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Review Article

Impact of Vitamin D deficiency on pregnancy outcomes: can we manage it effectively?

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Summary

Background: Vitamin D is essential for maternal health, fetal development, and pregnancy outcomes. Despite its importance, vitamin D deficiency is highly prevalent among pregnant women, increasing the risk of gestational diabetes mellitus (GDM), preeclampsia, preterm birth, and fetal growth restriction.

Objective: This article explores the impact of maternal vitamin D deficiency on pregnancy outcomes and evaluates current strategies for its management and prevention, and supplementation.

Methods: We onducted a comprehensive literature review of clinical trials, meta-analyses, and systematic reviews, focusing on the association between vitamin D levels and pregnancy complications and the effectiveness of supplementation and public health interventions.

Results: Studies suggest that vitamin D deficiency is linked to poor pregnancy outcomes, including hypertension, GDM, low birth weight, and neonatal health complications. Vitamin D supplementation (600–4,000 IU/day) has shown potential benefits in reducing these risks, but the optimal dosage and screening strategies remain debated. Food fortification and sunlight exposure may be complementary approaches to improve maternal vitamin D status.

Conclusion: Managing vitamin D deficiency during pregnancy requires a multifaceted approach, including early screening, appropriate supplementation, dietary interventions, and public health policies. However, further large-scale clinical trials are needed to establish standardised guidelines for universal supplementation. Addressing vitamin D deficiency can significantly enhance maternal and neonatal health outcomes, making it a crucial public health priority.

Key words: Gestational diabetes, fetal development, maternal health, preeclampsia, pregnancy outcomes, prenatal care, supplementation, vitamin D deficiency

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Introduction

Vitamin D is a fat-soluble vitamin that plays a crucial role in bone health, immune function, and cellular processes. It is primarily obtained through skin exposure to sunlight, with limited dietary sources such as fatty fish, fortified dairy products, and supplements. Vitamin D is essential for maternal and fetal health during pregnancy, particularly in calcium metabolism, fetal skeletal development, and immune system regulation. Despite its importance, vitamin D deficiency remains a global public health issue, affecting many pregnant women, especially in regions with limited sun exposure, darker skin pigmentation, and cultural practices that limit outdoor activities or skin exposure (Palacios and Gonzalez 2014). Maternal vitamin D deficiency has been increasingly linked to a range of adverse pregnancy outcomes, including preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and low birth weight (Aghajafari et al. 2013). Furthermore, inadequate vitamin D levels during pregnancy may have long-term health consequences for offspring, increasing the risk of childhood infections, asthma, and impaired bone development (Christesen et al. 2012). Despite growing evidence supporting the importance of maintaining adequate vitamin D levels during pregnancy, there is still ongoing debate regarding the optimal vitamin D level required for maternal and fetal health and the appropriate dosage for supplementation.

Given the significant implications of vitamin D deficiency in pregnancy, it is essential to understand its prevalence, risk factors, and potential effects on maternal and fetal outcomes. This article aims to explore the impact of vitamin D deficiency on pregnancy outcomes and discuss evidence-based strategies for its prevention and management, including supplementation, dietary modifications, and lifestyle changes. By addressing this critical issue, we can work towards improving maternal and neonatal health and reducing the burden of pregnancy-related complications.

Literature review

Role of Vitamin D in pregnancy

Vitamin D is a crucial nutrient during pregnancy, influencing maternal health, fetal development, and pregnancy outcomes. Its primary function is to regulate calcium and phosphate metabolism, which is essential for fetal skeletal development. However, vitamin D also plays a role in immune modulation, insulin regulation, and placental function, all contributing to a healthy pregnancy (Holick 2017).

Calcium homeostasis and fetal skeletal development

Vitamin D's primary role during pregnancy is maintaining calcium and phosphate balance, which is essential for fetal bone mineralisation. The active form of vitamin D, calcitriol (1,25-dihydroxy vitamin D), increases calcium absorption in the intestines, ensuring an adequate supply for the mother and the developing fetus (Munns et al. 2016). Insufficient vitamin D levels may lead to neonatal rickets, impaired skeletal development, and reduced bone mineral density in infants (Christesen et al. 2012).

Immune system regulation and pregnancy complications

Vitamin D modulates immune function, reduces inflammation, and promotes immune tolerance. Maternal immune adaptation is crucial during pregnancy to prevent fetal rejection and ensure a successful pregnancy. Vitamin D has been shown to regulate the expression of immune-related genes and modulate T-cell responses, reducing the risk of autoimmune conditions and infections that could negatively impact pregnancy (Hosseini et al. 2019). Studies suggest that vitamin D deficiency may contribute to an increased risk of preeclampsia, an inflammatory-mediated condition characterised by hypertension and organ dysfunction (Aghajafari et al. 2013).

Insulin sensitivity and gestational diabetes

Emerging evidence suggests that vitamin D plays a role in glucose metabolism and insulin sensitivity. The vitamin D receptor (VDR) is present in pancreatic P-cells responsible for insulin production. Vitamin D enhances insulin secretion and improves β-cell function, potentially reducing the risk of gestational diabetes mellitus (GDM) (Soheilykhah et al. 2013). Several studies have reported an association between maternal vitamin D deficiency and increased insulin resistance, which may contribute to the development of GDM and metabolic complications for both the mother and the fetus (Bi et al. 2018).

Placental function and pregnancy maintenance

The placenta expresses vitamin D receptors and enzymes that convert vitamin D into active form, suggesting that vitamin D plays a direct role in placental health (AlSubai et al. 2023). Adequate vitamin D levels have been associated with improved placental function, including enhanced vascularisation and reduced inflammation. Conversely, vitamin D deficiency may contribute to placental dysfunction, increasing the risk of complications such as fetal growth restriction and preterm birth (Schneuer et al. 2014).

Vitamin D is essential for maintaining maternal and fetal health during pregnancy. It regulates calcium homeostasis, supports fetal bone development, modulates immune responses, improves insulin sensitivity, and contributes to placental function. Given its critical role, ensuring adequate vitamin D levels in pregnant women is necessary to reduce the risk of adverse pregnancy outcomes. The next section explores how vitamin D deficiency contributes to specific pregnancy complications.

Adverse outcomes associated with deficiency

Vitamin D deficiency during pregnancy has been increasingly linked to multiple maternal and fetal complications. Pregnant women with insufficient vitamin D levels are at higher risk for conditions such as preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and fetal growth restriction. This section explores the evidence-based associations between vitamin D deficiency and adverse pregnancy outcomes.

Preeclampsia

Preeclampsia is a hypertensive disorder of pregnancy characterised by high blood pressure and signs of organ dysfunction, often leading to severe maternal and fetal complications. Research suggests that vitamin D plays a role in regulating vascular function and the immune system, which may influence the development of preeclampsia. Low maternal vitamin D levels have been associated with an increased risk of preeclampsia, possibly due to its role in placental function and inflammation control (Aghajafari et al. 2013). A meta-analysis found that pregnant women with vitamin D deficiency were at a significantly higher risk for developing preeclampsia compared to those with adequate levels (AlSubai et al. 2023).

Gestational Diabetes Mellitus (GDM)

Gestational diabetes is a condition characterised by glucose intolerance during pregnancy, increasing the risk of complications such as macrosomia, birth trauma, and neonatal hypoglycemia. Vitamin D has been shown to influence glucose metabolism by enhancing insulin secretion and sensitivity. Studies have indicated that vitamin D deficiency is associated with an increased risk of GDM (Soheilykhah et al. 2013). A systematic review found that vitamin D supplementation during pregnancy may improve glucose metabolism and reduce insulin resistance, suggesting a potential role in GDM prevention (Soheilykhah et al. 2013).

Preterm birth

Preterm birth, defined as birth before 37 weeks of gestation, is a leading cause of neonatal morbidity and mortality. Research has suggested that vitamin D plays a role in maintaining pregnancy through its effects on immune function and placental health. A prospective cohort study found that women with low serum 25-hydroxyvitamin D levels had a significantly increased risk of spontaneous preterm birth (Schneuer et al. 2014). Vitamin D deficiency may contribute to preterm birth by increasing the risk of infections, inflammation, and impaired placental function (Bi et al. 2018).

Small for Gestational Age (SGA) and low birth weight

Infants born small for gestational age (SGA) or with low birth weight (<2500 g) have a higher risk of neonatal complications and long-term health issues, including metabolic disorders and developmental delays. Maternal vitamin D deficiency has been linked to fetal growth restriction, likely due to its role in placental function and nutrient transport (Christesen et al. 2012). A meta-analysis found that vitamin D supplementation during pregnancy was associated with a reduced risk of SGA and low birth weight (Aghajafari et al. 2013).

Long-term health implications for offspring

Beyond immediate pregnancy complications, maternal vitamin D deficiency may have long-term consequences for offspring health. Studies suggest inadequate vitamin D levels during pregnancy can affect fetal immune system development,

increasing the risk of childhood infections, asthma, and allergic diseases (Hosseini et al. 2019). Additionally, low maternal vitamin D status has been linked to impaired bone development and a higher risk of osteoporosis later in life (Munns et al. 2016).

Vitamin D deficiency during pregnancy is associated with multiple adverse outcomes, including preeclampsia, GDM, preterm birth, and fetal growth restriction. Ensuring adequate maternal vitamin D levels may help reduce these risks and improve pregnancy and neonatal health outcomes. The next section focuses on strategies for managing and preventing prenatal vitamin D deficiency.

Strategies for managing and preventing Vitamin D deficiency during pregnancy

Given the strong association between maternal vitamin D deficiency and adverse pregnancy outcomes, it is essential to implement effective strategies for prevention and management. The main approaches include screening and monitoring, and vitamin D supplementation, dietary modifications, and safe sun exposure. Additionally, public health policies play a role in ensuring adequate vitamin D levels in pregnant women.

Screening and monitoring

Routine screening for vitamin D deficiency during pregnancy remains a debated topic. While some health organisations, such as the Endocrine Society, recommend screening high-risk pregnant women. Others, including the World Health Organisation (WHO), do not endorse universal screening due to limited evidence on its cost-effectiveness (Holick et al. 2011; WHO).

Risk factors that may warrant screening include:

- limited sun exposure (e.g., wearing full-body coverings, living in high-latitude regions);
- darker skin pigmentation (which reduces vitamin D synthesis);
- obesity (vitamin D is stored in fat, making it less bioavailable);
- vegetarian or vegan diets (low intake of vitamin D-rich foods);
- medical conditions affecting vitamin D metabolism (e.g., chronic kidney disease, malabsorption syndromes).

Serum 25-hydroxyvitamin D [25(OH)D] levels are used to assess vitamin D status, with deficiency commonly defined as <20 ng/mL (50 nmol/L) (Holick et al. 2011).

Vitamin D supplementation

Supplementation is a widely recommended strategy to prevent and treat prenatal vitamin D deficiency. However, the optimal dosage remains under investigation.

- The Institute of Medicine (IOM) recommends 600 IU/day of vitamin D for pregnant women (Ross et al. 2011).
- The Endocrine Society suggests that women at risk of deficiency may need 1,500–2,000 IU/day (Holick et al. 2011).

- Some studies indicate that higher doses (up to 4,000 IU/day) may be more effective in maintaining optimal maternal and fetal vitamin D levels without adverse effects (Hollis et al. 2011).

A Cochrane review found that vitamin D supplementation during pregnancy reduced the risk of preeclampsia, low birth weight, and preterm birth (Palacios et al. 2016). However, further research is needed to establish standardised guidelines.

Dietary modifications

Although diet alone is unlikely to provide sufficient vitamin D, incorporating vitamin D-rich foods can support supplementation efforts. Key dietary sources include:

- fatty fish (e.g., salmon, mackerel, tuna),
- fortified dairy products (e.g., milk, yogurt, cheese),
- egg yolk,
- mushrooms exposed to sunlight,
- fortified cereals and plant-based milk alternatives.

Pregnant women should be encouraged to consume a balanced diet that includes these sources of vitamin D.

Safe sun exposure

Sunlight exposure is the primary natural source of vitamin D. Ultraviolet B (UVB) rays trigger vitamin D synthesis in the skin. However, seasons, latitude, skin pigmentation, clothing, and sunscreen influence vitamin D production.

Recommendations for sun exposure vary, but in general:

- 10–30 minutes of midday sun exposure on the face, arms, and legs several times per week is often sufficient (Holick 2017).
- Darker-skinned individuals may require more prolonged exposure due to higher melanin levels.
- Public health messages should balance vitamin D synthesis with the risks of skin cancer from excessive UV exposure.

Public health policies and fortification

Food fortification has been implemented in many countries to combat widespread vitamin D deficiency. Fortified milk, cereals, and other staple foods have helped improve vitamin D intake, particularly in regions with limited sunlight (Pilz et al. 2018). Some countries, such as Canada and Finland, have mandatory fortification policies, while others rely on voluntary measures. Expanding fortification programs could be a cost-effective strategy to improve vitamin D status in pregnant women globally.

Managing vitamin D deficiency during pregnancy requires a multifaceted approach, including targeted screening, appropriate supplementation, dietary modifications, and safe sun exposure. While universal screening is not recommended, at-risk populations should be identified and treated. Vitamin D

supplementation has shown promising benefits in reducing pregnancy complications, but further research is needed to determine the optimal dosage. Public health initiatives, such as food fortification, can also play a crucial role in preventing deficiency on a larger scale.

Methodology

The research approach follows narrative literature review methodologies. The research used peer-reviewed clinical trials, meta-analyses, and systematic reviews from 2010 to 2024 sourced through PubMed, Scopus, and Google Scholar. The study incorporated the keywords "vitamin D deficiency" together with "pregnancy outcomes," "preeclampsia," "gestational diabetes," and "maternal supplementation." The selection of studies focused on their relevance, the strength of their evidence, and temporal relevance.

Analysis

The research analysis employed thematic evaluation to identify consistent connections between vitamin D deficiency in pregnant women and pregnancy complications. Researchers assessed each study for its ability to determine the connection between vitamin D deficiency and pregnancy complications, including preeclampsia and gestational diabetes mellitus (GDM), preterm birth and fetal growth restriction. A comprehensive review of maternal vitamin D improvement strategies involved supplementing diet, sunlight exposure, and nutritional fortification of food sources to analyse their impact on reducing health risks. Research results demonstrate that protective effects for pregnant women occur with vitamin D supplementation dosages ranging from 600 to 4,000 IU daily, although scientists remain uncertain about the best dosage. The evaluation method accounted for study design inconsistencies, population demographic disparities, and measurement technique discrepancies that led to diverging results. Research findings demonstrate clear backing for adequate vitamin D amounts to enhance various benefits for pregnant women.

Findings

Research findings demonstrated how insufficient vitamin D levels in pregnant women increase their chances of developing complications that include preeclampsia along with gestational diabetes mellitus (GDM), preterm birth, and reduced birth weight. Research indicates that vitamin D supplementation supports mother and newborn health by creating positive clinical results. During pregnancy, supplementation trials have assessed doses between 600 IU daily and 4,000 IU daily, and research indicates that higher doses tend to produce more excellent protection against adverse healthcare events. The study has not yet established the correct dosage because different people need different doses, and the standards set by medical organisations vary. Some pregnant women take insufficient vitamin D through diet and sun exposure since several populations cannot depend on these methods. The benefits of targeted supplementation warrant additional research on pregnancy screening and supplementation practices that lack worldwide consensus.

Discussion

Vitamin D plays a crucial role in pregnancy by supporting maternal health, fetal development, and overall pregnancy outcomes. Its involvement in calcium homeostasis, immune modulation, insulin sensitivity, and placental function highlights its importance in preventing complications such as preeclampsia, gestational diabetes mellitus (GDM), preterm birth, and fetal growth restriction.

Despite the well-documented benefits of adequate vitamin D levels, maternal deficiency remains prevalent worldwide, particularly in populations with limited sun exposure, darker skin pigmentation, or dietary insufficiencies. Managing vitamin D deficiency through screening, supplementation, nutritional modifications, and sun exposure is essential for optimising maternal and neonatal health. While current supplementation guidelines vary, emerging evidence suggests that higher doses (up to 4,000 IU/day) may be more effective in maintaining optimal vitamin D levels without adverse effects.

Public health strategies, including mandatory food fortification and targeted supplementation programs, may help address widespread vitamin D deficiency. However, standardised recommendations for vitamin D intake during pregnancy remain an active research area, requiring further large-scale trials.

Future research directions

Several knowledge gaps remain regarding vitamin D and pregnancy outcomes, necessitating further research in the following areas:

1. Optimal Vitamin D supplementation dosage

While current recommendations range from 600 IU/day (IOM) to 4,000 IU/day (Endocrine Society studies), the most effective and safe dosage for preventing pregnancy complications remains unclear. Future randomised controlled trials (RCTs) should establish precise dosing guidelines for different populations.

2. Universal vs. targeted screening

The cost-effectiveness of routine vitamin D screening for all pregnant women versus only high-risk groups needs further investigation. Longitudinal studies to assess the benefits of early vitamin D screening and intervention could help with future clinical guidelines.

3. Long-term effects on offspring

Studies suggest that maternal vitamin D levels influence fetal immune function, bone health, and metabolic outcomes. More research is needed to understand how prenatal vitamin D exposure affects childhood development, asthma risk, and long-term chronic disease susceptibility.

4. Role of genetic and environmental factors

Genetic polymorphisms affecting vitamin D metabolism, receptor function (VDR), and placental transport may influence individual responses to vitamin D supplementation. Investigating these gene-nutrient interactions could help develop personalised supplementation strategies.

5. Effects of Vitamin D on the placenta

Since the placenta expresses vitamin D receptors (VDRs) and metabolic enzymes, further research is needed to understand how vitamin D modulates placental health, vascularisation, and inflammation in pregnancy.

6. Public health policies and fortification

Food fortification programs have successfully improved vitamin D levels in some countries, but their impact on pregnancy outcomes requires further evaluation. More studies should assess whether fortification alone is sufficient or if supplementation remains necessary in high-risk populations.

Conclusion

Vitamin D is an essential nutrient that promotes health in pregnant women. Improving maternal and neonatal health depends on properly administering deficiency management through screening programs, supplementation, and public health strategies. Additional clinical studies should be conducted to develop general health guidance and individualised care methods.

Ensuring adequate vitamin D levels during pregnancy is an essential public health priority. While evidence supports the role of vitamin D in reducing pregnancy complications, future research is needed to refine screening, supplementation, and policy guidelines. A combination of clinical trials, epidemiological studies, and public health initiatives will help optimise vitamin D management and improve maternal and neonatal health outcomes worldwide.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statements

The authors declared that no clinical trials were used in the present study.

The authors declared that no experiments on humans or human tissues were performed for the present study.

The authors declared that no informed consent was obtained from the humans, donors or donors' representatives participating in the study.

The authors declared that no experiments on animals were performed for the present study.

The authors declared that no commercially available immortalised human and animal cell lines were used in the present study.

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Data availability

All of the data that support the findings of this study are available in the main text.

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