



Association Between Prenatal Nutritional Intake and Vitamin D Status in Newborns

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ABSTRACT:

Introduction: The vitamin D status of newborns is entirely dependent on placental transfer from the mother during pregnancy. Neonatal vitamin D deficiency is prevalent in various regions, including Southeast Asia, but evidence regarding the specific contribution of prenatal nutritional intake to neonatal vitamin D status is limited.

Objectives: This study aimed to analyze the relationship between prenatal nutritional intake (milk consumption, multivitamin supplementation, and vitamin D supplementation) and newborn vitamin D status..

Methods: A cross-sectional study was conducted at two hospitals in Makassar (August 2022-January 2023). A total of 87 full-term infants with normal birth weight were recruited by consecutive sampling. Cord blood 25-hydroxyvitamin D [25(OH)D] levels were analyzed using the ELISA method, while prenatal nutritional intake data were collected through a structured questionnaire. Association analysis was performed using the Fisher's Exact test with a significance level of $p < 0.05$.

Results: The median vitamin D level of newborns was 13.99 ng/mL (8.85-61.43 ng/mL). 81.6% of subjects had suboptimal vitamin D status (55.2% insufficiency and 26.4% deficiency). Vitamin D supplementation during pregnancy showed a significant association with newborn vitamin D status ($p = 0.004$), with a higher proportion of infants with sufficient status in the group taking Vitamin D supplements. In contrast, multivitamin consumption ($p = 0.565$) and regular milk consumption during pregnancy ($p = 0.420$) did not show a statistically significant association with newborn vitamin D levels.

Conclusions: Vitamin D supplementation during pregnancy is significantly associated with adequate newborn vitamin D status. These findings recommend integrating vitamin D supplementation as an essential component of antenatal care to prevent vitamin D deficiency and support long-term health.

1. Introduction

Prenatal nutritional intake plays a crucial role in determining fetal health status, particularly in the formation of vitamin D reserves that are transferred transplacentally to the umbilical cord blood circulation (1). The fetus is completely dependent on maternal nutrient supply, so the level of 25-hydroxyvitamin D [25(OH)D] in the umbilical cord blood of newborns directly reflects the accumulation and metabolism of maternal vitamin D during the last trimester of pregnancy (2). Recent epidemiological data indicate that the prevalence of vitamin D insufficiency and deficiency in neonates in various regions, including Southeast Asia, still reaches more than 80%, which is largely associated with low dietary vitamin D intake and inadequate dosage

and duration of prenatal supplementation consumed by pregnant women (3,4). Optimizing prenatal nutritional intake through a measured dietary approach and appropriate supplementation is a fundamental step to ensure adequate neonatal vitamin D status from the beginning of life.

Vitamin D acts as a steroid prohormone that is activated to 1,25-dihydroxyvitamin D [1,25(OH)2D] through sequential hydrolysis in the liver and kidneys, then binds to the vitamin D receptor (VDR) widely expressed in placental tissues, immune cells, and developing fetal organs (5,6). Transplacental transfer of 25(OH)D occurs primarily through facilitated diffusion and binding to binding proteins, ensuring a direct supply to the fetal circulation that is highly dependent on maternal status



(7). VDR activation modulates the expression of genes involved in cell proliferation, tissue differentiation, and regulation of immunometabolic signaling pathways, including inhibition of proinflammatory cytokines (IL-6, TNF- α) and induction of antimicrobial peptides such as cathelicidins and β -defensins (8,9). These mechanisms confirm that cord blood vitamin D levels are not simply a passive reflection of maternal intake, but rather a functional indicator of the epigenetic environment that shapes fetal developmental plasticity and neonatal defense readiness.

Prenatal vitamin D deficiency or insufficiency has been consistently linked to an increased risk of allergic and metabolic diseases in children through fetal programming pathways involving immune regulatory dysfunction and alterations in metabolic homeostasis (10). In the immune system, low cord 25(OH)D levels are correlated with decreased differentiation of regulatory T cells (Tregs), impaired oral tolerance, and a higher incidence of asthma, atopic dermatitis, and food allergies in childhood (11,12). From a metabolic perspective, intrauterine vitamin D status influences adipocyte differentiation, insulin sensitivity, and pancreatic β -cell function, thus prenatal deficiency increases susceptibility to pediatric obesity, insulin resistance, and dyslipidemia later in life (13). Recent evidence also expands the clinical implications of vitamin D on gut barrier maturation, modulation of neonatal microbiota composition, and support of neuromaturation and cognitive development, further strengthening the urgency of comprehensive prenatal dietary optimization (14).

2. Objectives

Given the complexity of the interactions between maternal dietary patterns, type and dose of prenatal supplements, and fetal biological outcomes, a more comprehensive understanding of how the combination of dietary intake containing vitamin D sources (milk), specific vitamin D supplementation, and general multivitamins collectively affects newborn vitamin D levels is needed. This study aimed to analyze the relationship between these defined prenatal nutrient intakes and neonatal vitamin D status, in order to provide a scientific basis for effective prenatal nutritional supplementation recommendations and policies in the

early prevention of allergic, metabolic, and other chronic conditions (15).

3. Methods

This research is part of the Vitadi Study with a descriptive design cross-sectional, implemented in Cahaya Medika Hospital and Malebu Hospital, City Makassar, South Sulawesi, from August 2022 to January 2023. The study population included all newborns in both hospitals, with samples taken using the consecutive sampling method. The sample size was calculated using the two-proportion ratio formula. With a 95% confidence level ($\alpha=0.05$), 80% power ($\beta=0.20$), and a 1:1 group ratio, a minimum of 80 subjects was required. Inclusion criteria include consent written from parents through informed consent, the baby was born healthy (APGAR score at 5 minutes > 7), and was born at full term (37-42 weeks), and normal birth weight (2500-4000 grams), while exclusion criteria include major congenital abnormalities, history of severe chronic disease in the mother during pregnancy, and incompleteness of questionnaire data and medical records.

All subjects who met the inclusion criteria were recruited into this study. Umbilical cord blood samples were collected immediately after delivery by trained nurses using aseptic techniques. A total of 2.5 mL of blood was placed into EDTA-containing vacuum tubes, then the plasma was separated by centrifugation and stored at -20°C until vitamin D levels were analyzed. Serum 25-hydroxyvitamin D [25(OH)D] levels were measured using the Human Vitamin D (VD) ELISA Kit, cat. No. Mbs267183 (MyBioSource, Inc., CA, USA), with results expressed in ng/mL. Vitamin D status was defined as the concentration of 25-hydroxyvitamin D [25(OH)D] in umbilical cord blood serum, classified into three categories: sufficiency (>20 ng/mL), insufficiency (12–20 ng/mL), and deficiency (<12 ng/mL) (16). Subsequently, data collection was conducted, including subject characteristics and maternal profiles. Prenatal nutritional intake is defined as the maternal consumption of vitamin D-containing foods (e.g., milk), vitamin D-specific supplements, and multivitamin preparations, as reported by parents via structured questionnaire.

Univariate analysis was performed to describe the distribution of the study variables. Bivariate analysis was performed to test associations between variables using



Fisher's exact test for categorical data. The statistical significance level was set at $p < 0.05$.

This study was approved by the Ethics Committee of the Faculty of Medicine, Hasanuddin University. The parents of the infant subjects provided written informed consent for their participation.

4. Results

A total of 104 subjects met the inclusion criteria. Of these, five were excluded due to a history of severe chronic illness in the mother during pregnancy, and 12 were excluded due to incomplete questionnaire and medical record data. Thus, 87 subjects were included in the final analysis.

Table 2. Basic Characteristics of Newborns

Variables	Newborn baby (n=87)
Gender	
Man	44 (50.6%)
Woman	43 (49.4%)
Birth Weight (gram), median (min-max)	
	3020 (2515–3840)
Vitamin D levels (ng/ml), median (min-max)	
	13.99 (8.85-61.43)
Sufficiency	16 (18.4%)
Insufficiency	48 (55.2%)
Deficiency	23 (26.4%)
Delivery Methods	
Caesarean	53 (60.9%)
Spontaneous	34 (39.1%)
Early Initiation of Breastfeeding	
Yes	57 (65.5%)
No	30 (34.5%)
Mother's Age (year), median (min-max)	
	28 (17–42)

Milk Consumption Routine (Hamil)

Yes	71 (81.6%)
No	16 (18.4%)

General Multivitamin Supplementation (Hamil)

Yes	76 (87.4%)
No	11 (12.6%)

Specific Supplementation Vitamin D (Hamil)

Yes	16 (18.4%)
No	71 (81.6%)

Table 2 presents the basic characteristics of the newborns who were the subjects of the study. Of the 87 newborns, the gender distribution was nearly balanced, with 44 boys (50.6%) and 43 girls (49.4%). The median birth weight was 3020 grams, with a range of 2515-3840 grams. Most babies were born via cesarean section 53 babies (60.9%), while 34 babies (39.1%) were born through spontaneous/vaginal delivery. Regarding early initiation of breastfeeding, 57 babies (65.5%) received breastfeeding within 1 hour of birth, while 30 babies (34.5%) did not. The median maternal age was 28 years, with a range of 17-42 years.

Newborn serum vitamin D levels showed a median of 13.99 ng/mL with a range of 8.85-61.43 ng/mL. Based on vitamin D status categorization, only 16 infants (18.4%) had sufficient vitamin D status. Most infants, namely 48 infants (55.2%), experienced vitamin D insufficiency, and 23 infants (26.4%) experienced vitamin D deficiency. Thus, the total number of infants with suboptimal vitamin D status (insufficiency and deficiency) reached 81.6% of the total study subjects. Regarding consumption and supplementation patterns during pregnancy, most mothers, namely 71 mothers (81.6%), reported regular milk consumption during pregnancy, while 16 mothers (18.4%) did not consume milk.

Regarding general multivitamin supplementation during pregnancy, 76 mothers (87.4%) consumed multivitamins, and 11 mothers (12.6%) did not.



However, specific vitamin D supplementation during pregnancy remained very low, with only 16 mothers (18.4%) consuming vitamin D supplements, while the majority, 71 mothers (81.6%), did not.

Table 3. Prenatal Nutrition Intake and Umbilical Cord Blood Vitamin D Status

Variables	Sufficiency n=16	Insufficiency n=48	Deficiency n=23	Total n=87	p value
Supplement Multivitamin (Hamil)					
Yes	15 (93.8%)	42 (87.5%)	19 (82.6%)	76 (87.4%)	0.565
No	1 (6.2%)	6 (12.5%)	4 (17.4%)	11 (12.6%)	
Supplement Vitamin D (Hamil)					
Yes	8 (50.0%)	6 (12.5%)	2 (8.7%)	16 (18.4%)	0.004
No	8 (50.0%)	42 (87.5%)	21 (91.3%)	71 (81.6%)	
Milk Consumption (Hamil)					
Yes	15 (93.8%)	37 (77.1%)	19 (82.6%)	71 (81.6%)	0.420
No	1 (6.2%)	11 (22.9%)	4 (17.4%)	16 (18.4%)	

*Analysis Fisher Exact

Table 3 shows the distribution of cord blood vitamin D status based on maternal prenatal nutritional intake during pregnancy. Of the 87 study subjects, most newborns had suboptimal vitamin D status, with 16 (18.4%) having sufficient vitamin D status, 48 (55.2%) having insufficient vitamin D status, and 23 (26.4%) having vitamin D deficiency.

Of the 76 mothers (87.4%) who consumed general multivitamin supplements during pregnancy, the distribution of newborn vitamin D status showed that 15 infants (93.8%) achieved sufficient status, 42 infants (87.5%) experienced insufficiency, and 19 infants (82.6%) experienced deficiency. Meanwhile, in the 11 mothers (12.6%) who did not consume multivitamins, there was 1 infant (6.2%) with sufficient status, 6 infants (12.5%) with insufficiency, and 4 infants (17.4%) with vitamin D deficiency. The relationship between consumption of general multivitamin supplements and cord blood vitamin D status did not show statistical significance ($p=0.565$).

The analysis showed a significant association between specific vitamin D supplementation during pregnancy and newborn vitamin D status ($p=0.004$). Of the 16 mothers (18.4%) who took vitamin D supplements, 8 infants (50.0%) achieved vitamin D sufficiency, 6 infants (12.5%) experienced insufficiency, and only 2 infants (8.7%) experienced deficiency. In contrast, in the group

of 71 mothers (81.6%) who did not take vitamin D supplements, only 8 infants (50.0%) achieved sufficiency, while the majority experienced insufficiency (42 infants; 87.5%) and deficiency (21 infants; 91.3%). These findings suggest that specific vitamin D supplementation during pregnancy plays an important role in preventing vitamin D deficiency in newborns.

Regarding milk consumption during pregnancy, of the 71 mothers (81.6%) who consumed milk regularly, the distribution of infant vitamin D status showed that 15 infants (93.8%) achieved sufficiency, 37 infants (77.1%) experienced insufficiency, and 19 infants (82.6%) experienced deficiency. In the group of 16 mothers (18.4%) who did not consume milk, there was 1 infant (6.2%) with sufficiency status, 11 infants (22.9%) with insufficiency, and 4 infants (17.4%) with deficiency. However, no significant association was found between milk consumption during pregnancy and cord blood vitamin D status ($p=0.420$).

The results of the analysis using the Fisher Exact test showed that only specific vitamin D supplementation was significantly associated with the vitamin D status of newborns, while multivitamin supplements and milk consumption did not show a statistically significant relationship.

5. Discussion

The demographic and clinical characteristics of newborns (term infants) in this study showed a balanced distribution between male and female gender, with a median birth weight of 3020 grams which is in the normal category. A worrying finding is the high prevalence of vitamin D deficiency and insufficiency in newborns, where only 18.4% achieved sufficient status, while 81.6% experienced suboptimal vitamin D status with a median value of 13.99 ng/mL. This high prevalence of neonatal vitamin D deficiency is consistent with a cohort study in China which reported 87.86% of newborns had umbilical cord vitamin D levels <20 ng/mL, with a median concentration of 13.65 ± 5.35 ng/mL which is also below the adequacy standard (17). A recent study in North India also reported similar findings with a prevalence of vitamin D deficiency reaching 71.6% in term neonates, with median levels of 15.8 ± 6.4 ng/mL, which is in good agreement with our results (18).



This study showed that specific vitamin D supplementation during pregnancy was significantly associated with newborn vitamin D status ($p=0.004$), while general multivitamin supplementation and milk consumption did not show a statistically significant association. This finding is in line with a prospective observational cohort study in Romania that reported that only 10.96% of mothers used specific vitamin D supplements during pregnancy, and that supplementation was shown to be an independent factor reducing the risk of maternal and neonatal vitamin D deficiency (19). A large-scale randomized controlled trial by Roth et al. in Bangladesh also showed that prenatal vitamin D supplementation had a strong dose-response effect on cord blood 25-hydroxyvitamin D levels, although it did not significantly affect fetal growth outcomes (20). The high prevalence of neonatal vitamin D deficiency (81.6%) in our study confirms global findings that neonatal vitamin D status is highly dependent on maternal intake during pregnancy (21).

The lack of a significant association between multivitamin supplementation and neonatal vitamin D status in this study may be explained by inadequate vitamin D dosages in multivitamin formulations. A study by Radu et al. reported that although 43.15% of mothers consumed multivitamins containing vitamin D during pregnancy, only specific vitamin D supplements were shown to be effective in preventing deficiency (19). This is supported by systematic evidence showing that prenatal multivitamins generally contain low doses of vitamin D (200–400 IU/day), which are insufficient to achieve sufficiency in pregnant women and their fetuses (1,22). Recent meta-analyses confirmed that vitamin D doses >400 IU/day are required to significantly improve maternal and neonatal 25(OH)D levels (23,24). Therefore, recommendations for specific vitamin D supplementation with adequate doses should be considered in clinical practice, especially in areas with a high prevalence of deficiency.

An interesting finding from this study was the lack of a significant association between regular milk consumption during pregnancy and neonatal vitamin D status. Although fortified milk can be a source of vitamin D, its effectiveness depends largely on the vitamin D content of the product and the frequency of consumption (25). A study by Wani et al. reported a strong positive correlation between maternal and neonatal vitamin D

levels ($p=0.001$), but found no association with specific milk intake (26). Although milk consumption is important for calcium and other nutrient intake, specific vitamin D supplementation remains necessary to ensure optimal vitamin D status in pregnant women and newborns, especially in high-risk populations.

This study reveals a silent epidemic of neonatal vitamin D deficiency, with 81.6% of subjects born with suboptimal vitamin D status. This finding is consistent with recent reports from China and India, indicating that neonatal vitamin D deficiency is a global health problem that is often overlooked, even in areas with abundant sunlight exposure. This high prevalence does not solely reflect low supplementation compliance, but rather is a manifestation of a multifactorial interaction that includes limited sunlight exposure due to cultural norms, geographic conditions, and lifestyle, exacerbated by dietary patterns low in natural vitamin D sources. These findings emphasize that adequate macronutrient status (term infants with normal birth weight) does not necessarily reflect the adequacy of essential micronutrients such as vitamin D. Therefore, we recommend the integration of selective screening and specific vitamin D supplementation at adequate doses (>600 -1000 IU/day) as a standard part of antenatal care, considering that the critical window for maternal-fetal vitamin D transfer occurs during the third trimester of pregnancy. Without targeted interventions, the next generation is at risk of facing the long-term burden of disease associated with vitamin D deficiency, including impaired bone development, immune dysfunction, and potential increased susceptibility to degenerative diseases in the future.

This study acknowledges several limitations that should be considered when interpreting the results. First, while the sample size may limit broad generalization, it meets the minimum standards for adequate statistical power. Second, potential variables such as sun exposure intensity and dietary documentation were not included in the analysis. Third, given the cross-sectional design, these findings require further confirmation through randomized controlled trials designed to evaluate the dose-response relationship and long-term clinical impact on neonatal vitamin D status. These limitations provide valuable opportunities for further, more comprehensive research to gain a more comprehensive picture of the



relationship between prenatal nutrient intake and newborn vitamin D status.

6. Conclusion

Based on the research results, it can be concluded that Specific vitamin D supplementation during pregnancy was significantly associated with adequate newborn vitamin D status ($p=0.004$), while general multivitamin and milk consumption during pregnancy did not show a statistically significant association. These findings recommend that specific vitamin D supplementation be integrated as an essential component of antenatal care services to prevent vitamin D deficiency in neonates and support long-term health.

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