# Bioscene

**Bioscene**
**Volume- 22 Number- 03**
**ISSN: 1539-2422 (P) 2055-1583 (O)**
**www.explorebioscene.com**

# The Multifaceted Role of Vitamin D in Pregnancy, Lactation, and Neonatal Health

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**Abstract:** Vitamin D, a fat-soluble vitamin, plays a crucial role in maternal health, foetal development, and lactation. Deficiency in vitamin D is a global health concern, affecting pregnant women and neonates, with implications for bone health, immune regulation, and metabolic function. Emerging research links insufficient vitamin D levels to adverse pregnancy outcomes, including preeclampsia, gestational diabetes, and preterm birth, as well as neonatal complications such as low birth weight, impaired skeletal development, and increased risk of chronic diseases. Supplementation has shown promise in reducing these risks. Additionally, vitamin D is essential during lactation, supporting maternal recovery and infant growth. This review synthesizes current knowledge on vitamin D's biological roles, risks of deficiency, and clinical relevance in pregnancy, neonatal development, and lactation.

**Keywords**: Vitamin D, pregnancy, neonates, lactation, deficiency, supplementation

## 1. Introduction

Vitamin D a fat-soluble secosteroid plays a crucial role in human health through both endocrine and autocrine/paracrine pathways. It predominantly exists in two forms: ergocalciferol (D2) sourced from plants and cholecalciferol (D3) synthesized in the skin via the photochemical conversion of 7-dehydrocholesterol upon exposure to ultraviolet B radiation (290-315 nm). This photosynthesized D3, along with dietary vitamin D, undergoes hepatic 25-hydroxylation to form 25-hydroxyvitamin D [25(OH) D], the primary circulating metabolite used to assess vitamin D status. Subsequent renal 1α-hydroxylation produces the biologically active hormone 1,25-dihydroxyvitamin D [1,25(OH)2D], which exerts genomic effects through nuclear vitamin D receptors (VDRs) present in nearly all human tissues.[1]The dietary sources include fish oil, fish flesh, dietary supplements, eggs, butter, fortified foods, liver, and mushrooms.[13]

The widespread distribution of VDRs underscores vitamin D's pleiotropic effects beyond its traditional role in calcium homeostasis and bone metabolism. Recent research has highlighted its importance in immune modulation, cardiovascular function, neuroprotection, and cellular differentiation.[2] Vitamin D insufficiency has been linked to various pathological conditions including autoimmune diseases, metabolic disorders, malignancies, and increased susceptibility to infections. Current guidelines define deficiency as serum 25hydroxy D levels below 20 ng/mL (50 nmol/L), while levels between 20-30 ng/mL (50-75 nmol/L) are considered insufficient.[3]

The high global prevalence of vitamin D deficiency, affecting approximately 1 billion individuals worldwide, represents a significant public health concern. Risk factors include limited sun exposure, skin pigmentation, aging, obesity, and certain medical conditions affecting absorption.[4] Achieving optimal vitamin D status requires balanced sun exposure, dietary intake, and supplementation when necessary, with ongoing research continuing to refine our understanding of its diverse physiological roles and therapeutic potential.[5]Evidence indicates that mental health disorders may have their origins in foetal development and are linked to deficiencies in various micronutrients, including vitamin D. During pregnancy, the balance of vitamin D is influenced by an increase in maternal calcitriol and a notable rise in maternal Vitamin D Binding Protein levels. In the early stages of life, vitamin D is essential for regulating numerous brain functions, such as cell proliferation, apoptosis, and neurotransmission. Moreover, vitamin D is recognized for its anti-inflammatory properties, which typically help to suppress inflammation. Increased activity of the hypothalamo-pituitary-adrenal axis (HPA) and inflammation during pregnancy can affect both maternal health and foetal brain development during and after pregnancy. A deficiency in vitamin D and maternal stressors during pregnancy, such as perinatal depression, may impact the immune system's effectiveness by altering its function. Vitamin D deficiency during pregnancy has been extensively documented and linked to reduced foetal brain development, which is associated with changes in the production of brain-derived neurotrophic factor.[6]

## 2. Role of Vitamin D in Pregnancy

Vitamin D plays a many-sided role during pregnancy, impacting both maternal and foetal health. Its functions extend beyond its classical role in calcium and phosphorus homeostasis, impacting a variety of physiological systems crucial during pregnancy. Vitamin D is critical for maintaining calcium levels, which in turn supports foetal skeletal development. Maternal vitamin D deficiency has been associated with inadequate calcium transfer to the foetus, potentially affecting bone health and growth[7]

Vitamin D metabolism undergoes significant changes during pregnancy compared to when a woman is not pregnant. In the initial weeks of pregnancy,

there is a more than two- to threefold increase in calcitriol levels. Meanwhile, maternal 25-hydroxyvitamin D traverses the placental barrier, acting as the primary vitamin D reservoir for the developing foetus. Furthermore, the expression of vitamin D receptors and regulatory metabolic enzymes in the placenta and decidua during pregnancy points to a potentially vital role in immune system modulation at the maternal-foetal interface.[5]

There is evidence linking low maternal vitamin D status to adverse pregnancy outcomes, such as preeclampsia, gestational diabetes, and bacterial vaginosis. These conditions not only affect maternal health but can also result in complications such as preterm birth and low birth weight[8] .Furthermore, vitamin D's role in maternal immune function and its potential to modulate inflammation at the maternal-foetal interface is significant. It helps balance immune protection and tolerance, preventing foetal rejection while safeguarding against infections.[9]While some studies have shown improvements in pregnancy outcomes with vitamin D supplementation, results are mixed, and the optimal intake levels during pregnancy remain under investigation. The American College of Obstetrics and Gynaecology (ACOG) recommends 600 IU of vitamin D daily during pregnancy to support bone metabolism.[10]

**Table 1-Recommended daily Intake During Pregnancy**

| Organization | Recommended Daily Intake | Target Blood Level |
|---|---|---|
| WHO (2020) | 200–400 IU/day | ≥20 ng/mL (50 nmol/L) |
| Endocrine Society (2011) | 1500–2000 IU/day | ≥30 ng/mL (75 nmol/L) |
| ACOG (2020) | 600 IU/day (but higher doses often needed) | |
| European Food Safety Authority | 600IU/day(15μg/day) | |

Research has expanded to explore vitamin D's non-classical roles, such as its immunomodulatory effects and potential involvement in reducing the risk of conditions like type 1 diabetes and schizophrenia in offspring. However, there remains a need for well-designed clinical trials to clarify these associations and establish definitive causal relationships.[11] Overall, maintaining adequate vitamin D levels during pregnancy is crucial for optimizing health outcomes for both the mother and the foetus. Although more research is needed to fully understand its diverse roles, ensuring sufficient vitamin D intake appears to be a beneficial strategy in pregnancy management .[12]

The immunomodulatory properties of vitamin D are particularly relevant during pregnancy, where it helps maintain the delicate balance between maternal immune tolerance and protection against infections[13].Epidemiological studies have consistently associated vitamin D deficiency (<20 ng/mL) with adverse

pregnancy outcomes including preeclampsia, gestational diabetes, and preterm birth.[14]Moreover, experimental studies demonstrate that vitamin D is critical for placental development, influencing trophoblast invasion and angiogenesis . In one data indicates that changes in maternal gene expression during pregnancy are related to Vitamin D levels. It remains uncertain whether these Vitamin D changes directly influence foetal development through the placental interface or if maternal gene expression independently affects the foetus. Due to ethical constraints in human studies, animal models will be necessary to evaluate maternal gene expression and foetal development simultaneously.[15]

**3. Role of Vitamin D in Neonates**

For the developing foetus, vitamin D is essential for skeletal mineralization, with severe deficiency leading to congenital rickets[16]. Emerging evidence suggests it also programs foetal immune function and neurodevelopment, potentially influencing long-term health outcomes Recent trends show a concurrent increase in both vitamin D deficiency and autism spectrum disorders (ASD), with new findings suggesting that vitamin D is crucial for brain development.[17]Vitamin D deficiency during pregnancy might lead to lower birthweight and elevate the chances of HIV transmission from mother to child, as well as increase the likelihood of respiratory infections, wheezing, rhinitis, eczema, type 1 diabetes, and schizophrenia in children. However, the evidence supporting these associations is either inconsistent or limited. The vitamin D receptor is expressed in foetal brain tissue as early as the first trimester, supporting its role in neurogenesis[18].

Despite these critical functions, significant gaps remain in our understanding of optimal vitamin D status during pregnancy. Current guidelines vary widely, with recommended supplementation doses ranging from 400 to 4000 IU/day.[19] Furthermore, most evidence comes from observational studies, with randomized controlled trials showing inconsistent result[20]. This highlights the need for further research to establish causal relationships and develop evidence-based recommendations tailored to different populations and pregnancy stages.

Maternal vitamin D levels play a crucial role in foetal development. Insufficient vitamin D can negatively impact the development of the foetal brain and neurodevelopmental functions, resulting in delays in infant's motor abilities and problem-solving skills [21]. Additionally, vitamin D is vital for immune regulation, and a deficiency might increase foetal exposure to glucocorticoids, which can influence foetal development and potentially lead to negative health effects later in life [22]. Vitamin D is also important for placental function, with research indicating reduced expression of vitamin D receptors in instances of foetal growth restriction[23]

**Table3-Impact of Vitamin D Deficiency on Perinatal Health in Developed and Developing Countries**

| Outcome | Developed Countries | Developing Countries |
|---|---|---|
| Preeclampsia | Moderate increase | Severe increase |
| Gestational Diabetes | Mild-moderate link | Less studied but likely significant |
| Preterm Birth | 30–50% higher risk | Up to 2times higher risk |
| Low Birth Weight | Moderate risk | Severe risk (malnutrition + VDD) |
| Neonatal Rickets | Rare (due to supplements) | More common (severe deficiency) |
| Note: Developing countries face compounding factors (malnutrition, infections) that worsen VDD(Vitamin D Deficiency) effects. | | |

**4. Lactation and Vitamin D: Implications for Maternal and Infant Health**

During lactation, vitamin D assumes vital importance for both the mother's health and the infant's development. The physiological demands of breastfeeding increase maternal calcium requirements, with vitamin D playing a key role in maintaining calcium homeostasis through enhanced intestinal absorption and bone mineral metabolism[24] . Recent studies indicate that insufficient vitamin D levels in lactating women may be associated with adverse outcomes including compromised bone health, mood disorders, and immune dysfunction[25].For neonates; adequate vitamin D status is crucial for proper skeletal formation, immune competence, and neurological development, with deficiency states predisposing to rickets and increased susceptibility to infections[26]. Current clinical recommendations advocate for daily supplementation with 400 IU in breastfed infants and 600-2000 IU for nursing mothers, with dosage adjustments based on individual risk factors and baseline vitamin [19]. These findings highlight the importance of maintaining optimal vitamin D nutrition during the lactation period to support both maternal recovery and infant development.

**Table 3-Vitamin D Concentration During Lactation**

| Category | Recommendation | Details | References |
|---|---|---|---|
| **Maternal Intake** | 600–800 IU/day (15–20 µg/day) | Adequate for maternal health but insufficient to enrich breast milk. | Institute of Medicine (IOM). *Dietary Reference Intakes for Calcium and Vitamin D*. 2011. |

| | | | |
|---|---|---|---|
| **High-Dose Maternal Intake** | 4000–6400 IU/day (100–160 µg/day) | Can elevate breast milk Vitamin D to ~400 IU/day (infant requirement). | Hollis BW, et al. *Pediatrics*. 2015. |
| **Infant Supplementation** | 400 IU/day (10 µg/day) | AAP recommendation for exclusively breastfed infants (from birth). | AAP Section on Breastfeeding. *Pediatrics*. 2008. |
| **Breast Milk (Standard)** | 5–80 IU/L (0.125–2 µg/L) | Low unless mother supplements or gets sun exposure. | Dawodu A & Tsang RC. *SeminPerinatol*. 2012. |
| **Breast Milk (High-Dose)** | 300–500 IU/L (7.5–12.5 µg/L) | Achieved with maternal intake ≥4000 IU/day. | Hollis BW & Wagner CL. *J ClinEndocrinolMetab*. 2013. |
| **Sun Exposure** | 10–30 mins sunlight (skin exposure) | Variable impact based on skin tone, latitude, and season. | Holick MF. *N Engl J Med*. 2007. WHO .UVRadiation guidelines2023 dccccrrrrrrhhggrafhgvhc jkjhkh2023HO. *UV Radi Guidelines*. 2023 |

**5. Various Sources of Vitamin D During Pregnancy, Lactation, and for New Borns**

Vitamin D is crucial for maintaining optimal health during pregnancy, lactation, and for new-borns. The primary sources of vitamin D during these stages include sunlight exposure, dietary intake, and supplements.Fortified foods may contain either D3, D2, or the vitamin D metabolite 25-hydroxy vitamin D. Few foods are rich in vitamin D (more than 4 µg/100 g), such as certain fish (5–25 µg/100 g), mushrooms (21.1–58.7 µg/100 g), Reindeer lichen (87 µg/100 g), and fish liver oils (250 µg/100 g). Other sources include cheese, beef liver, and eggs (1.3–2.9 µg/100 g), dark chocolate (4 µg/100 g), and fortified foods like milk, yogurt, fat spreads, orange juice, breakfast cereals, and plant-based drinks.[32]

Pregnant women obtain vitamin D from sunlight, fortified foods, oily fish, and supplements. Adequate vitamin D levels during pregnancy are essential for foetal bone mineralization and maternal health. However, many pregnant women, especially in regions with limited sunlight, exhibit vitamin D deficiency,

necessitating supplementation[27]. Vitamin D deficiency is linked to several adverse health outcomes such as preeclampsia, gestational diabetes, and low birth weight.[28]

Newborns primarily depend on maternal vitamin D stores during gestation and, after birth, on breast milk or formula. Breastfed infants often require additional vitamin D supplementation, as breast milk may not provide adequate levels. It is generally recommended that all infants receive a minimum daily intake of 400 IU of vitamin D to prevent deficiencies and conditions such as rickets.[29]

Lactating mothers need to maintain sufficient vitamin D levels to ensure adequate transfer to their infants through breast milk. Similar to pregnancy, sunlight, diet, and supplements are vital sources of vitamin D during lactation. Lactating women may require higher vitamin D intakes to meet both their own needs and those of their nursing infants. Studies suggest that maternal vitamin D supplementation is effective in improving the vitamin D status of breastfed infants[30].Overall, understanding and addressing vitamin D needs during these critical life stages can support maternal and infant health, reduce the risk of complications, and foster healthy development in newborns.

## 6. Enhancing Prenatal Care: The Role of Vitamin D Screening

Vitamin D deficiency is highly prevalent in pregnant women and neonates, making screening and prevention crucial due to its potential impact on maternal and neonatal health. A study in Iran showed vitamin D deficiency in 66.8% of pregnant women and an even higher rate of 93.3% in neonates (cord blood samples), indicating widespread deficiency in newborns.[31] Effective screening should focus on early detection and monitoring of vitamin D levels throughout pregnancy. Screening typically involves measuring serum 25-hydroxyvitamin D concentrations. Maternal vitamin D status is directly correlated with neonatal vitamin D levels. Factors influencing vitamin D levels that should be considered in screening protocols include: Seasons, Education level, Body mass index (BMI ),physical activity .Living in regions with limited sunlight exposure (especially during winter) .Lack of dietary intake of vitamin D-rich foods.[33]Overall, implementing effective screening and preventive strategies can help mitigate the high rates of vitamin D deficiency observed in pregnant women and neonates, thereby improving both maternal and neonatal health outcomes.

## 7. Conclusion

Vitamin D is crucial for maternal health, foetal development, and neonatal outcomes. A deficiency in vitamin D is associated with adverse pregnancy complications such as preeclampsia, gestational diabetes, and preterm birth, and it also impacts foetal skeletal formation, immune function, and neurodevelopment. Postpartum, maintaining adequate vitamin D levels is essential for lactation, ensuring optimal bone health and immune protection for both mother and infant. Despite varying supplementation guidelines, it is vital to

maintain sufficient vitamin D through sunlight exposure, diet, and supplementation. Further research is needed to establish standardized recommendations, but current evidence highlights the importance of routine screening and supplementation to mitigate risks associated with deficiency. Addressing vitamin D insufficiency during pregnancy and lactation can significantly enhance maternal and neonatal health outcomes worldwide.

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