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Original Research Article

Evaluation of the Correlation Between Serum Vitamin D Levels and Glycemic Control in Patients with Type 2 Diabetes Mellitus

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Abstract:

Background: Type 2 Diabetes Mellitus (T2DM) is a growing global health concern, with poor glycemic control leading to serious complications. Emerging evidence suggests a role of vitamin D in glucose metabolism.

Aim: To evaluate the correlation between serum vitamin D levels and glycemic control (HbA1c) in T2DM patients.

Methodology: A cross-sectional study was conducted on 50 T2DM patients aged 30–70 years. Serum 25(OH)D levels were measured using CLIA and HbA1c by HPLC. Vitamin D status was categorized as deficient, insufficient, or sufficient. Correlation was analyzed using Pearson's coefficient.

Results: Vitamin D deficiency was observed in 62% of patients, while 72% had poor glycemic control. Mean HbA1c was highest in deficient (8.4±1.1%) and lowest in sufficient groups (6.7±0.6%). Most deficient patients (26/31) had poor control, whereas better control was seen with sufficient vitamin D levels.

Conclusion: An inverse relationship exists between vitamin D levels and HbA1c. Vitamin D deficiency is associated with poor glycemic control, suggesting its potential role in T2DM management.

Keywords: Type 2 Diabetes Mellitus, Vitamin D, HbA1c, Glycemic Control, Insulin Resistance.

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Introduction

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder associated with resistance to insulin and progressive β-cell dysfunction causing sustained hyperglycemia. With time, chronic hyperglycemia causes microvascular and macrovascular complications such as retinopathy, nephropathy, neuropathy and cardiovascular complication, which are significant causes of morbidity and mortality [1]. T2DM is one of the greatest health challenges facing the world today and its rate of occurrence is rising at an alarming rate in all the developed and developing countries. Based on the current epidemiological patterns, diabetes is likely to create a significant burden in the next few decades, which will cause a massive burden on the healthcare systems of various countries in the world [2].

The country of India is also known as the capital of the World in terms of diabetes as the number of patients with T2DM is growing especially fast there. This increase has been blamed on both genetic prone and environmental factors including urbanization, sedentary lifestyles, poor dietary habits and rising obesity. Also, socio-economic changes and lack of physical exercise have also enhanced the incidence of T2DM both in urban and rural settings. The increasing trends of diabetes in India highlight the necessity to find a solution to the modifiable risk factors and to develop new options to support the management of the disease and the prevention of complications [3].

Over the last few years, Vitamin D has become one of the potential factors that affect glucose metabolism and general metabolic health. Once established as a vital part of the calcium homeostasis and bone mineralization, Vitamin D is currently known to have numerous extra-skeletal activities. Vitamin D receptors (VDR) are found on a wide range of tissues such as pancreatic 9 of the 10 -cells, skeletal muscle, fat tissue, and immune cells [4]. This ubiquity is indicative of the possibility that Vitamin D can have an important part in other non-skeletal physiological functions, such as immune regulation, inflammation, and metabolism.

Calcitriol is the biologically active form of Vitamin D, which is thought to have a direct effect on insulin secretion through binding to VDRs located on the

pancreatic β- cells. It can also control the levels of intracellular calcium that is very important in processes of insulin mediation. Moreover, Vitamin D was reported to increase insulin sensitivity in peripheral tissues including skeletal muscle and adipose tissue by increasing the expression of insulin receptors and augmenting in glucose uptake. Besides these mechanisms, Vitamin D is also an anti-inflammatory agent, which can also help reverse chronic low-grade inflammation, one of the major causative factors of insulin resistance and T2DM pathogenesis [5].

There is increasing evidence that indicates that Vitamin D deficiency is strongly correlated with the development and the progression of T2DM. It has been epidemiologically reported that 25-hydroxyvitamin D [25(OH)D] is lower in the people who are at a higher risk of developing impaired glucose tolerance and T2DM. Additionally, Vitamin D deficiency is also attributed to the inadequate glycemic control in patients who have already been diagnosed with diabetes [6]. HbA1c, a good biomarker of glycemic control over a long period of time, has been established to be negatively correlated with serum Vitamin D levels. The HbA1c levels have been identified to be higher with lower Vitamin D levels, which leads to poorer glycemic control.

In spite of these findings, Vitamin D status and glycemic control have not been conclusively found to be related in various populations. The difference in the outcomes of the studies can be explained by geographical position, the amount of sunlight exposed, food that was taken, the pigmentation of the skin, the cultural value and genetic predisposition. As an example, the population of those areas where there is a shortage of sunlight is more likely to experience Vitamin D deficiency that can, in its turn, affect the metabolic results. On the same note, the food diet and the consumption of food rich in Vitamin D or fortified foods are also not even across regions, which also adds to the disparities in Vitamin D status [7].

This is a common phenomenon in India where Vitamin D deficiency is one of the most widespread even in an environment where sunlight is abundant, which is commonly known as the Vitamin D paradox. Indoor living, air pollution, and use of sun protection, traditional cloths, and dietary insufficiency due to limited sources of Vitamin D among the populace are some of the causes of poor Vitamin D levels among the people. This systemic deficiency could have significant consequences in the metabolic health of people with T2DM [8]. Nonetheless, the existing region-specific data examining the relationship between Vitamin D levels and glycemic control mainly concerns the states in Europe and North America, whereas in such states as Bihar, socio-economic and environmental factors might have additional effects on the health outcomes.

It is of clinical significance to understand the relationship between serum Vitamin D and glycemic control. In case a meaningful correlation is determined, it is possible that Vitamin D supplementation is a simple inexpensive adjunctive tool in the treatment of T2DM. This may be especially useful in resource-starved environments, where other more sophisticated therapies may be minimal. Also, prevention and treatment of Vitamin D deficiency can be performed at an early age and consequently cause an increase in insulin sensitivity, a better functioning of the 1 -cells and eventually achieve improved glycemic results.

Considering the growing impact of T2DM and excessive rates of Vitamin D deficiency, there is a necessity of thorough research to investigate their connection in particular groups of people. The proposed study will assess the relationship between serum Vitamin D and glycemic control, as determined by the HbA1c, in T2DM patients in Bihar. Through this association, the study aims at making a contribution to the already available body of knowledge and giving insights on how diabetes can be integrative approached.

Methodology

Study Design and Setting: This study was designed as a cross-sectional, observational study conducted in the Department of Biochemistry at Virat Ramayan Institute of Medical Science, located in Koyla Belwa, Chakiya, Motihari, Bihar, India.

Study Area: The study was carried out in the central laboratory of the Department of Biochemistry, which provides diagnostic services to both outpatient and inpatient departments of the institute. The setting ensured access to a heterogeneous group of patients diagnosed with Type 2 Diabetes Mellitus, thereby allowing for a representative sample within the defined study period.

Study Duration: The total duration of the study was three months. During this period, patient recruitment, clinical data recording, blood sample collection, biochemical analysis, and data compilation were systematically completed.

Sample Size: A total of 50 patients diagnosed with Type 2 Diabetes Mellitus were included in the study. The sample size was determined based on feasibility within the limited study duration and available patient flow in the department.

Study Population: The study population consisted of adult patients diagnosed with Type 2 Diabetes Mellitus who attended the outpatient and inpatient departments of the institute during the study period. Patients represented varying durations of disease and treatment modalities, providing a broad overview of glycemic control status in relation to vitamin D levels.

Inclusion Criteria

- Patients aged 30–70 years
- Confirmed diagnosis of Type 2 Diabetes Mellitus as per American Diabetes Association (ADA) criteria
- Patients willing to provide written informed consent

Exclusion Criteria

- Patients with Type 1 Diabetes Mellitus
- Chronic kidney disease
- Chronic liver disease
- Malabsorption syndromes
- Patients on vitamin D supplementation within the last 6 months
- Pregnant or lactating women

Data Collection: After obtaining written informed consent, detailed demographic and clinical information was collected from each participant using a structured proforma. This included age, gender, duration of diabetes, and treatment history. Venous blood samples were collected under aseptic conditions and processed in the laboratory for further biochemical analysis.

Biochemical Analysis: Serum levels of 25-hydroxyvitamin D [25(OH)D] were measured using chemiluminescent immunoassay (CLIA). Based on standard reference values, vitamin D levels were categorized as deficient (<20 ng/mL), insufficient (20–30 ng/mL), or sufficient (>30 ng/mL). Glycemic control was assessed by measuring glycated hemoglobin (HbA1c) using high-performance liquid chromatography (HPLC). HbA1c levels below 7% were considered indicative of good glycemic control, while levels of 7% or higher were classified as poor control.

Procedure: All eligible patients were screened according to the inclusion and exclusion criteria. Upon enrollment, relevant clinical data were recorded, and blood samples were collected following standard protocols. The samples were analyzed in the Department of Biochemistry, and results for serum vitamin D and HbA1c were documented. The obtained values were then categorized and prepared for statistical analysis.

Statistical Analysis: All collected data were entered into Microsoft Excel and analyzed using SPSS version 25. Descriptive statistics such as mean, standard deviation, and percentages were used to summarize baseline characteristics. The correlation between serum vitamin D levels and HbA1c was assessed using Pearson's correlation coefficient. A p-value of less than 0.05 was considered statistically significant."

Result

Table 1 summarizes the demographic and baseline characteristics of the 50 patients in the study. Out of the total participants, 27 (54%) were male and 23 (46%) were female, showing a slight male predominance. The mean age of the study population was 55.6 ± 9.5 years, indicating that most patients were middle-aged to older adults. Overall, the table reflects a relatively balanced gender distribution with a predominance of patients in the later age group.

Table 1: Demographic and Baseline Characteristics (n = 50)

Variable	Value
Total Patients	50
Male	27 (54%)
Female	23 (46%)
Mean Age (years)	55.6 ± 9.5

Table 2 shows the distribution of Vitamin D status among the patients. A majority of participants, 31 (62%), were Vitamin D deficient (<20 ng/mL). Additionally, 11 patients (22%) were classified as insufficient (20–30 ng/mL), while only 8 patients (16%) had sufficient Vitamin D levels (>30 ng/mL). This indicates that most of the study population had suboptimal Vitamin D levels, with deficiency being the most prevalent condition.

Table 2: Distribution of Vitamin D Status

Vitamin D Status	Number of Patients	Percentage (%)
Deficient (<20 ng/mL)	31	62%
Insufficient (20–30 ng/mL)	11	22%
Sufficient (>30 ng/mL)	8	16%

Table 3 presents glycemic control based on HbA1c levels among the patients. The majority of patients, 36 (72%), had poor glycemic control with HbA1c ≥7%, while only 14 patients (28%) achieved good control with HbA1c <7%. This indicates that a significant proportion of the study population had suboptimal glycemic control.

Table 3: Glycemic Control Based on HbA1c		
HbA1c Category	**Number of Patients**	**Percentage (%)**
Good Control (<7%)	14	28%
Poor Control (≥7%)	36	72%

Table 4 shows the relationship between Vitamin D status and glycemic control among the study participants. Among those with Vitamin D deficiency, a large majority had poor glycemic control (26 patients) compared to only 5 with good control. In the insufficient group, 7 patients had poor control while 4 maintained good control. Conversely, in the sufficient Vitamin D group, more patients had good glycemic control (5 patients) than poor control (3 patients). This pattern indicates that better Vitamin D status is associated with improved glycemic control, while deficiency is strongly linked to poorer outcomes.

Table 4: Vitamin D Status vs. Glycemic Control		
Vitamin D Status	**Good Control (n)**	**Poor Control (n)**
Deficient	5	26
Insufficient	4	7
Sufficient	5	3

Table 5 shows the mean HbA1c levels according to Vitamin D status. Patients with Vitamin D deficiency had the highest mean HbA1c (8.4% ± 1.1), indicating poorer glycemic control. Those with insufficient Vitamin D levels had a lower mean HbA1c of 7.6% (± 0.9), while patients with sufficient Vitamin D levels had the lowest mean HbA1c at 6.7% (± 0.6). This trend suggests an inverse relationship between Vitamin D levels and HbA1c, where better Vitamin D status is associated with improved glycemic control.

Table 5: Mean HbA1c by Vitamin D Status		
Vitamin D Status	**Mean HbA1c (%)**	**Standard Deviation**
Deficient	8.4	1.1
Insufficient	7.6	0.9
Sufficient	6.7	0.6

Discussion

The current research showed that 62 percent of patients were vitamin D deficient with another 22 percent exhibiting insufficiency, which means that a significant number of individuals with Type 2 Diabetes Mellitus have a high burden of hypovitaminosis D. The result is comparable to previous studies among similar populations. As an example, Abubaker et al. (2022) [9] found that the prevalence of vitamin D deficiency among diabetic patients in Saudi Arabia is high, which supports the idea that vitamin D deficiency is a widespread phenomenon in patients with diabetes in different geographical locations. Likewise, the findings of Salih et al. (2021) [10] show that most of their diabetic group had inadequate vitamin D in their cohort, which is very close to ours. Nevertheless, disparities in prevalence rates have been reported, which is probably because of differences in sunlight exposure, dieting habits, and demographic traits. As an illustration, Haidari et al. (2016) [11] have found comparatively lower deficiency in a non-obese diabetic cohort, indicating that further effects of obesity and lifestyle on the status of vitamin D could be present."

Regarding glycemic control, our study determined that 72 percent of the patients were poor glycemic controllers (HbA1c 7-percent and higher) which is similar to the trends seen in other observational studies. The lack of glycemic control by a group of diabetics has been very well reported, especially in developing nations where access to healthcare and lifestyle change may not be optimal. The fact that poor glycemic control is correlated with vitamin D deficiency in our study is evidenced by the fact that Pittas et al. (2007) [12] reported that low vitamin D levels were correlated with the impaired glucose metabolism and insulin resistance.

Our findings indicated that a much larger proportion of vitamin D-deficient subjects (26 of 31) had poor glycemic control than the numbers of those with adequate levels, which had good glycemic control. This tendency is aligned with the conclusions of Salih et al. (2021) [10], who indicated that, in patients with Type 2 Diabetes Mellitus, low levels of vitamin D are associated with high values of HbA1c levels. Moreover, it was additionally noticed by Haidari et al. [11] that reduced serum vitamin D concentration was linked to increased HbA1c and inflammatory agents, indicating a multicomponent impact of vitamin D on the regulation of metabolism. These correlations reinforce the cases in favor of a negative correlation between the status of vitamin D and the glycemic control.

This connection is further supported by the mean values of HbA1c, where the highest values are in the group of patients who were deficient in vitamin D (8.4 ± 1.1%), and the lowest values were in the group of patients who had adequate levels of vitamin D (6.7 ± 0.6%). Such graded relationship corresponds to the dose-response association observed by Mohammadi et al. (2022) [13] who discovered that the reduction in the level of vitamin D was strongly linked to the heightened risk of Type 2 Diabetes and worse glycemic results. Equally, El Lithy et al. (2014) [14] in their study on gestational diabetes also established that less vitamin D levels had higher relationship with higher HbA1c implying that the association could be an extension to other types of glucose intolerance.

Interventional studies have not given a consistent result in spite of the consistency of observational findings. Indicatively, Nikooyeh et al. (2011) [15] indicated that the use of vitamin D-enriched yogurt had a significant positive effect on the level of HbA1c in the Type 2 Diabetes patients indicating potential benefits of the supplementation. Conversely, Jorde and Figenschau (2009) [16] established that the glycemic control in patients with normal baseline vitamin D levels was not enhanced significantly by the vitamin D supplementation, which is an indication that the effects of supplementation could be restricted to patients with deficiencies. Equally, Soric et al. (2012) [17] noted that post-supplementation HbA1c changes were only slightly positive, indicating inconsistency in responses. George et al. (2012) [18] also identified a systematic review and meta-analysis in which they concluded that although vitamin D supplementation might have a small effect on insulin resistance, its effect on HbA1c was not always significant across studies.

These opposing results indicate that our study results have a strong connection between poor glycemic control and vitamin D deficiency, but this cannot be conclusively determined. Factors like the baseline level of vitamin D, a span of diabetes, the dosage and the length of the supplement intake and differences in individual metabolism can change the outcome. Also, the environment and behaviors like sunlight exposure, dietary food, and physical activity which we did not control might serve as confounders and cause variation in findings in our study.

Comprehensively, the results of the current research article are broadly consistent with the available literature, proving the high rates of vitamin D deficiency and its linkage with inadequate glycemic control, among patients with Type 2 Diabetes Mellitus. Nevertheless, the differences in the interventional studies indicate that sound longitudinal and randomized controlled trials are required to comprehend the causal relationship and therapeutic implications of vitamin D in treatment of diabetes better.

Conclusion

The research indicates that serum vitamin D level is significantly correlated with the glycemic control among type 2 diabetes mellitus patients. Low vitamin D levels were associated with worse glycemic control in patients, whereas sufficient levels were associated with better control of glucose in the blood. Also, there was a tendency of mean HbA1c levels to decline with improvement in vitamin D status implying that vitamin D status was inversely correlated with glycemic markers. These results suggest that vitamin D deficiency can also be associated with poor glycemic control and demonstrate the possible significance of ensuring that the level of vitamin D remains at an optimal level in diabetes management.

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