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Original Article

Association Between Vitamin D Deficiency and Glycemic Control in Patients with Type 2 Diabetes Mellitus: A Cross-Sectional Study.

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is characterized by insulin resistance and progressive β-cell dysfunction, resulting in chronic hyperglycemia. Poor glycemic control increases the risk of microvascular and macro vascular complications. Vitamin D deficiency has emerged as a potential modifiable factor influencing glucose metabolism; however, evidence regarding its association with glycemic control remains inconsistent.

Objectives: To evaluate the association between serum vitamin D deficiency and glycemic control (HbA1c) among patients with type 2 diabetes mellitus attending a tertiary care hospital and to determine whether vitamin D deficiency is independently associated with poor glycemic control.

Methods: This cross-sectional study included 100 adults with T2DM attending the outpatient Department of Pulmonology, PIMS Islamabad from jan 2025 june 2025. Demographic, clinical, anthropometric, and laboratory data were collected. Serum glycated hemoglobin (HbA1c) was measured using high-performance liquid chromatography (HPLC), while serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using chemiluminescent immunoassay (CLIA). Vitamin D deficiency was defined as serum 25(OH)D <20 ng/mL.Data were analyzed using IBM SPSS Statistics version 27.0. Continuous variables were compared using the independent-samples t-test, categorical variables using the Chi-square test, Pearson's correlation coefficient was used to assess the relationship between serum vitamin D and HbA1c, and multivariable logistic regression analysis was performed to identify independent predictors of poor glycemic control. A p-value <0.05 was considered statistically significant.

Results: Vitamin D deficiency was identified in 62 (62%) participants, whereas 38 (38%) had sufficient serum vitamin D levels. (≥20 ng/mL). Mean HbA1c was significantly higher among vitamin D-deficient participants than non-deficient participants (8.9 ± 1.3% vs. 7.5 ± 1.2%; p<0.001). Poor glycemic control (HbA1c ≥7%) was more frequent in vitamin D-deficient patients (81.3% vs. 52.8%; p=0.003). Multivariable logistic regression demonstrated that vitamin D deficiency was independently associated with poor glycemic control (adjusted OR 3.21; 95% CI 1.36–7.59; p=0.008)

Conclusion: Vitamin D deficiency is highly prevalent among patients with T2DM and is independently associated with poor glycemic control. Prospective studies and randomized controlled trials are warranted to determine whether correction of vitamin D deficiency improves long-term glycemic outcomes.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is one of the most prevalent chronic metabolic disorders worldwide and represents a major public health challenge because of its increasing prevalence and associated morbidity and mortality. It is characterized by insulin resistance, progressive pancreatic β-cell dysfunction, and persistent hyperglycemia, resulting in long-term complications affecting the eyes, kidneys, nerves, cardiovascular system, and peripheral vasculature. The global burden of T2DM continues to rise, particularly in low- and middle-income countries, owing to increasing obesity, sedentary lifestyles, unhealthy dietary habits, and population aging. Despite advances in pharmacological therapy and lifestyle interventions, achieving optimal glycemic control remains challenging for many patients, highlighting the need to identify additional modifiable factors that may improve metabolic outcomes [1,2]. Vitamin D is a fat-soluble vitamin that plays a crucial role in calcium and phosphorus homeostasis and skeletal health. Emerging evidence suggests that vitamin D also exerts important extra-skeletal effects, including regulation of immune responses, inflammation, cell proliferation, and glucose metabolism. Vitamin D

receptors are expressed in pancreatic β-cells, skeletal muscle, and adipose tissue, indicating a potential role in insulin secretion and insulin sensitivity. Experimental studies have demonstrated that vitamin D enhances insulin receptor expression, promotes insulin-mediated glucose transport, and reduces systemic inflammation, thereby contributing to improved glucose homeostasis [3,4]. Vitamin D deficiency is common among individuals with T2DM and has been proposed as a potential contributor to poor glycemic control. Reduced sunlight exposure, obesity, aging, inadequate dietary intake, and decreased physical activity contribute to the high prevalence of vitamin D deficiency in diabetic populations. Deficiency may impair pancreatic β-cell function, reduce insulin secretion, and increase insulin resistance, ultimately leading to poor glycemic control [5]. Glycated hemoglobin (HbA1c) is the gold-standard biomarker for assessing long-term glycemic control because it reflects average blood glucose levels over the preceding two to three months. Elevated HbA1c is strongly associated with the development of diabetic microvascular and macrovascular complications. Therefore, identifying factors associated with elevated HbA1c is essential for optimizing diabetes management and reducing diabetes-related morbidity [6,7]. Several observational studies have investigated the association between serum vitamin D Levels and glycemic control; however, findings remain inconsistent. While many studies have demonstrated an inverse relationship between vitamin D status and HbA1c, others have reported weak or non-significant associations after adjustment for confounding variables such as age, obesity, duration of diabetes, and medication use. These discrepancies may reflect differences in ethnicity, geographic location, seasonal variation, laboratory methods, and study design [8,9]. Pakistan has a high prevalence of both T2DM and vitamin D deficiency, making these conditions significant public health concerns. Despite this, local evidence evaluating the association between vitamin D status and glycemic control remains limited. Better understanding of this relationship may facilitate early identification of patients at increased risk of poor metabolic control and support targeted preventive and therapeutic strategies. Therefore, this study was conducted to evaluate the association between vitamin D deficiency and glycemic control among patients with T2DM attending a tertiary care hospital in Pakistan [10].

Study Objectives

To examine the relationship between serum vitamin D deficiency and glycemic control (HbA1c levels) in patients with type 2 diabetes mellitus attending a tertiary care hospital and to determine whether vitamin D deficiency is independently associated with poor glycemic control.

MATERIALS AND METHODS

Study Design & Setting

This cross-sectional study was conducted in the Department of Medicine at PIMS Hospital Islamabad from January 2025 to June 2025. Adult patients with established type 2 diabetes mellitus attending the outpatient department during the study period were enrolled using consecutive non-probability sampling.

Participants

A total of 100 consecutive patients were recruited from the medical outpatient department who had been diagnosed with type 2 diabetes mellitus for at least 1 year. Demographic data, medical history, anthropometric measurements, and laboratory investigations were collected after obtaining written informed consent using a structured data collection form. Serum glycated hemoglobin (HbA1c) was measured using high-performance liquid chromatography (HPLC), while serum 25-hydroxyvitamin D 25(OH)D concentrations were measured using chemiluminescent immunoassay (CLIA) according to the manufacturer's instructions.

Sample Size Calculation

The sample size was calculated using the World Health Organization (WHO) Sample Size Calculator. Assuming a prevalence of vitamin D deficiency among patients with type 2 diabetes mellitus of 50%, a 95% confidence level, and a 10% margin of error, the minimum required sample size was calculated to be 96 participants. To enhance the study's precision and account for potential incomplete data, a total of 100 participants were enrolled through consecutive non-probability sampling.

INCLUSION CRITERIA

- Adults aged 18 years or older.
- Diagnosed with type 2 diabetes mellitus for at least 1 year.
- Both male and female patients.
- Patients attending the medical outpatient department during the study period.
- Willing to provide written informed consent.

EXCLUSION CRITERIA

- Patients with Type 1 Diabetes Mellitus.
- Women who are pregnant or breastfeeding.
- Patients who have been given Vitamin D in the last 3 months.
- People with chronic kidney disease (Stage IV and V), chronic liver disease, malabsorption syndromes, hyperparathyroidism, and other vitamin D metabolism disorders.
- Acute infection, malignant processes, and patients with incomplete clinical and laboratory data.

Diagnostic Management Strategy

All participants underwent a detailed clinical evaluation, including medical history, physical examination, and anthropometric measurements. Venous blood samples were collected to estimate glycated hemoglobin HbA1c, which was measured using high-performance liquid chromatography (HPLC), while serum 25-hydroxyvitamin D [25(OH)D] concentrations were measured using chemiluminescent immunoassay (CLIA). No study-specific therapeutic interventions were performed, and all participants continued to receive standard diabetes care in accordance with institutional clinical guidelines.

STATISTICAL ANALYSIS

Data were analyzed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. The normality of continuous variables was assessed using the Shapiro–Wilk test. Comparisons between vitamin D-deficient and non-deficient groups were performed using the independent-samples t-test for normally distributed continuous variables and the Chi-square test or Fisher's exact test, where appropriate, for categorical variables. Pearson's correlation coefficient (r) was calculated to assess the relationship between serum 25-hydroxyvitamin D [25(OH)D] levels and HbA1c. Variables with clinical relevance, including age, gender, body mass index (BMI), duration of diabetes, and vitamin D deficiency, were entered into a multivariable logistic regression model to identify independent predictors of poor glycemic control (HbA1c ≥7%). Results were expressed as adjusted odds ratios (AORs) with 95% confidence intervals (CIs). A two-tailed p-value <0.05 was considered statistically significant.

RESULTS

A total of 100 patients with type 2 diabetes mellitus were enrolled. The mean age of the participants was 54.8 ± 10.6 years (range: 31–78 years). There were 58 (58.0%) males and 42 (42.0%) females. The mean duration of diabetes was 8.1 ± 4.3 years, while the mean body mass index (BMI) was 29.1 ± 4.5 kg/m².The mean serum 25-hydroxyvitamin D [25(OH)D] level was 20.4 ± 8.3 ng/mL, and the mean HbA1c was 8.4 ± 1.5%. Vitamin D deficiency (<20 ng/mL) was identified in 62 (62.0%) participants, whereas 38 (38.0%) had sufficient vitamin D levels. Poor glycemic control (HbA1c ≥7%) was observed in 68 (68.0%) patients.

Table 1. Baseline Demographic and Clinical Characteristics of Patients with Type 2 Diabetes Mellitus (n = 100)

Variable	Value
Age (years), Mean ± SD	54.8 ± 10.6
Age Range (years)	31–78
Male, n (%)	58 (58.0)
Female, n (%)	42 (42.0)
Duration of Diabetes (years), Mean ± SD	8.1 ± 4.3
Body Mass Index (kg/m²), Mean ± SD	29.1 ± 4.5
Serum 25(OH) Vitamin D (ng/mL), Mean ± SD	20.4 ± 8.3
HbA1c (%), Mean ± SD	8.4 ± 1.5

Values are presented as mean ± standard deviation (SD) for continuous variables and frequency (percentage) for categorical variables. BMI = Body Mass Index; HbA1c = Glycated Hemoglobin; 25(OH)D = 25-Hydroxyvitamin D.

Table 2. Distribution of Vitamin D Status and Glycemic Control among Study Participants (n = 100)

Variable	Frequency (n)	Percentage (%)
Vitamin D Status		
Deficient (<20 ng/mL)	62	62.0
Sufficient (≥20 ng/mL)	38	38.0
Glycemic Control (HbA1c)		
Good Control (<7%)	32	32.0
Poor Control (≥7%)	68	68.0

Vitamin D deficiency was defined as serum 25-hydroxyvitamin D

concentration <20 ng/mL. Poor glycemic control was defined as HbA1c ≥7%, according to the American Diabetes Association recommendations.

Table 3. Comparison of Clinical Characteristics According to Vitamin D Status

Variable	Vitamin D Deficient (n = 62)	Vitamin D Sufficient (n = 38)	p-value
Age (years), Mean ± SD	55.6 ± 10.4	53.6 ± 10.9	0.356
Male, n (%)	35 (56.5)	23 (60.5)	0.694
BMI (kg/m²), Mean ± SD	30.0 ± 4.2	27.6 ± 4.3	0.008
Duration of Diabetes (years), Mean ± SD	8.9 ± 4.4	6.8 ± 3.8	0.018
HbA1c (%), Mean ± SD	8.9 ± 1.4	7.6 ± 1.2	<0.001

Continuous variables were compared using the independent-samples t-test, while categorical variables were compared using the Chi-square test. A p-value <0.05 was considered statistically significant.

Table 4. Multivariable Logistic Regression Analysis for Predictors of Poor Glycemic Control (HbA1c ≥7%)

Variable	Adjusted Odds Ratio (AOR)	95% Confidence Interval (CI)	P-value
Vitamin D Deficiency	3.21	1.36–7.59	0.008
Age (per one-year increase)	1.02	0.98–1.06	0.284
Male Sex	1.18	0.52–2.69	0.688
Body Mass Index (per kg/m² increase)	1.11	1.01–1.23	0.036
Duration of Diabetes (per one-year increase)	1.15	1.02–1.30	0.024

Multivariable logistic regression analysis was performed to identify independent predictors of poor glycemic control (HbA1c ≥7%). Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were calculated after adjustment for age, gender, body mass index, Duration of diabetes, and vitamin D deficiency. A p-value <0.05 was considered statistically significant.

Discussion

In the present study, vitamin D deficiency was highly prevalent among patients with type 2 diabetes mellitus (T2DM). Patients with vitamin D deficiency had significantly higher HbA1c levels than those without deficiency, and serum vitamin D concentrations were inversely correlated with HbA1c levels. Furthermore, vitamin D deficiency remained independently associated with poor glycemic control after adjustment for age, sex, body mass index, and duration of diabetes. These findings suggest that lower serum vitamin D levels may contribute to impaired glucose metabolism in patients with T2DM and are consistent with previous studies reporting an inverse association between serum vitamin D concentrations and glycemic control [11,12]. The vitamin D deficiency rate observed in this study is similar to rates reported in recent studies of Asian and Middle Eastern populations, which ranged between 50% and 75% among those with T2DM [13]. This high prevalence could be accounted for by the lower levels of physical activity outdoors, obesity, nutritional inadequacy, aging, and less sunlight exposure that are associated with diabetes patients. This is consistent with recent regional studies highlighting vitamin D deficiency as a prominent comorbidity in T2DM patients [14]. We observed a significant increase in HbA1c levels in vitamin D-deficient patients compared with those with adequate vitamin D levels. This finding is consistent with several cross-sectional studies demonstrating that lower serum 25-hydroxyvitamin D levels are associated with poorer glycemic control and higher HbA1c levels. This correlation is supported by biological evidence, as the vitamin D receptor is present in peripheral insulin-sensitive tissues and pancreatic β-cells. Vitamin D may promote insulin secretion, stimulate insulin receptor expression, inhibit inflammatory cytokines, and reduce insulin resistance, thereby playing a role in glucose homeostasis [15,16]. Our finding of a significant inverse correlation between serum vitamin D and HbA1c is consistent with observational studies showing that lower vitamin D levels predict higher HbA1c and fasting plasma glucose. Other investigators, however, have observed a weaker or non-significant correlation after controlling for obesity, diabetes duration, physical activity, and renal function. These variations may be due to ethnic differences, geographic location, seasonal differences in sunlight exposure, variations in laboratory assays, sample size, and study design [17,18]. The present study found that vitamin D deficiency was independently associated with poor glycemic control in the multivariable logistic regression analysis, even after adjustment for age, sex, body mass index, and duration of diabetes. Similar findings have been reported in recent observational studies, indicating that vitamin D deficiency is independently associated with metabolic dysregulation, even after accounting for traditional risk factors. Although causality cannot be inferred from observational studies, the consistency of these findings across different populations supports a clinically relevant

association between vitamin D status and glycemic control [19, 20]. In addition, the findings are corroborated by systematic reviews and meta-analyses. These analyses concluded that vitamin D supplementation might modestly decrease HbA1c, fasting blood glucose, fasting insulin, and insulin resistance, especially in patients with vitamin D deficiency, elevated BMI, and short-term high-dose protocols. The level of benefit remains relatively low, however, and there is significant variability across RCTs in dose, treatment duration, initial vitamin D level, and patient characteristics. Thus, along with the other approaches to diabetes treatment, vitamin D supplementation may be considered [21,22]. The clinical significance of the present study lies in its implications, especially in countries where T2DM and vitamin D deficiency are high-prevalence diseases. Periodic measurement of vitamin D levels in patients with poorly controlled diabetes could help identify those who may need vitamin D supplementation in addition to standard lifestyle modifications and pharmacotherapy. However, as this is a cross-sectional study, it does not allow for causal relationships to be established. To establish the long-term effects of vitamin D supplementation on glycemic control and the prevention of long-term diabetic complications, large, prospective, multicenter, randomized controlled trials are needed [23,24].

LIMITATIONS

This study has several limitations. The cross-sectional design makes it difficult to draw causal inferences about the relationship between vitamin D deficiency and glycemic control. The results might not apply to other larger centers or other groups due to the limited sample size (100 participants) and the single-center setting. Furthermore, dietary vitamin D intake, sunlight exposure, seasonal variations, physical activity, medication adherence, and other potential confounding factors were not fully evaluated. Prospective multicenter studies with larger sample sizes are necessary to confirm the results.

Conclusion

Vitamin D deficiency was highly prevalent among patients with type 2 diabetes mellitus and was significantly associated with poor glycemic control. Lower serum vitamin D levels were inversely correlated with HbA1c, suggesting a potential role of vitamin D in glucose metabolism. Routine assessment of vitamin D status may be considered in patients with poorly controlled T2DM. However, due to the cross-sectional design of this study, a causal relationship cannot be established. Large prospective studies and randomized controlled trials are warranted to determine whether correction of vitamin D deficiency improves long-term glycemic outcomes and reduces diabetes-related complications.

Disclaimer: Nil

Conflict of Interest: Nil

Funding Disclosure: Nil

Ethical Approval

Ethical approval was obtained from the Institutional Research and Ethics Board, PIMS Islamabad (Approval No. 1431/04/PIMS/IRB/2024) before the study commenced. The study was conducted in accordance with the Declaration of Helsinki (2013).

Informed Consent

Written informed consent was obtained from all participants before enrollment in the study.

Authors' Contributions

Muhammad Salman: Conceived and designed the study; collected, analyzed, and interpreted the data; drafted and critically revised the manuscript for important intellectual content; approved the final version of the manuscript; and agrees to be accountable for all aspects of the work in accordance with the **ICMJE authorship criteria.**

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