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Original Research Article

Correlation of Maternal Serum Vitamin D Levels with Development of Gestational Diabetes Mellitus and Adverse Pregnancy Outcomes

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Abstract

Introduction: Gestational diabetes mellitus (GDM) is a common metabolic disorder of pregnancy associated with significant maternal and neonatal complications. Vitamin D has been implicated in glucose regulation through its effects on pancreatic β-cell function, insulin sensitivity, and inflammatory pathways. The present study was conducted to evaluate the correlation between maternal serum vitamin D levels, development of GDM, and adverse pregnancy outcomes.

Materials and Methods: A prospective observational study was conducted among 150 pregnant women. Maternal demographic and clinical characteristics were recorded, and serum 25-hydroxyvitamin D [25(OH)D] levels were measured during pregnancy. Participants were screened for GDM using an oral glucose tolerance test between 24 and 28 weeks of gestation. Women were followed until delivery, and maternal and neonatal outcomes were documented. Statistical analysis was performed using appropriate comparative tests, correlation analysis, and multivariate logistic regression.

Results: Among 150 participants, vitamin D deficiency (<20 ng/mL) was observed in 68 (45.3%) women, vitamin D insufficiency in 54 (36.0%), and sufficient vitamin D levels in 28 (18.7%). GDM developed in 29 (19.3%) women. The incidence of GDM was significantly higher among women with vitamin D deficiency compared with vitamin D-sufficient women (26.5% vs 7.1%, p=0.028). Women with GDM had significantly lower mean serum vitamin D levels compared with non-GDM women (17.62 ± 6.42 vs 22.85 ± 8.88 ng/mL, p=0.004). Maternal serum vitamin D levels showed significant negative correlations with fasting glucose (r=-0.32, p<0.001), 1-hour OGTT glucose (r=-0.36, p<0.001), 2-hour OGTT glucose (r=-0.34, p<0.001), and HbA1c (r=-0.28, p=0.001). Vitamin D deficiency independently predicted GDM development (AOR 2.84, 95% CI: 1.21–6.65, p=0.016). Lower vitamin D levels were also associated with increased frequency of adverse pregnancy outcomes.

Conclusion: Maternal vitamin D deficiency was common and was significantly associated with increased risk of gestational diabetes mellitus and adverse pregnancy outcomes. Assessment of maternal vitamin D status may provide a useful approach for early identification of women at increased metabolic and obstetric risk.

Keywords: Gestational Diabetes Mellitus; Vitamin D Deficiency; 25-Hydroxyvitamin D; Pregnancy Outcomes; Insulin Resistance; Maternal Health.

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Introduction

Gestational diabetes mellitus (GDM) is defined as abnormal glucose tolerance first recognized during pregnancy that does not fulfill the criteria for overt diabetes mellitus [1]. It is one of the most common metabolic complications of pregnancy and is associated with significant maternal and fetal consequences. Maternal complications include hypertensive disorders, increased operative delivery rates, postpartum metabolic abnormalities, and a higher risk of developing type 2 diabetes mellitus. Fetal and neonatal complications include macrosomia, shoulder dystocia, birth trauma, neonatal hypoglycemia, respiratory distress, and long-term metabolic disorders. Despite these risks, GDM often remains asymptomatic and is usually detected only through routine screening[1].The

prevalence of GDM has increased globally due to rising maternal obesity, sedentary lifestyle, advanced maternal age, and metabolic disorders among women of reproductive age. Current guidelines recommend screening between 24 and 28 weeks of gestation using a 75-g oral glucose tolerance test (OGTT). Common diagnostic thresholds include fasting glucose ≥5.1 mmol/L, 1-hour glucose ≥10.0 mmol/L, or 2-hour glucose ≥8.5 mmol/L [2]. However, insulin resistance and metabolic alterations may develop earlier in pregnancy, highlighting the need for early predictive biomarkers [3].

The pathogenesis of GDM involves an imbalance between pregnancy-related insulin resistance and inadequate pancreatic β-cell compensation. Multiple mechanisms, including chronic inflammation, oxidative stress, altered adipokines, mitochondrial dysfunction, placental abnormalities, and genetic susceptibility, contribute to impaired glucose regulation [3]. Recent research has focused on the role of micronutrients, particularly vitamins, in maternal metabolic adaptation and pregnancy outcomes. Studies have reported altered vitamin levels and metabolites among women with GDM, suggesting their potential involvement in disease development [4].Vitamin D, a fat-soluble secosteroid hormone, has emerged as an important regulator of glucose metabolism beyond its classical role in calcium homeostasis.

Vitamin D receptors (VDR) are expressed in pancreatic β-cells, adipose tissue, placenta, and immune cells [5]. Vitamin D influences insulin secretion, β-cell function, peripheral insulin sensitivity, inflammatory pathways, and calcium-mediated insulin signaling. Adequate maternal vitamin D levels are also important for placental development, fetal growth, and immune regulation [6].Vitamin D deficiency remains highly prevalent among pregnant women worldwide due to reduced sunlight exposure, inadequate dietary intake, obesity, altered vitamin D metabolism, and socioeconomic factors [6].

Apart from its association with abnormal glucose metabolism, maternal vitamin D status has also been investigated in relation to adverse pregnancy outcomes. Vitamin D deficiency has been linked with increased risks of preeclampsia, fetal growth restriction, preterm birth, low birth weight, and neonatal complications [7].

Proposed mechanisms include impaired placental angiogenesis, endothelial dysfunction, increased oxidative stress, altered immune responses, and dysregulation of inflammatory pathways. However, the clinical significance of maternal vitamin D assessment and its role as an independent predictor of GDM and adverse pregnancy outcomes remain subjects of ongoing investigation [8]. Early identification of women at risk for GDM through easily measurable biomarkers such as maternal serum vitamin D levels may provide opportunities for targeted nutritional interventions, closer monitoring, and prevention of pregnancy-related complications. A better understanding of the relationship between maternal vitamin D status, development of GDM, and subsequent maternal and neonatal outcomes may contribute to improved antenatal care strategies.

Therefore, the present study was undertaken to evaluate the correlation of maternal serum vitamin D levels with the development of gestational diabetes mellitus and its association with adverse pregnancy outcomes.

Materials and Methods

The present study was conducted as a prospective observational study to evaluate the correlation between maternal serum vitamin D levels and the development of gestational diabetes mellitus (GDM) along with associated adverse pregnancy outcomes. The study was carried out in the Department of Obstetrics and Gynaecology at tertiary care centre.

Study Setting and Duration: The study was conducted in the Department of Obstetrics and Gynaecology, ESIC Medical College, PGIMSR and Hospital, Kalaburagi, Karnataka, from January 2025 to November 2025.

Study Population: Pregnant women attending the antenatal outpatient department during the study period were screened for eligibility. Women fulfilling the predefined inclusion criteria were enrolled and followed prospectively throughout pregnancy until delivery.

Maternal serum vitamin D levels were assessed during pregnancy, and participants were subsequently evaluated for the development of GDM and pregnancy outcomes.

Inclusion Criteria: The study included pregnant women who fulfilled the following criteria:

- Pregnant women aged 18 years or above.
- Singleton pregnancy.
- Women attending antenatal care during the first or early second trimester.
- Women willing to participate and provide written informed consent.
- Women available for follow-up until delivery.

Exclusion Criteria:

Participants were excluded if they had:

- Pre-existing diabetes mellitus diagnosed before pregnancy.
- Multiple gestation.

- Chronic renal disease, liver disease, or endocrine disorders affecting glucose metabolism.
- History of metabolic disorders or conditions affecting vitamin D metabolism.
- Current use of vitamin D supplementation or medications interfering with vitamin D metabolism.
- Any medical condition requiring long-term corticosteroid or immunosuppressive therapy.
- Incomplete follow-up or missing laboratory data.

Baseline Assessment and Data Collection: Detailed demographic and clinical information was collected from all participants using a structured proforma. Data regarding maternal age, parity, gestational age, body mass index (BMI), socioeconomic characteristics, dietary habits, sun exposure, history of previous GDM, family history of diabetes mellitus, and other relevant obstetric and medical factors were recorded. A detailed obstetric examination was performed, and gestational age was confirmed using last menstrual period and/or early obstetric ultrasonography. Maternal weight and height were measured, and BMI was calculated as weight in kilograms divided by height in square meters.

Assessment of Maternal Serum Vitamin D Levels: Venous blood samples were collected from all participants during antenatal visits for estimation of serum vitamin D levels. Serum 25-hydroxyvitamin D [25(OH)D] concentration was measured as the primary indicator of maternal vitamin D status using a standardized laboratory assay. Vitamin D status was categorized according to established criteria:

- Vitamin D sufficient: serum 25(OH)D ≥30 ng/mL
- Vitamin D insufficient: serum 25(OH)D 20–29 ng/mL
- Vitamin D deficient: serum 25(OH)D <20 ng/mL

Screening and Diagnosis of Gestational Diabetes Mellitus: All participants underwent screening for GDM between 24 and 28 weeks of gestation using a standard oral glucose tolerance test (OGTT). After overnight fasting, venous blood glucose levels were measured following administration of a 75-g oral glucose load. GDM was diagnosed according to accepted diagnostic criteria when one or more plasma glucose values exceeded the predefined threshold values. Participants were categorized into two groups based on GDM status:

- GDM group: Women diagnosed with gestational diabetes mellitus.
- Non-GDM group: Women with normal glucose tolerance during pregnancy.

Assessment of Maternal and Pregnancy Outcomes: All participants were followed until delivery. Maternal outcomes including development of hypertensive disorders of pregnancy, mode of delivery, and other obstetric complications were recorded. Neonatal outcomes including birth weight, preterm birth, low birth weight, neonatal hypoglycemia, and admission to neonatal intensive care unit (NICU) were documented.

Adverse pregnancy outcomes were defined as the occurrence of one or more of the following:

- Preterm delivery.
- Low birth weight.
- Fetal growth restriction.
- Macrosomia.
- Hypertensive disorders of pregnancy.
- Neonatal complications requiring intensive care.

Statistical Analysis: The collected data were entered into a Microsoft Excel spreadsheet and analyzed using SPSS.27statistical software. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on data distribution. Categorical variables were presented as frequency and percentage. Comparison of continuous variables between groups was performed using the independent samples t-test or Mann–Whitney U test, as appropriate. Categorical variables were compared using the Chi-square test or Fisher's exact test. Correlation between maternal serum vitamin D levels and glycemic parameters was assessed using Pearson's or Spearman's correlation analysis. Logistic regression analysis was performed to determine whether vitamin D deficiency independently predicted the development of GDM and adverse pregnancy outcomes. A p-value <0.05 was considered statistically significant.

Results

A total of 150 pregnant women were included in the present study. The mean maternal age was 27.12 ± 4.36 years. The majority of participants belonged to the age group of 25–34 years (82; 54.7%), followed by women aged <25 years (54; 36.0%) and ≥35 years (14; 9.3%). Among the study participants, 78 (52.0%) were primigravida and 72 (48.0%) were multigravida.

The mean gestational age at enrolment was 15.84 ± 2.26 weeks. The mean BMI of participants was 24.36 ± 3.42 kg/m², with 96 (64.0%) women having normal BMI, 42 (28.0%) being overweight, and 12 (8.0%) being obese. A family history of diabetes mellitus was present in 28 (18.7%) women, while previous history of GDM among multigravida women was observed in 8 (11.1%)

participants (Table 1).Assessment of maternal serum vitamin D levels showed that vitamin D deficiency was common among study participants. The mean serum vitamin D level was 21.84 ± 8.62 ng/mL. Vitamin D deficiency (<20 ng/mL) was observed in 68 (45.3%) women, while 54 (36.0%) women had vitamin D insufficiency (20–29 ng/mL). Only 28 (18.7%) participants had sufficient vitamin D levels (≥30 ng/mL) (Table 2). The distribution of maternal serum vitamin D status among the study population is illustrated in Figure 1.During follow-up, GDM was diagnosed in 29 (19.3%) women, whereas 121 (80.7%) women did not develop GDM.

A significant association was observed between maternal vitamin D status and development of GDM. Among women with vitamin D deficiency, 18 (26.5%) developed GDM compared with 9 (16.7%) women with vitamin D insufficiency and only 2 (7.1%) women with sufficient vitamin D levels. The proportion of GDM was significantly higher among vitamin D-deficient women compared with women with adequate vitamin D status (p=0.028) (Table 3).

The association between vitamin D status and occurrence of GDM is shown in Figure 2.Comparison between GDM and non-GDM groups revealed significant differences in maternal characteristics. Women who developed GDM were significantly older compared with women without GDM (30.12 ± 4.18 years vs 26.40 ± 4.15 years; p<0.001). Similarly, mean BMI was significantly higher among women with GDM compared with the non-GDM group (27.42 ± 3.64 kg/m² vs 23.63 ± 3.12 kg/m²; p<0.001). Maternal serum vitamin D levels were significantly lower among women with GDM compared with those without GDM (17.62 ± 6.42 ng/mL vs 22.85 ± 8.88 ng/mL; p=0.004). A significantly higher proportion of women with GDM had a family history of diabetes mellitus (34.5% vs 14.9%; p=0.018) and previous history of GDM (17.2% vs 2.5%; p=0.006) compared with the non-GDM group (Table 4).Maternal serum vitamin D levels demonstrated a significant negative correlation with glycemic parameters. Serum vitamin D levels showed a negative correlation with fasting plasma glucose (r=-0.32, p<0.001), 1-hour OGTT glucose (r=-0.36, p<0.001), and 2-hour OGTT glucose (r=-0.34, p<0.001). A significant inverse correlation was also observed between serum vitamin D levels and HbA1c values (r=-0.28, p=0.001) (Table 5)(Figure 3). These findings indicated that lower vitamin D levels were associated with higher maternal glycemic values. The occurrence of adverse pregnancy outcomes was significantly higher among women with vitamin D deficiency or insufficiency compared with women having sufficient vitamin D levels. Preeclampsia occurred in 14 (11.5%) women with deficient/insufficient vitamin D levels compared with 1 (3.6%) woman with sufficient vitamin D levels (p=0.024). Similarly, preterm delivery was observed in 16 (13.1%) women with low vitamin D levels compared with 2 (7.1%) women with adequate vitamin D levels (p=0.038). Low birth weight occurred in 19 (15.6%) versus 2 (7.1%) women (p=0.041), fetal growth restriction occurred in 12 (9.8%) versus 1 (3.6%) woman (p=0.048), and NICU admission was required in 14 (11.5%) versus 2 (7.1%) neonates (p=0.049) among vitamin D deficient/insufficient and sufficient groups, respectively (Table 6).

Multivariate logistic regression analysis was performed to identify independent predictors of GDM. Vitamin D deficiency was found to be an independent predictor of GDM development, with women having vitamin D deficiency demonstrating 2.84-fold higher odds of developing GDM (AOR: 2.84; 95% CI: 1.21–6.65; p=0.016).

Other independent predictors included BMI ≥25 kg/m² (AOR: 3.12; 95% CI: 1.42–6.84; p=0.004), previous GDM history (AOR: 3.48; 95% CI: 1.12–10.82; p=0.031), maternal age ≥30 years (AOR: 2.42; 95% CI: 1.08–5.41; p=0.032), and family history of diabetes mellitus (AOR: 2.56; 95% CI: 1.02–6.41; p=0.045) (Table 7). The forest plot demonstrating adjusted odds ratios and corresponding 95% confidence intervals for predictors of GDM is presented in Figure 4.

Table 1: Baseline Maternal Characteristics of Study Participants (n=150)

Variables	n (%) / Mean ± SD
Maternal age (years)	
Mean ± SD	27.12 ± 4.36
Age group (years)	
<25 years	54 (36.0%)
25–34 years	82 (54.7%)
≥35 years	14 (9.3%)
Parity	
Primigravida	78 (52.0%)
Multigravida	72 (48.0%)
Gestational age at enrolment (weeks)	

Mean ± SD	15.84 ± 2.26
BMI (kg/m²)	
Mean ± SD	24.36 ± 3.42
Normal BMI (<25 kg/m²)	96 (64.0%)
Overweight (25–29.9 kg/m²)	42 (28.0%)
Obese (≥30 kg/m²)	12 (8.0%)
Family history of diabetes mellitus	28 (18.7%)
Previous history of GDM (n=72 multigravida)	8 (11.1%)

Table 2: Distribution of Maternal Serum Vitamin D Status among Study Participants (n=150)

Vitamin D status	Serum 25(OH)D level	n (%)
Vitamin D deficient	<20 ng/mL	68 (45.3%)
Vitamin D insufficient	20–29 ng/mL	54 (36.0%)
Vitamin D sufficient	≥30 ng/mL	28 (18.7%)
Total		150 (100%)

Mean maternal serum vitamin D level: 21.84 ± 8.62 ng/mL

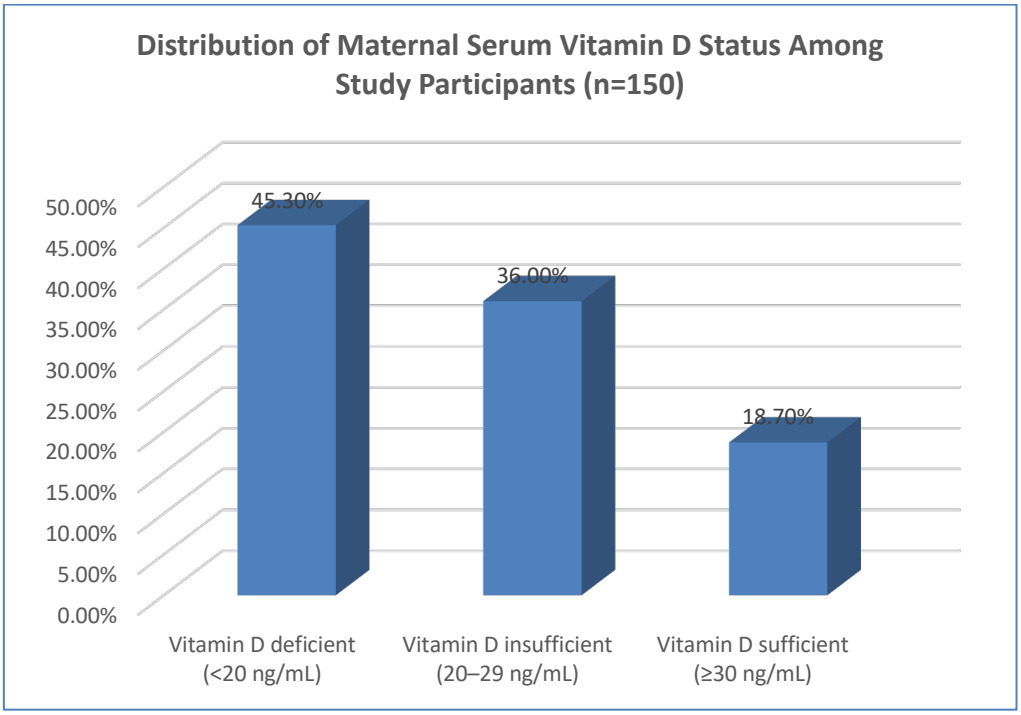

Figure 1: Distribution of Maternal Serum Vitamin D Status among Study Participants (n=150)

Table 3: Association between Maternal Vitamin D Status and Development of Gestational Diabetes Mellitus (n=150)

Vitamin D status	GDM Present n (%)	GDM Absent n (%)	Total	p-value
Vitamin D deficient	18 (26.5%)	50 (73.5%)	68	
Vitamin D insufficient	9 (16.7%)	45 (83.3%)	54	
Vitamin D sufficient	2 (7.1%)	26 (92.9%)	28	
Total	29 (19.3%)	121 (80.7%)	150	0.028

Statistical test used: Chi-square test

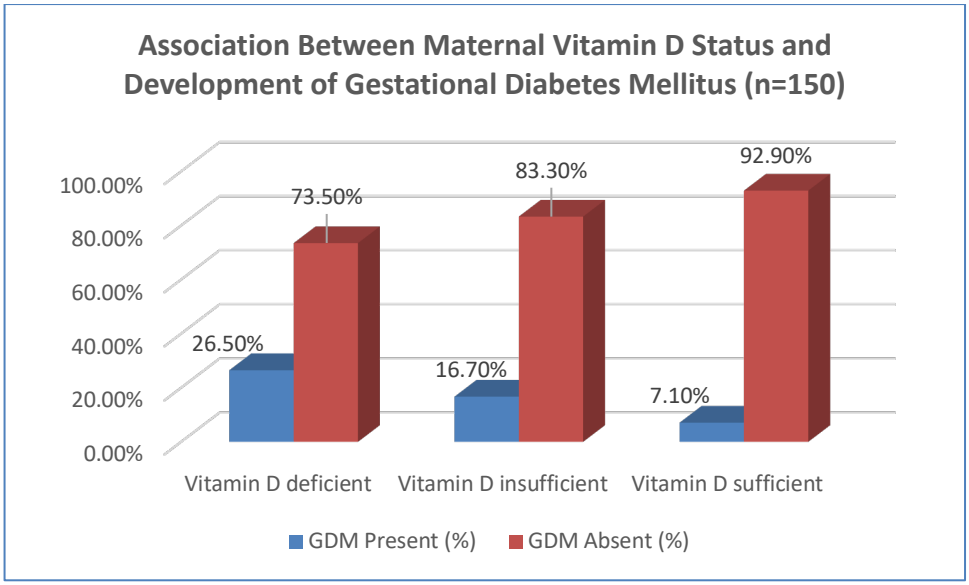

Figure 2: Association between Maternal Vitamin D Status and Development of Gestational Diabetes Mellitus (n=150)

Table 4: Comparison of Maternal Characteristics between GDM and Non-GDM Groups

Parameters	GDM Group (n=29)	Non-GDM Group (n=121)	p-value
Maternal age (years), Mean ± SD	30.12 ± 4.18	26.40 ± 4.15	<0.001
BMI (kg/m²), Mean ± SD	27.42 ± 3.64	23.63 ± 3.12	<0.001
Serum vitamin D (ng/mL), Mean ± SD	17.62 ± 6.42	22.85 ± 8.88	0.004
Family history of diabetes, n (%)	10 (34.5%)	18 (14.9%)	0.018
Previous GDM history, n (%)	5 (17.2%)	3 (2.5%)	0.006

Table 5: Correlation of Maternal Serum Vitamin D Levels with Glycemic Parameters

Parameters	Correlation coefficient (r)	p-value
Vitamin D vs Fasting plasma glucose	-0.32	<0.001
Vitamin D vs 1-hour OGTT glucose	-0.36	<0.001
Vitamin D vs 2-hour OGTT glucose	-0.34	<0.001
Vitamin D vs HbA1c	-0.28	0.001

Statistical test used: Pearson correlation analysis

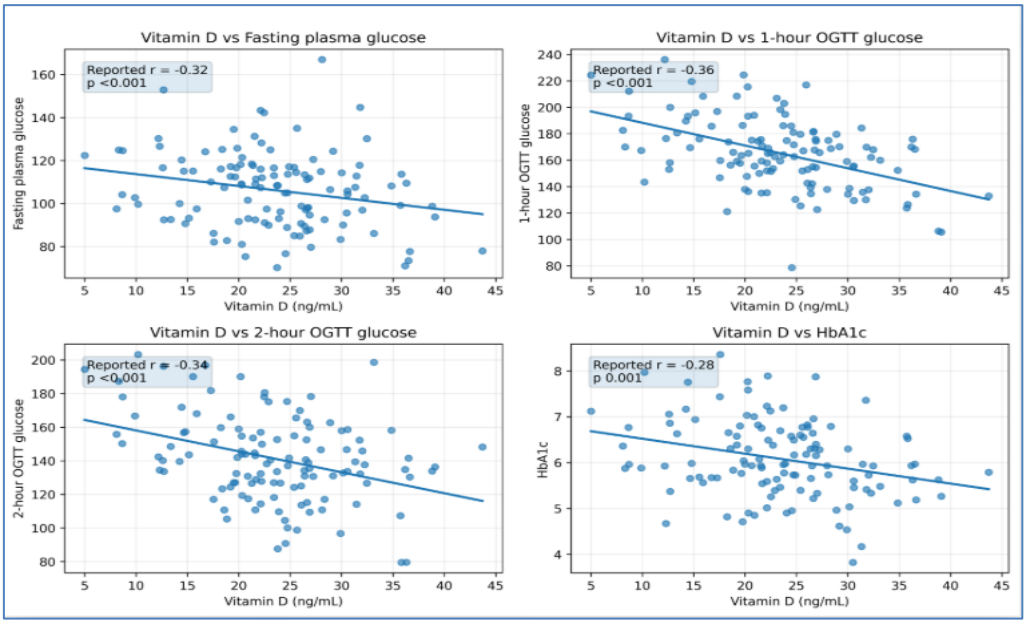

Figure 3: Correlation of Maternal Serum Vitamin D Levels with Glycemic Parameters

Table 6: Association between Maternal Vitamin D Status and Adverse Pregnancy Outcomes

Pregnancy outcome	Vitamin D deficient/insufficient (n=122)	Vitamin D sufficient (n=28)	p-value
Preeclampsia	14 (11.5%)	1 (3.6%)	0.024
Preterm delivery	16 (13.1%)	2 (7.1%)	0.038
Low birth weight	19 (15.6%)	2 (7.1%)	0.041
Fetal growth restriction	12 (9.8%)	1 (3.6%)	0.048
NICU admission	14 (11.5%)	2 (7.1%)	0.049

Statistical test used: Chi-square/Fisher's exact test

Table 7: Multivariate Logistic Regression Analysis for Predictors of Gestational Diabetes Mellitus

Variables	Adjusted Odds Ratio (AOR)	95% CI	p-value
Vitamin D deficiency (<20 ng/mL)	2.84	1.21–6.65	0.016
Maternal age ≥30 years	2.42	1.08–5.41	0.032
BMI ≥25 kg/m²	3.12	1.42–6.84	0.004
Family history of diabetes	2.56	1.02–6.41	0.045
Previous GDM history	3.48	1.12–10.82	0.031

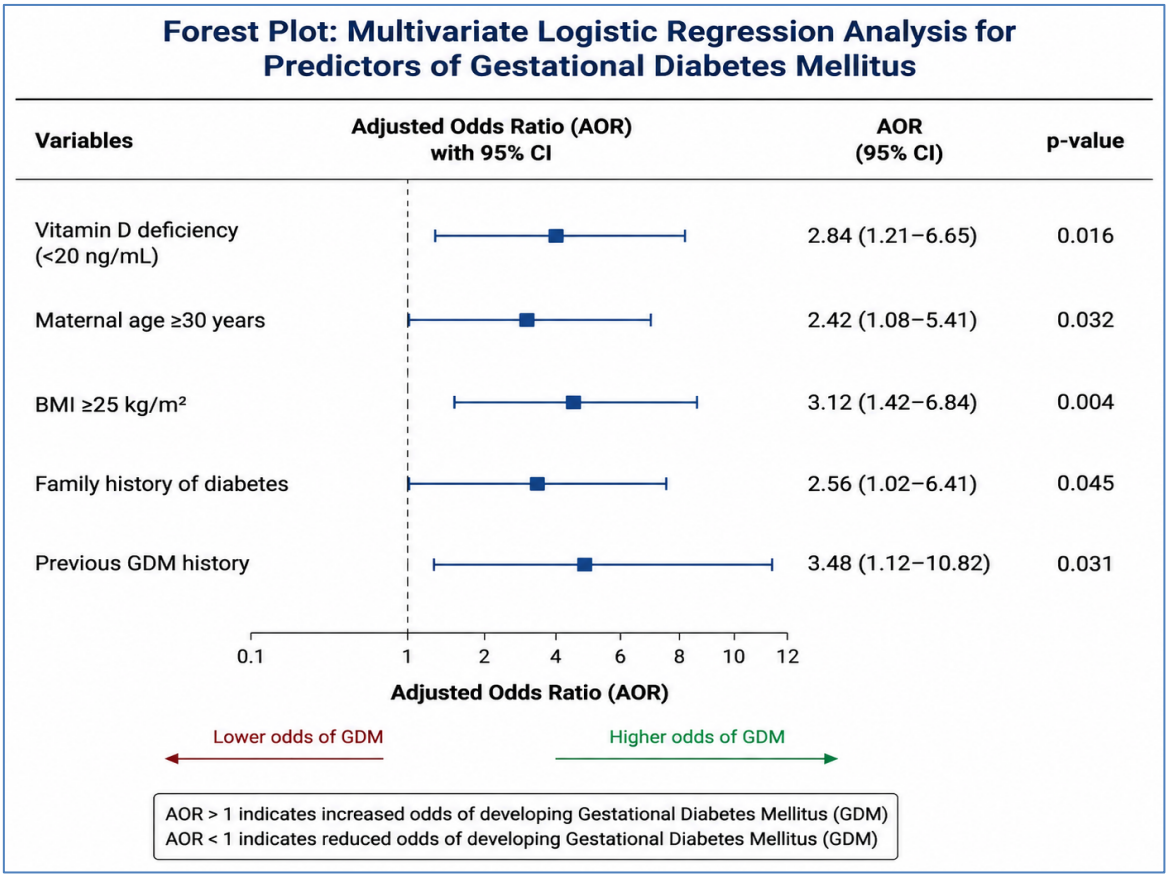

Figure 4: Multivariate Logistic Regression Analysis for Predictors of Gestational Diabetes Mellitus

Discussion

The present prospective observational study evaluated the association between maternal serum vitamin D levels, development of gestational diabetes mellitus (GDM), and adverse pregnancy outcomes among 150 pregnant women. Vitamin D insufficiency was highly prevalent, with 68 (45.3%) women having deficiency (<20 ng/mL), 54 (36.0%) having insufficiency (20–29 ng/mL), and only 28 (18.7%) having sufficient levels (≥30 ng/mL). The mean maternal serum vitamin D concentration was 21.84 ± 8.62 ng/mL, indicating a high burden of inadequate vitamin D status during pregnancy. Vitamin D plays an important role in glucose metabolism through its effects on pancreatic β-cell function, insulin secretion, and peripheral insulin sensitivity.

Vitamin D receptors in pancreatic and peripheral tissues regulate calcium-mediated insulin signaling, and deficiency may contribute to insulin resistance through impaired β-cell function and increased inflammatory activity. Several studies have

suggested that reduced maternal 25-hydroxyvitamin D [25(OH)D] levels are associated with increased risk of GDM. In the present study, GDM was diagnosed in 29 (19.3%) women. Vitamin D-deficient women had a significantly higher incidence of GDM compared with vitamin D-sufficient women (18/68 [26.5%] vs 2/28 [7.1%]; p=0.028). Additionally, women with GDM had significantly lower mean vitamin D levels compared with women without GDM (17.62 ± 6.42 ng/mL vs 22.85 ± 8.88 ng/mL; p=0.004). These findings suggest that inadequate vitamin D status may contribute to impaired glucose regulation during pregnancy.

The findings are consistent with the meta-analysis by Milajerdi et al. (2021)[9], which demonstrated a significant association between maternal vitamin D deficiency and increased risk of GDM. Similarly, Harshinee et al. (2025)[10] reported that first-trimester vitamin D deficiency was associated with subsequent GDM development, supporting the importance of early pregnancy vitamin D assessment. Zhang et al.[11] also observed that lower maternal plasma 25(OH)D levels during early pregnancy increased the risk of GDM, suggesting a potential predictive role of vitamin D status. In the present study, maternal serum vitamin D levels showed significant inverse correlations with fasting plasma glucose ($r=-0.32$, $p<0.001$), 1-hour OGTT glucose ($r=-0.36$, $p<0.001$), 2-hour OGTT glucose ($r=-0.34$, $p<0.001$), and HbA1c ($r=-0.28$, $p=0.001$).

These findings indicate that lower vitamin D concentrations were associated with poorer glycemic control, possibly due to reduced insulin receptor activity, altered intracellular calcium regulation, and increased inflammatory cytokine production. Traditional risk factors for GDM were also observed in this study. Women with GDM had significantly higher BMI compared with non-GDM women (27.42 ± 3.64 vs 23.63 ± 3.12 kg/m²; $p<0.001$).

Multivariate logistic regression analysis showed that vitamin D deficiency independently predicted GDM development (AOR 2.84; 95% CI: 1.21–6.65; p=0.016), along with BMI ≥25 kg/m² (AOR 3.12; 95% CI: 1.42–6.84; p=0.004) and maternal age ≥30 years (AOR 2.42; 95% CI: 1.08–5.41; p=0.032).

The present study also demonstrated an association between low vitamin D status and adverse pregnancy outcomes. Women with deficient or insufficient vitamin D levels had higher frequencies of preeclampsia, preterm delivery, low birth weight, fetal growth restriction, and NICU admission compared with women with adequate vitamin D levels. These findings are supported by previous systematic reviews showing that vitamin D insufficiency is associated with increased risks of GDM, preeclampsia, and small-for-gestational-age infants.[12] The possible mechanisms include impaired placental angiogenesis, endothelial dysfunction, oxidative stress, and altered immune regulation.

Conclusion

The present study demonstrated that maternal vitamin D deficiency was highly prevalent among pregnant women and was significantly associated with an increased risk of gestational diabetes mellitus and adverse pregnancy outcomes.

Women with lower serum 25(OH)D levels had significantly higher rates of GDM, and vitamin D deficiency was identified as an independent predictor of abnormal glucose metabolism during pregnancy. Reduced vitamin D levels were also associated with increased occurrence of complications such as preeclampsia, preterm delivery, low birth weight, fetal growth restriction, and neonatal intensive care admission.

Assessment of maternal serum vitamin D status during pregnancy may therefore help in early identification of high-risk women and facilitate timely nutritional and preventive interventions. Further randomized controlled trials are required to establish whether vitamin D supplementation can reduce the incidence of GDM and improve maternal and neonatal outcomes.

Limitations

The study had certain limitations, including its single-center observational design, which restricted the ability to establish a causal relationship between vitamin D deficiency and gestational diabetes mellitus. Factors influencing vitamin D status, such as dietary intake, sunlight exposure, seasonal variation, physical activity, and genetic factors, were not evaluated. The sample size was relatively limited, and larger multicentric studies with long-term follow-up are required to validate these findings and determine the clinical benefits of vitamin D supplementation during pregnancy.

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