs, population characteristics, definitions of vitamin D deficiency, and reported outcomes, a quantitative meta-analysis was not performed. Second, the included studies differed in the extent of adjustment for potential confounding factors, including maternal age, body mass index, ethnicity, seasonality, dietary intake, vitamin D supplementation, and socioeconomic status. Third, most of the available evidence was derived from observational studies, which limits causal interpretation. Therefore, the findings should be interpreted as evidence of association rather than definitive proof of causality.

Conclusion. The findings of this study demonstrate a critically high prevalence of vitamin D deficiency among pregnant women in the first trimester. The results support the hypothesis that low serum 25(OH)D levels in early pregnancy are associated with an increased risk of complications such as preeclampsia, gestational diabetes mellitus, hypertensive disorders of pregnancy, and preterm birth. Vitamin D deficiency may be considered a potentially modifiable factor associated with increased obstetric risk.

From a public health perspective, these findings support the need to revise antenatal care protocols toward early screening of vitamin D status. Identifying the first trimester as a critical window for intervention allows timely nutritional correction, which has important prognostic implications for reducing maternal morbidity. The implementation of monitoring programs and personalized vitamin D supplementation strategies may represent a cost-effective approach to improving perinatal outcomes at the population level.

References

1. Abbasalizadeh, F., Bavand, S., & Fathnezhad-Kazemi, A. Prevalence and determinants of hypovitaminosis D in early pregnancy: A cross-sectional study among first-trimester pregnant women. *BMC Pregnancy and Childbirth*, 2025, 25(1), 1028.
2. Al Balawi, A. N., et al.. Impact of Vitamin D deficiency on immunological and metabolic responses in women with recurrent pregnancy loss. *BMC Pregnancy and Childbirth*, 2024, 24(1), 709.
3. Alkhalaf, Z. M., et al. Preconception vitamin D status and subsequent risk of preeclampsia: A secondary cohort analysis from the EAGeR trial. *Pregnancy Hypertension*, 2026, 43, 101417.
4. Arce-Sánchez, L., et al. First trimester vitamin D deficiency and risk of gestational diabetes mellitus in a Mexican cohort. *Nutrients*, 2025, 17(1), 12.
5. Aslan Çin, N. N., Yalçın, M., & Yardimci, H. Vitamin D deficiency during the first trimester of pregnancy and the risk of developing gestational diabetes mellitus. *Journal of Obstetric, Gynecologic & Neonatal Nursing*, 2022, 51(5), 526–535.

6. Beck, C., et al. Maternal vitamin D status, fetal growth patterns, and adverse pregnancy outcomes in a multisite prospective pregnancy cohort. *The American Journal of Clinical Nutrition*, 2025, 121(2), 376–384.
7. Chen, Q., et al. Predictive value of Vitamin D levels in pregnant women on gestational length and neonatal weight in China: A population-based retrospective study. *Reproductive Biology and Endocrinology*, 2024, 22(1), 102.
8. Dahma, G., et al. The effects of vitamin D supplementation before 20 weeks of gestation on preeclampsia: A systematic review. *Journal of Personalized Medicine*, 2023, 13(6), 996.
9. Das, B., Singhal, S. R., & Ghalaut, V. S. Evaluating the association between maternal vitamin D deficiency and preeclampsia among Indian gravidas. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, 2021, 261, 103–109.
10. Flores-Bazán, T., et al. Maternal Vitamin D status, oxidative stress, and implications for neonatal development: A cross-sectional study. *Nutrients*, 2025, 17(1), 18.
11. Giourga, C., et al. Vitamin D deficiency as a risk factor of preeclampsia during pregnancy. *Diseases*, 2023, 11(4), 158.
12. Ibrahim, A., et al. The impact of nutritional supplementation during pregnancy on the incidence of gestational diabetes and glycaemic control: A review. *Frontiers in Nutrition*, 2022, 9, 833215.
13. Karpova, N., et al. Review: Influence of 25(OH)D blood concentration and supplementation during pregnancy on preeclampsia development and neonatal outcomes. *International Journal of Molecular Sciences*, 2022, 23(21), 12935.
14. Ku, T. W., et al. The effect of vitamin D supplementation in pregnant women with overweight and obesity: A randomised controlled trial. *Nutrients*, 2024, 16(1), 146.
15. Lee, J. Y., et al. Assessing the influence of maternal vitamin D deficiency in early pregnancy and subsequent improvement on perinatal outcomes and long-term child development. *PLoS ONE*, 2025, 20(5), e0323146.
16. Malm, G., et al. Maternal serum vitamin D level in early pregnancy and risk for preeclampsia: A case-control study in Southern Sweden. *PLoS ONE*, 2023, 18(2), e0281234.
17. Mansur, J. L., et al. Vitamin D: Before, during and after pregnancy: Effect on neonates and children. *Nutrients*, 2022, 14(9), 1900.
18. Polanek, E., et al. A study of vitamin D status and its influencing factors among pregnant women in Szeged, Hungary: A secondary outcome of a case-control study. *Nutrients*, 2024, 16(10), 1431.
19. Reverzani, C., et al. Prevalence of vitamin D deficiency and its association with adverse obstetric outcomes among pregnant women in Uganda: A cross-sectional study. *BMJ Open*, 2025, 15(1), e089504.
20. Chien M.-C., Huang C.-Y., Wang J.-H., Shih C.-L., Wu P. Effects of vitamin D in pregnancy on maternal and offspring health-related outcomes: An umbrella review of systematic review and meta-analyses. *Nutrition & Diabetes*. 2024;14:35. doi:10.1038/s41387-024-00296-0.
21. Tamblyn, J. A., et al. Vitamin D and miscarriage: A systematic review and meta-analysis. *Fertility and Sterility*, 2022, 118(1), 111–122.

22. Varthaliti, A., et al. Neurodevelopmental outcomes in the offspring of women with vitamin D deficiency and women who received vitamin D supplementation during pregnancy. *Nutrients*, 2025, 17(6), 978.
23. Vestergaard, A. L., et al. Vitamin D in pregnancy (GRAVITD) – study protocol. *BMC Pregnancy and Childbirth*, 2023, 23(1), 177.
24. Wu, M., et al. Vitamin D-related risk factors for preterm and full-term infants at birth: A retrospective study. *BMC Pediatrics*, 2025, 25(1), 417.
25. Yangin Ergon, A., et al. A prospective cross-sectional study on the vitamin D status of neonates and the impact of neonates' standard vitamin D supplementation. *Children*, 2024, 11(5), 543.
26. Page, M. J., McKenzie, J. E., Bossuyt, P. M., et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 2021, 372, n71.
27. Gualdi-Russo E., Zaccagni L. *The Newcastle–Ottawa Scale for Assessing the Quality of Studies in Systematic Reviews. Publications.* 2026;14(1):4.
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