Evaluation of Metabolic and Nutritional Biomarkers across varying Glycaemic Control States in Type 2 Diabetes Mellitus

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ABSTRACT

Background: Type 2 Diabetes Mellitus (T2DM) is a multifactorial metabolic disorder with rising global prevalence, particularly in India. Glycemic control, commonly monitored using glycated hemoglobin (HbA1c), influences not only glucose homeostasis but also several metabolic and nutritional biomarkers. Among these, Vitamin D_3 has garnered interest for its emerging role in glucose metabolism and insulin sensitivity. However, the association of glycemic control with serum Vitamin D_3, fasting blood sugar (FBS), total cholesterol (TC), and body mass index (BMI) remains underexplored in Indian diabetic populations.

Objective: To evaluate the association of varying glycemic control states (good, unsatisfactory, and poor) with metabolic and nutritional biomarkers—serum Vitamin D_3, FBS, TC, and BMI—in patients with Type 2 Diabetes Mellitus.

Methods: A cross-sectional observational study was conducted from December 2023 to December 2024 at Index Medical College and Hospital, Indore. A total of 200 T2DM patients aged 30–70 years were enrolled. HbA1c was used to categorize participants into three groups: good control (HbA1c 5.7–8%), unsatisfactory control (HbA1c 8.1–8.9%), and poor control (HbA1c $\geq$ 9%). Serum 25-hydroxy Vitamin D_3 [25(OH)D] was estimated using the VIDAS Immunoassay analyzer; HbA1c, FBS, TC, and BMI were also assessed using standard methods. Statistical analysis was performed using SPSS v22, employing descriptive statistics, one-way ANOVA, and multivariate regression.

Results: Among 200 participants, 47% were male and 53% female. The mean HbA1c was $8.72 \pm 0.70\%$, indicating overall poor glycemic control. A significant inverse relationship was observed between HbA1c levels and Vitamin D_3 levels ($p < 0.001$), with patients in the good control group having the highest mean Vitamin D_3 levels (26.53 ± 6.45 ng/mL) and the poor control group the lowest (12.51 ± 5.73 ng/mL). FBS also showed significant variation across glycemic control groups ($p < 0.001$). However, total cholesterol ($p = 0.086$) and BMI ($p = 0.72$) did not differ significantly among groups.

Conclusion: This study highlights a significant inverse association between Vitamin D_3 levels and glycemic control in T2DM patients, along with significant variations in fasting glucose. These findings suggest that Vitamin D_3 may play a contributory role in glycemic regulation. Regular screening and potential correction of Vitamin D_3 deficiency could support better metabolic outcomes in diabetic care. Further longitudinal and interventional studies are needed to establish causality and therapeutic benefit.

Keywords: Type 2 Diabetes Mellitus, Glycemic Control, Vitamin D_3, HbA1c, Fasting Blood Sugar, Body Mass Index, Total Cholesterol, India.

INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a complex and progressive metabolic disorder marked by chronic hyperglycemia due to insulin resistance and/or impaired insulin secretion. It accounts for over 90% of all diabetes cases worldwide and is increasingly prevalent in both developed and developing nations, including India, where lifestyle transitions have significantly contributed to its rising burden. Uncontrolled blood glucose levels in T2DM are associated with multiple microvascular and macrovascular complications, necessitating stringent monitoring of glycemic status.

Glycated hemoglobin (HbA1c) is widely recognized as a reliable indicator of long-term glycemic control, reflecting average plasma glucose concentrations over the preceding 8 to 12 weeks. Based on HbA1c values, glycemic control can

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be categorized as good, unsatisfactory, or poor, which provides clinical insight into disease progression and therapeutic outcomes.

Beyond glucose regulation, T2DM is also linked to alterations in various metabolic and nutritional biomarkers, including fasting blood sugar (FBS), serum lipids, body mass index (BMI), and micronutrients such as Vitamin D_3. Vitamin D_3, a secosteroid hormone traditionally known for its role in calcium and bone homeostasis, has recently been implicated in insulin secretion, glucose metabolism, and inflammation. Deficiency of Vitamin D_3 is frequently reported among individuals with T2DM and may exacerbate poor metabolic control.

Despite emerging evidence, the association between glycemic control and metabolic- nutritional parameters, particularly Vitamin D_3, remains inadequately understood and inconsistently reported across different populations. Understanding these associations may provide insights into adjunctive strategies for comprehensive diabetes management.

This study aims to evaluate the relationship between varying glycemic control states— categorized as good, unsatisfactory, and poor—and key metabolic and nutritional biomarkers, including serum Vitamin D_3 levels, fasting blood glucose, total cholesterol, and BMI, in patients with Type 2 Diabetes Mellitus. [1-4]

METHODOLOGY[5-7]

Study Design: A cross-sectional observational comparative study

Study Setting: The study was conducted at Index Medical College and Hospital, located in Indore, Madhya Pradesh, India.

Study Duration: Dec.2023 to Dec.2024

Sample size &Study Population

The study enrolled total of 200 T2DM patients, aged 30 to 70 years who have been diagnosed with T2DM for at least six months and are attending the outpatient or inpatient departments of Index Medical College and Hospital.

Inclusion Criteria

- A confirmed diagnosis of Type 2 Diabetes Mellitus (T2DM) for at least six months.
- Age between 30 and 70 years.
- Willingness to participate in the study and provide informed consent.

Exclusion Criteria

- Current or recent (within the last 3 months) use of Vitamin D supplements.
- Chronic kidney disease, hepatic failure, or any malabsorption syndromes that may affect Vitamin D metabolism.
- Pregnant or lactating women.

Data Collection

- Demographic and Clinical Information: including age, sex, body mass index (BMI), duration of diabetes, and dietary habits was collected by taking persona interview and Anthropometric parameter was recorded by using standard measurements.

Laboratory Investigations:

o Serum 25-hydroxy Vitamin D [25(OH)D], was estimated by using VIDAS Immunoassay analyser
o HbA1c was estimated **by using Bio-Rad D-10 HbA1c program**
o Fasting blood glucose (FBS) was done by Hexokinase method using Roche/Hitachi COBAS fully automated analyser
o Lipid profile was done by enzymatic methods

Statistical Analysis was done by using latest SPSS software version 22

- Descriptive analysis
- Correlation Analysis: Pearson or Spearman correlation coefficients will be used to assess the relationship between serum Vitamin D levels and HbA1c in the study participants.
- Multivariate Regression: To control for potential confounding factors (such as age, sex, BMI, and duration of diabetes), multivariate regression models employed to analyse the association.
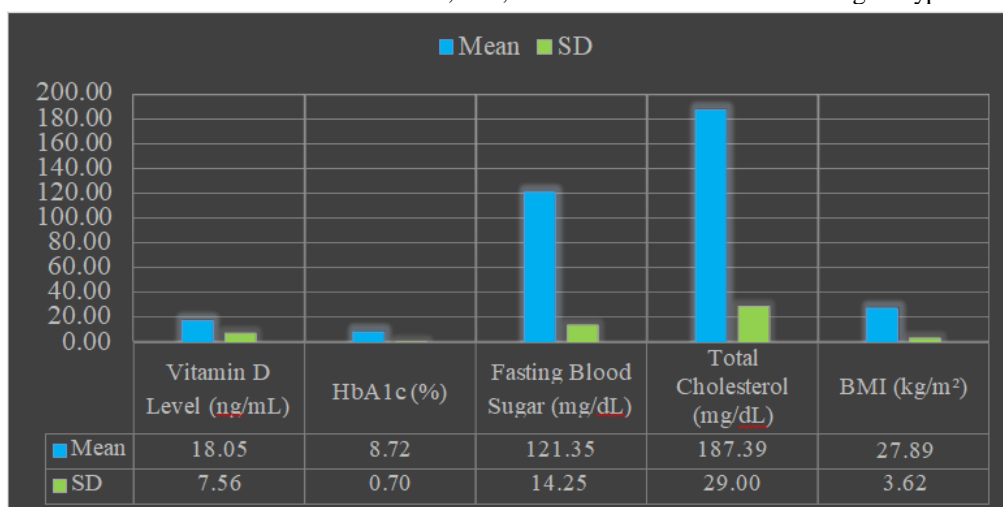
RESULT

The present study comprises of 200 patients, all cases of Type II DM. The overall distribution of patients by gender is shown in graph1.

Graph 1: Distribution of patients by gender

Chart Title

	TYPE 2 DM PATIENTS	PERCENTAGE
FEMALE	106	53
MALE	94	47
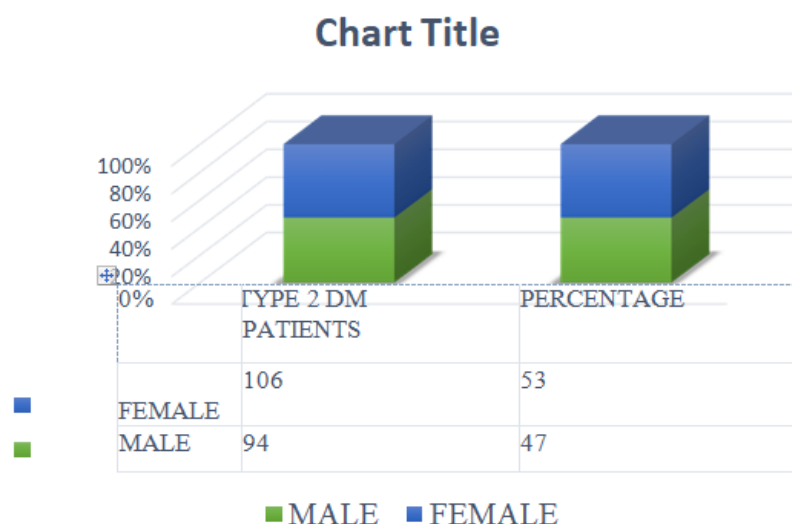
■ MALE ■ FEMALE

Out of these 94 (47%) were male and 106 (53%) were female type 2 Diabetes mellitus patient.

Graph 2: Mean± S.D. value of vitamin D levels HbA1c,FBS, total cholesterol and BMI among all type 2 DM.

	Vitamin D Level (ng/mL)	HbA1c (%)	Fasting Blood Sugar (mg/dL)	Total Cholesterol (mg/dL)	BMI (kg/m²)
■Mean	18.05	8.72	121.35	187.39	27.89
■SD	7.56	0.70	14.25	29.00	3.62

Graph 2 displays the mean ± standard deviation (SD) values of Vitamin D level, glycemic control parameters, lipid status, and BMI among 200 patients with Type II Diabetes Mellitus. The mean Vitamin D level was 18.05 ± 7.56 ng/mL, indicating a predominance of Vitamin D deficiency in this cohort. The mean HbA1c was 8.72 ± 0.70%, showing poor glycemic control in most patients. The mean fasting blood sugar (FBS) was 121.35 ± 14.25 mg/dL, suggesting ongoing hyperglycemia. Total cholesterol had a mean value of 187.39 ± 29.00 mg/dL, nearing borderline high levels. The mean Body Mass Index (BMI) was 27.89 ± 3.62 kg/m², categorizing the majority of subjects as overweight, further compounding metabolic risk.

Table-1: Comparison of mean, S.D, f-value and p-value of measured parameters of good, unsatisfactory and poor glycemic control.

PARAMETER	Group A (Good) HbA1c 5.7-8%		Group B (unsatisfactory) HbA1c 8.1-8.9%		Group C (Poor) HbA1c ≥ 9%			
	Mean	SD	Mean	SD	Mean	SD	f-value	p-value
Vitamin D levels (ng/ml)	26.53	6.45	19.67	5.61	12.51	5.73	54.62	<0.001*
FBS (mg/dl)	105.11	12.76	118.98	10.58	131.01	11.26	30.43	<0.001*
TC (mg/dl)	175.23	29.53	189.22	29.75	189.94	26.25	2.49	0.086
BMI	27.79	3.42	27.68	3.49	28.21	3.82	0.33	0.72

*P <0.05 was considered as statistically significant

A one-way ANOVA was conducted to compare the effect of glycemic control status (based on HbA1c) on various metabolic parameters. There was a statistically significant difference in Vitamin D levels [F= 54.62, p < 0.001] and fasting blood sugar (FBS) [F= 30.43, p < 0.001] among the three glycemic control groups. However, total cholesterol [F= 2.49, p = 0.086] and BMI [F = 0.33, p = 0.72] did not significantly differ across the groups.

DISCUSSION

This cross-sectional study aimed to explore the relationship between glycemic control and metabolic parameters such as Vitamin D levels, fasting blood sugar (FBS), total cholesterol, and body mass index (BMI) in patients with Type II Diabetes Mellitus (T2DM). A total of 200 patients were enrolled, with a slightly higher representation of females (53%) compared to males (47%).

The overall mean HbA1c level was 8.72 ± 0.70%, indicating poor glycemic control in the majority of the population. The mean Vitamin D level was 18.05 ± 7.56 ng/mL, which is below the threshold of sufficiency defined by the Endocrine Society (>30 ng/mL), pointing to a widespread Vitamin D deficiency among diabetic individuals. This finding is consistent with prior studies that have documented high rates of Vitamin D deficiency in T2DM patients, particularly in South Asian regions where sun exposure may not correlate with adequate serum levels due to lifestyle and pigmentation factors[11,12].

The results of one-way ANOVA revealed a statistically significant inverse relationship between glycemic control and Vitamin D levels (F = 54.62, p < 0.001). Patients in the well- controlled group (HbA1c 5.7–8%) had significantly higher Vitamin D levels (mean = 26.53 ng/mL) compared to those with poor control (≥9%), who had a mean of 12.51 ng/mL. This supports the hypothesis that Vitamin D may play a regulatory role in insulin secretion and sensitivity via pancreatic β-cell function and modulation of inflammatory responses[13].

Fasting blood sugar (FBS) also showed a significant variation among groups (F = 30.43, p < 0.001), with progressively higher FBS levels in the poor glycemic control group. These findings align with prior literature linking Vitamin D insufficiency to insulin resistance and elevated blood glucose levels[14].

Interestingly, total cholesterol (TC) and BMI did not show statistically significant differences among the HbA1c-defined groups (p = 0.086 and p = 0.72, respectively). This indicates that while dyslipidemia and obesity are common comorbidities in T2DM, they may not directly correlate with the degree of glycemic control. The relationship between BMI and Vitamin D is complex and may be influenced by Vitamin D sequestration in adipose tissue, as previously reported[15], though this was not evident in the current data.

Overall, the findings reinforce the possible influence of Vitamin D status on glycemic control. Whether Vitamin D supplementation could serve as an adjunct therapy to improve glucose metabolism in T2DM patients remains an area for future interventional studies.

CONCLUSION

The present study highlights a significant inverse association between Vitamin D levels and glycemic control in patients with Type II Diabetes Mellitus. Individuals with better glycemic control exhibited higher Vitamin D levels, whereas those with poor control had significantly lower levels. Fasting blood glucose also differed significantly across glycemic control categories, supporting the interrelationship between Vitamin D and glucose metabolism. However, no significant association was found with total cholesterol and BMI. These findings suggest the potential role of Vitamin D in diabetes management and underscore the importance of routine screening for Vitamin D deficiency in diabetic patients.

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