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PROSPECTIVE EVALUATION OF SERUM VITAMIN D LEVELS IN TYPE 2 DIABETES MELLITUS PATIENTS AND CORRELATION WITH GLYCEMIC CONTROL

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Abstract

Background: Type 2 Diabetes Mellitus (T2DM) is a growing global health concern. Recent evidence suggests a potential link between Vitamin D deficiency and poor glycemic control. This study aimed to evaluate serum Vitamin D levels in T2DM patients and analyze their correlation with glycemic parameters.

Methods: This prospective observational study was conducted in the Department of Biochemistry, FH Medical College, Agra over 12 months. A total of 150 diagnosed T2DM patients were included. Serum 25(OH) Vitamin D and glycemic parameters (HbA1c, Fasting Blood Glucose [FBG], Postprandial Blood Glucose [PPBG]) were measured and analyzed.

Results: Vitamin D deficiency (<20 ng/mL) was observed in 68% of patients. A statistically significant inverse correlation was found between serum Vitamin D levels and HbA1c ($r = –0.42$, $p < 0.01$). Similar trends were seen with FBG and PPBG.

Conclusion: Vitamin D deficiency is highly prevalent in T2DM patients and is significantly associated with poor glycemic control. Screening and supplementation of Vitamin D may serve as an adjunct in the management of T2DM.

Keywords: Type 2 Diabetes Mellitus, Vitamin D, HbA1c, Glycemic Control, Biochemistry

Introduction

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia due to insulin resistance and/or relative insulin deficiency. According to the International Diabetes Federation (IDF), an estimated 537 million adults globally were living with

diabetes in 2021, and this figure is projected to rise to 643 million by 2030 and 783 million by 2045 [1]. India, with over 77 million diabetics, represents one of the largest populations affected by this condition, giving rise to significant public health and economic burdens [2].

In recent years, beyond the well-established factors such as obesity, sedentary lifestyle, and genetic predisposition, micronutrient imbalances have been increasingly recognized as potential modulators in the pathogenesis and progression of T2DM. One such micronutrient gaining significant attention is Vitamin D, a secosteroid hormone primarily involved in calcium-phosphorus metabolism and skeletal health. Emerging evidence, however, suggests that Vitamin D may play a broader role in several non-skeletal physiological functions, including modulation of the immune system, inflammation, and insulin secretion [3–5].

The biological plausibility for Vitamin D's role in glucose metabolism is supported by the presence of Vitamin D Receptors (VDRs) and 1-alpha hydroxylase enzyme in pancreatic β-cells, skeletal muscle, and adipose tissues. These findings suggest that Vitamin D may directly or indirectly influence insulin synthesis, secretion, and sensitivity [6]. In particular, Vitamin D is believed to enhance insulin sensitivity by stimulating the expression of insulin receptors and improving β-cell function through its anti-inflammatory effects and regulation of intracellular calcium levels [7].

Vitamin D deficiency is widely prevalent globally, with estimates suggesting that over 1 billion people may have suboptimal Vitamin D status [8]. In India, despite abundant sunlight, the prevalence of Vitamin D deficiency is alarmingly high, reported in up to 70–90% of the population across various age groups and geographic regions [9]. Factors contributing to this paradox include skin pigmentation, cultural clothing practices, limited sun exposure due to urbanization, and dietary insufficiency.

Several observational studies have demonstrated a negative association between serum 25-hydroxyvitamin D [25(OH)D] levels and markers of glycemic control such as HbA1c, fasting blood glucose (FBG), and postprandial blood glucose (PPBG) [10–12]. Additionally, randomized controlled trials and meta-analyses have attempted to explore whether Vitamin D supplementation improves glycemic outcomes, though findings remain inconsistent, possibly due to differences in baseline Vitamin D status, dosage, duration of therapy, and study designs [13–14].

While global research has explored this association extensively, there is a paucity of prospective Indian studies that evaluate the serum Vitamin D status in T2DM patients and its correlation with glycemic control, particularly in North Indian populations. Considering the high burden of both Vitamin D deficiency and diabetes in India, and the potential implications for patient management, there is a need to investigate this relationship further in a regional context.

Given the immunomodulatory, anti-inflammatory, and insulin-sensitizing properties of Vitamin D, understanding its role in glycemic control could open avenues for adjunctive nutritional interventions in diabetes management. Identifying and correcting Vitamin D deficiency in diabetic patients may serve as a cost-effective strategy to complement standard therapeutic approaches.

This study was designed to prospectively evaluate the serum Vitamin D levels in patients with T2DM attending a tertiary care hospital in Agra and to assess the correlation between serum 25(OH)D and glycemic parameters including HbA1c, fasting blood glucose, and postprandial blood glucose levels.

Materials and Methods

This prospective observational study was conducted in the Department of Biochemistry at FH Medical College and Hospital, Agra, over a period of one year, from January 2024 to December 2024. Ethical clearance was obtained from the Institutional Ethics Committee prior to initiation of the study. A total of 150 patients with a confirmed diagnosis of Type 2 Diabetes Mellitus (T2DM), as per the American Diabetes Association (ADA) diagnostic criteria, were enrolled. Written informed consent was obtained from all participants.

Inclusion criteria for the study comprised adult patients aged 30 years or above, having a known history of T2DM for at least six months, and not receiving Vitamin D supplementation in the past six months. Patients with Type 1 Diabetes Mellitus, gestational diabetes, chronic kidney disease, hepatic dysfunction, malabsorption syndromes, thyroid or parathyroid disorders, or those on medications

known to interfere with Vitamin D metabolism (such as corticosteroids or antiepileptics) were excluded from the study.

A structured data collection proforma was used to record demographic and clinical information including age, sex, duration of diabetes, body mass index (BMI), lifestyle habits, and dietary intake. Following an overnight fast of 8–10 hours, venous blood samples were collected from each participant. Serum was separated and analyzed for 25-hydroxyvitamin D [25(OH)D] levels using a Chemiluminescent Immunoassay (CLIA) method, which is considered a reliable and widely accepted technique for Vitamin D assessment. Glycemic parameters including fasting blood glucose (FBG), postprandial blood glucose (PPBG), and glycated hemoglobin (HbA1c) were also measured. FBG and PPBG were determined by the glucose oxidase-peroxidase (GOD-POD) enzymatic method using an automated biochemistry analyzer, while HbA1c was estimated using high-performance liquid chromatography (HPLC).

Based on the Endocrine Society's clinical practice guidelines, Vitamin D status was categorized into three groups: deficiency (<20 ng/mL), insufficiency (20–29 ng/mL), and sufficiency (≥30 ng/mL). Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics such as mean, standard deviation, and percentage distribution were used to summarize the data. Pearson's correlation coefficient was employed to examine the relationship between serum Vitamin D levels and glycemic parameters. A p-value of less than 0.05 was considered statistically significant.

Results

Demographic and Clinical Characteristics

A total of 150 patients diagnosed with Type 2 Diabetes Mellitus were enrolled in this study. Among them, 92 (61.3%) were male and 58 (38.7%) were female. The mean age of the study population was 52.6 ± 10.4 years. The average duration of diabetes was 6.2 ± 3.5 years, and the mean Body Mass Index (BMI) was 26.4 ± 3.9 kg/m².

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

Parameter	Value (Mean ± SD) / n (%)
Age (years)	52.6 ± 10.4
Gender	Male: 92 (61.3%), Female: 58 (38.7%)
Duration of Diabetes (years)	6.2 ± 3.5
BMI (kg/m²)	26.4 ± 3.9
Sedentary Lifestyle	104 (69.3%)
Family History of Diabetes	86 (57.3%)

Distribution of Vitamin D Status

Vitamin D deficiency (<20 ng/mL) was observed in 102 (68%) patients, while 28 (18.7%) had insufficiency (20–29 ng/mL) and only 20 (13.3%) had sufficient Vitamin D levels (≥30 ng/mL).

Table 2: Distribution of Vitamin D Status Among T2DM Patients

Vitamin D Status	Serum 25(OH)D Level (ng/mL)	Number of Patients (n)	Percentage (%)
Deficient	<20	102	68.0%
Insufficient	20–29	28	18.7%
Sufficient	≥30	20	13.3%

Glycemic Parameters and Vitamin D Categories

Patients with sufficient Vitamin D levels showed better glycemic control compared to those who were deficient.

Table 3: Comparison of Glycemic Parameters Across Vitamin D Categories

Vitamin D Status	Mean FBG (mg/dL)	Mean PPBG (mg/dL)	Mean HbA1c (%)
Deficient (<20)	168.2 ± 29.4	242.5 ± 45.2	8.5 ± 1.1
Insufficient	153.4 ± 27.8	225.7 ± 42.3	8.0 ± 0.9
Sufficient (≥30)	137.6 ± 24.3	202.3 ± 38.9	7.2 ± 0.8
p-value	<0.01	<0.01	<0.01

Correlation Between Serum Vitamin D and Glycemic Parameters

A significant negative correlation was observed between serum 25(OH) Vitamin D levels and all three glycemic parameters — HbA1c, FBG, and PPBG. The strongest inverse correlation was noted with HbA1c.

Table 4: Pearson Correlation Between Serum Vitamin D and Glycemic Markers

Parameter	Correlation Coefficient (r)	*p*-value
HbA1c (%)	–0.42	<0.01
Fasting Blood Glucose	–0.36	<0.01
Postprandial Glucose	–0.39	<0.01

Gender-wise Vitamin D Status and HbA1c Comparison

The association between Vitamin D deficiency and poor glycemic control was more pronounced in females than in males.

Table 5: Gender-wise Distribution of Vitamin D Deficiency and Glycemic Control

Gender	Mean Vitamin D (ng/mL)	Mean HbA1c (%)	Deficiency Prevalence (%)
Male	21.3 ± 7.2	8.0 ± 1.0	62.0%
Female	18.2 ± 6.5	8.5 ± 1.3	75.9%
p-value	<0.05	<0.05	<0.05

Vitamin D Status vs Duration of Diabetes

Vitamin D levels were inversely related to the duration of diabetes, suggesting chronicity may influence Vitamin D metabolism or vice versa.

Table 6: Mean Vitamin D Levels Based on Duration of Diabetes

Duration of Diabetes	n (%)	Mean Vitamin D (ng/mL)
<5 years	58 (38.7%)	24.5 ± 6.8
5–10 years	64 (42.7%)	20.3 ± 7.1
>10 years	28 (18.6%)	17.1 ± 6.5
p-value		<0.01

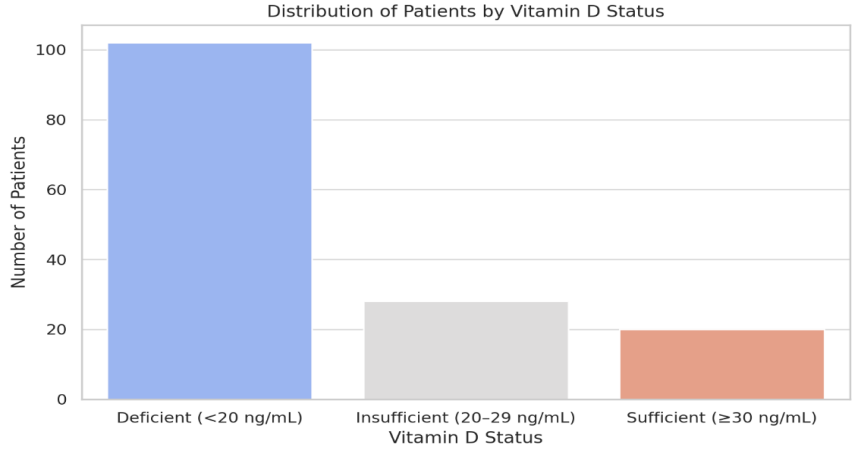

Figure 1: Distribution of patients with Type 2 Diabetes Mellitus based on serum Vitamin D status. The majority (68%) of patients were found to be Vitamin D deficient (<20 ng/mL), while only

13.3% had sufficient levels (≥30 ng/mL), indicating a high burden of hypovitaminosis D in the study population.

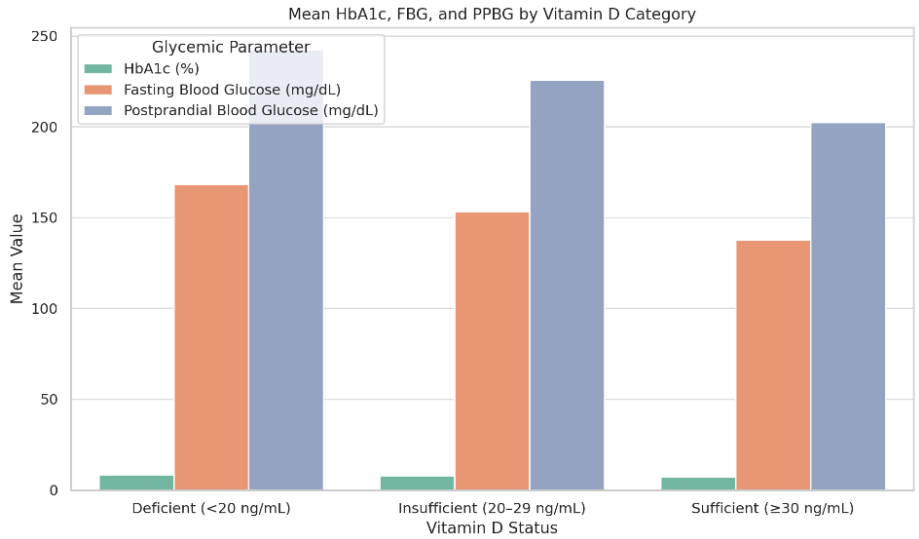

Figure 2: Comparison of mean glycemic parameters (HbA1c, FBG, and PPBG) across Vitamin D status categories. Patients with sufficient Vitamin D levels (≥30 ng/mL) had lower mean HbA1c (7.2%), FBG (137.6 mg/dL), and PPBG (202.3 mg/dL) compared to those with deficient levels, indicating a significant association between adequate Vitamin D status and better glycemic control.

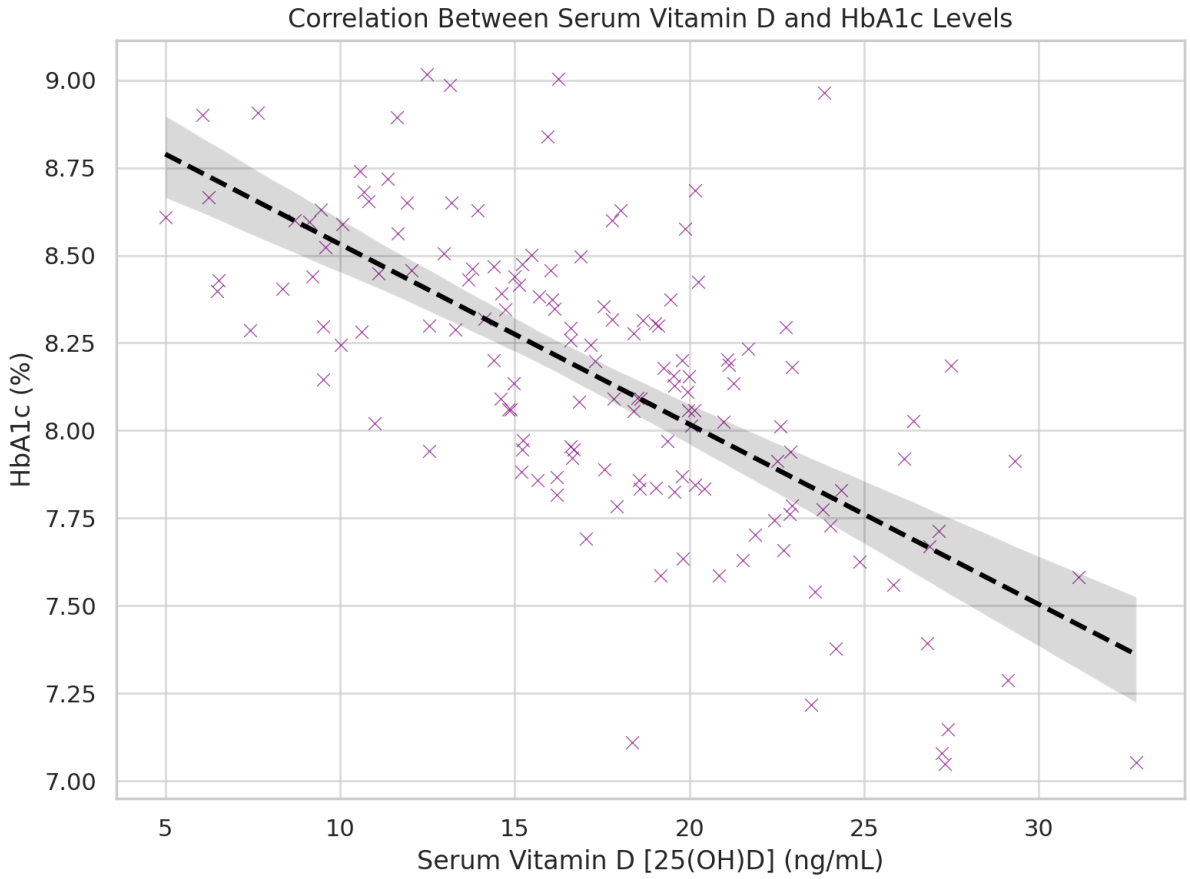

Figure 3: Scatter plot showing an inverse relationship between serum 25(OH) Vitamin D levels and HbA1c values. A statistically significant negative correlation ($r = –0.42$, $p < 0.01$) indicates that lower Vitamin D concentrations are associated with poorer glycemic control among T2DM patients.

Discussion

The present prospective study was undertaken to evaluate serum Vitamin D levels in patients with Type 2 Diabetes Mellitus (T2DM) and to explore the correlation between Vitamin D status and glycemic control. Our findings revealed a high prevalence of Vitamin D deficiency (68%) among T2DM patients, with only 13.3% having sufficient serum 25(OH)D levels. Moreover, there was a statistically significant inverse correlation between serum Vitamin D levels and glycemic parameters including HbA1c, fasting blood glucose (FBG), and postprandial blood glucose (PPBG), indicating that lower Vitamin D levels are associated with poorer glycemic control.

These results are consistent with several previous studies, both nationally and internationally, that have highlighted the widespread occurrence of Vitamin D deficiency among diabetic individuals. A study by Bansal et al. in North India reported Vitamin D deficiency in over 70% of T2DM patients and demonstrated a similar negative correlation with HbA1c and FBG [1]. Likewise, Chiu et al. found that hypovitaminosis D was independently associated with insulin resistance and impaired β-cell function [2]. The presence of Vitamin D receptors (VDRs) in pancreatic β-cells and peripheral insulin-responsive tissues provides a mechanistic basis for the role of Vitamin D in modulating insulin secretion and sensitivity [3].

In our study, patients with sufficient Vitamin D levels (≥30 ng/mL) had significantly better glycemic profiles compared to those with deficient or insufficient levels. The mean HbA1c in Vitamin D sufficient individuals was 7.2%, whereas it was 8.5% in deficient patients, underscoring a clinically relevant difference. This finding supports the hypothesis that Vitamin D may exert a protective effect in glucose metabolism. Vitamin D is thought to enhance insulin action by promoting the expression of insulin receptors and facilitating glucose transport in target tissues [4]. Additionally, it may modulate inflammatory cytokines and reduce chronic low-grade inflammation, a known contributor to insulin resistance in T2DM [5].

Interestingly, we also observed that the prevalence of Vitamin D deficiency and poor glycemic control was more pronounced among female patients. This could be attributed to several socio-cultural and physiological factors including lesser outdoor activity, conservative clothing limiting sun exposure, higher body fat percentage, and post-menopausal hormonal changes, all of which can influence Vitamin D synthesis and metabolism [6]. Gender-specific strategies may therefore be warranted to address Vitamin D deficiency more effectively in diabetic women.

Another notable observation was the inverse relationship between the duration of diabetes and serum Vitamin D levels. Patients with longer disease duration (>10 years) exhibited significantly lower Vitamin D concentrations compared to those recently diagnosed. Chronic hyperglycemia and metabolic stress may lead to oxidative damage and impair Vitamin D metabolism over time. Furthermore, poor dietary habits and limited mobility in longstanding diabetics could further compromise their nutritional status, including Vitamin D levels [7].

While our study establishes a significant correlation between Vitamin D deficiency and poor glycemic control, it is important to recognize that correlation does not imply causation. Although several interventional studies and meta-analyses have attempted to evaluate the effect of Vitamin D supplementation on glycemic outcomes, the results remain inconclusive. Some trials have shown marginal improvement in insulin sensitivity and HbA1c levels following Vitamin D supplementation, particularly in those with baseline deficiency, while others have reported minimal or no effect [8–9]. Heterogeneity in study design, dosage, duration, and population characteristics could explain these discrepancies. The strengths of our study include a prospective design, use of standardized biochemical methods, and analysis of multiple glycemic parameters. However, it also has certain limitations. It was conducted at a single tertiary care center, thereby limiting its generalizability. The absence of a non-diabetic control group and lack of post-supplementation follow-up data restricts our ability to draw causal inferences. Furthermore, confounding variables such as sun exposure, dietary intake, physical activity, and seasonal variations were not comprehensively analyzed.

Despite these limitations, our findings have important clinical implications. Given the high prevalence of Vitamin D deficiency and its association with poor glycemic control, routine screening for Vitamin

D status in T2DM patients may be warranted. Early identification and correction of deficiency could serve as a low-cost, adjunctive strategy in diabetes management. Future randomized controlled trials with larger sample sizes and longer follow-up durations are needed to determine the therapeutic benefits of Vitamin D supplementation on glycemic and metabolic outcomes in T2DM patients.

Conclusion

This study underscores the high burden of Vitamin D deficiency in T2DM patients and its significant negative correlation with glycemic control. Routine screening and correction of Vitamin D deficiency may be considered as an adjunct to glycemic management in diabetic care protocols.

Recommendations

- Incorporation of Vitamin D screening in the routine assessment of T2DM patients
- Larger, multicentric studies and randomized controlled trials to evaluate the impact of supplementation on glycemic outcomes

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