Section: Miscellaneous

Original Research Article

ASSOCIATION BETWEEN SERUM VITAMIN D LEVELS AND GLYCEMIC CONTROL IN PATIENTS WITH TYPE 2 DIABETES MELLITUS: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Vitamin D deficiency is common in patients with type 2 diabetes mellitus (T2DM) and has been proposed to influence glycemic control through effects on insulin secretion and sensitivity. Data from eastern India remains limited. This study aimed to determine the prevalence of vitamin D deficiency and its association with glycemic control among patients with T2DM.

Materials and Methods: This cross-sectional observational study was conducted among 150 patients with T2DM, aged 18-65 years, attending MGM Medical College and Hospital, Jamshedpur, Jharkhand, over one year (June 2025-June 2026). Serum 25-hydroxyvitamin D, HbA1c, fasting blood glucose, lipid profile, calcium, and albuminuria were estimated, along with demographic and lifestyle data. Vitamin D status was categorized as deficient, insufficient, or sufficient. Correlation, ANOVA, t-test, and chi-square tests were applied, with $p<0.05$ considered significant.

Results: Mean serum vitamin D was 16.61 +/- 5.72 ng/mL; 70.0% of patients were deficient and 30.0% insufficient. Vitamin D correlated significantly and inversely with HbA1c ($r=-0.966$, $p<0.001$) and fasting blood glucose ($r=-0.938$, $p<0.001$). Mean HbA1c was significantly higher in deficient (8.47 +/- 0.84%) than insufficient patients (6.73 +/- 0.27%) ($p<0.001$). Vitamin D also correlated with BMI, lipid profile, albuminuria, calcium, smoking, and physical activity (all $p<0.001$), and was significantly lower in males than females.

Conclusion: Vitamin D deficiency was highly prevalent and strongly associated with poorer glycemic control among patients with T2DM in this population, supporting consideration of vitamin D screening as part of comprehensive diabetes care, pending confirmation from longitudinal and interventional studies.

Keywords: Vitamin D deficiency; Type 2 diabetes mellitus; Glycemic control; HbA1c; Cross-sectional study; Jharkhand.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by insulin resistance and progressive pancreatic beta-cell dysfunction, and it continues to rise in prevalence worldwide, placing a substantial burden on healthcare systems, particularly in low- and middle-income countries. Alongside conventional determinants of glycemic control, several micronutrients have drawn attention for their possible role in modulating insulin action, and vitamin D is among the most widely studied of these. Vitamin D, traditionally recognized for its role in calcium homeostasis and skeletal health, has more recently been implicated in glucose metabolism through its influence on pancreatic beta-cell function, insulin secretion, and peripheral insulin sensitivity. Vitamin D receptors and the enzyme 1-alpha-hydroxylase are expressed in pancreatic beta cells and skeletal

muscle, and vitamin D is believed to regulate insulin secretion directly, as well as indirectly through modulation of extracellular calcium flux required for insulin exocytosis.[1-3]

Cross-sectional studies from several regions have consistently reported a high prevalence of vitamin D deficiency among patients with T2DM.[1,10,25] A number of these analyses have further demonstrated an inverse relationship between serum 25-hydroxyvitamin D and glycated hemoglobin (HbA1c), suggesting that lower vitamin D status may correlate with poorer glycemic control.[2,8,12] Comparable associations have been reported with fasting blood glucose,[11,23] lipid parameters,[7,13,15] and markers of renal involvement such as albuminuria.[9] Mechanistically, several pathways have been proposed to explain the relationship between vitamin D and glycemia, including its influence on inflammatory cytokines, oxidative stress, and insulin receptor expression.[4,6,17] Interventional trials and meta-analyses of vitamin D supplementation in T2DM have yielded mixed results,[5,19,20] although several suggest a modest glycemic benefit, particularly among patients who are deficient at baseline,[4,6] with additional favorable effects reported on inflammatory and cardiovascular risk markers.[21,22]

Despite this expanding body of evidence, the strength and consistency of the vitamin D-glycemia association appear to vary across populations, likely reflecting differences in sun exposure, skin pigmentation, dietary habits, body composition, and methodology.[14,16,18] Data from the Indian subcontinent, and eastern India in particular, remain comparatively limited, even though this region has a population at risk of vitamin D deficiency owing to dietary patterns, predominantly indoor occupational habits, and cultural practices that restrict sun exposure despite abundant year-round sunlight.[24,26] Beyond glycemic parameters, vitamin D status has also been linked with dyslipidemia and diabetic microvascular complications in several populations, indicating that its influence may extend beyond glucose homeostasis to the broader metabolic milieu that accompanies T2DM.[7,9,13,15] Identifying and characterizing these associations in region-specific cohorts is important, since the clinical utility of vitamin D screening and correction in diabetes care is likely to depend on the local burden of deficiency and the strength of its relationship with disease control.

Against this background, the present study was undertaken to determine the prevalence of vitamin D deficiency and to examine its association with glycemic control, assessed through HbA1c and fasting blood glucose, among patients with T2DM attending a tertiary care teaching hospital in Jamshedpur, Jharkhand. A secondary objective was to explore the relationship of vitamin D status with anthropometric, biochemical, and lifestyle parameters, including body mass index, duration of diabetes, lipid profile, albuminuria, smoking, and physical activity, in this population.

MATERIALS AND METHODS

Study design and setting: This hospital-based, cross-sectional observational study was carried out in the Department of General Medicine, MGM Medical College and Hospital (MGM MCH), Jamshedpur, Jharkhand, over a period of one year, from June 2025 to June 2026. Patients with a known diagnosis of type 2 diabetes mellitus (T2DM) attending the medicine outpatient and inpatient departments during this period were screened, and eligible patients were enrolled after obtaining written informed consent.

Study population and sampling: A total of 150 patients with T2DM, aged between 18 and 65 years, were enrolled using a consecutive sampling technique until the calculated sample size was achieved. The sample size was estimated assuming an expected prevalence of vitamin D deficiency of approximately 70% among T2DM patients based on earlier regional literature, with 95% confidence and an absolute precision of 8%, which yielded a minimum requirement of 126 patients; this was rounded up to 150 to allow for subgroup comparisons and possible incomplete records.

Inclusion criteria:

Patients of either sex, aged 18-65 years, with a confirmed diagnosis of T2DM as per American Diabetes Association criteria, who provided informed consent, were included.

Exclusion criteria:

Patients with type 1 diabetes mellitus or gestational diabetes, chronic kidney disease (estimated glomerular filtration rate <30 mL/min/1.73m2), chronic liver disease, known malabsorption syndromes, primary hyperparathyroidism or other established disorders of calcium-vitamin D metabolism, pregnant and lactating women, and those who had received vitamin D or calcium supplementation within the preceding three months were excluded, as were patients unwilling to participate.

Data collection: A structured, pre-tested proforma was used to record demographic details (age, sex), anthropometric measurements (height, weight, body mass index [BMI]), duration of diabetes, comorbid conditions (hypertension, dyslipidemia), current antidiabetic medication use (metformin, sulfonylureas, insulin), smoking status, and self-reported physical activity level (categorized as low, moderate, or high based on routine occupational and leisure-time activity). Season of enrollment (spring, summer, monsoon, autumn, winter) was also recorded to account for seasonal variation in cutaneous vitamin D synthesis.

Biochemical investigations: A fasting venous blood sample was collected from each participant under aseptic precautions. Fasting blood glucose (FBG) was estimated by the glucose oxidase-peroxidase

method, and HbA1c was measured using high-performance liquid chromatography. Serum 25-hydroxyvitamin D [25(OH)D] was estimated by chemiluminescent immunoassay. Serum calcium, fasting lipid profile (total cholesterol, low-density lipoprotein [LDL], high-density lipoprotein [HDL], and triglycerides) were measured using standard enzymatic methods on an automated biochemistry analyzer. Albuminuria was assessed from a spot urine sample and expressed as urinary albumin (mg/g creatinine).

Operational definitions: Serum vitamin D status was categorized according to the Endocrine Society Clinical Practice Guideline as deficient (<20 ng/mL), insufficient (20-29.9 ng/mL), or sufficient (>=30 ng/mL). Glycemic control was defined according to American Diabetes Association targets, with HbA1c <7% classified as controlled and HbA1c >=7% classified as uncontrolled.

Statistical analysis: Data were entered in Microsoft Excel and analyzed. Continuous variables were expressed as mean +/- standard deviation and categorical variables as frequency and percentage. The relationship between serum vitamin D and HbA1c/FBG was assessed using Pearson and Spearman correlation coefficients. Comparison of glycemic parameters across vitamin D status categories was performed using one-way analysis of variance (ANOVA) and independent-samples t-test, as appropriate. The Association between categorical variables was tested using the chi-square test. A two-tailed p-value <0.05 was considered statistically significant throughout.

Ethical considerations: The study was conducted after approval from the Institutional Ethics Committee of MGM Medical College and Hospital, Jamshedpur, and in accordance with the ethical principles laid down in the Declaration of Helsinki. Written informed consent was obtained from all participants prior to enrolment, and confidentiality of patient data was maintained throughout the study by anonymizing records with unique patient identification codes accessible only to the investigators.

Quality control: All biochemical assays were performed in the central laboratory of MGM Medical College and Hospital using internal quality control sera run alongside patient samples in each batch, and equipment calibration was verified daily as per standard laboratory protocol to minimize inter-assay variability. Data entry was independently cross-checked against the original proforma by a second investigator to reduce transcription errors prior to statistical analysis.

Handling of missing data and confounders: Patients with incomplete biochemical records or missing key covariates were excluded at the time of data cleaning so that the final analytic dataset of 150 patients was complete for all variables of interest. Season of enrolment was captured specifically to allow assessment of, and adjustment for, the known seasonal variation in cutaneous vitamin D synthesis when interpreting the vitamin D-glycemia association, and physical activity level and smoking status were recorded as potential lifestyle confounders of vitamin D status.

RESULTS

A total of 150 patients with type 2 diabetes mellitus, aged between 18 and 65 years, were enrolled over the one-year study period and included in the final analysis, comprising 75 males (50.0%) and 75 females (50.0%). The mean age of participants was 50.17 +/- 8.96 years (range 33-65 years), and the mean BMI was 29.24 +/- 2.72 kg/m2. The mean duration of diabetes was 7.09 +/- 4.57 years. Hypertension was present in 110 patients (73.3%) and dyslipidemia in 90 patients (60.0%). Metformin was the most commonly used antidiabetic agent (114 patients, 76.0%), followed by sulfonylureas (74 patients, 49.3%) and insulin (37 patients, 24.7%). Regarding lifestyle factors, 74 patients (49.3%) reported low physical activity, and 75 patients (50.0%) were non-smokers. The baseline characteristics of the study population are summarized in [Table 1].

Table 1: Sociodemographic and Clinical Characteristics of Study Participants (n=150)

Variable	Value
Age, years (mean ± SD)	50.17 ± 8.96
Sex – Male / Female, n (%)	75 (50.0) / 75 (50.0)
Body mass index, kg/m² (mean ± SD)	29.24 ± 2.72
Duration of diabetes, years (mean ± SD)	7.09 ± 4.57
Hypertension present, n (%)	110 (73.3)
Dyslipidemia present, n (%)	90 (60.0)
Metformin use, n (%)	114 (76.0)
Sulfonylurea use, n (%)	74 (49.3)
Insulin use, n (%)	37 (24.7)
Smoking status – Non / Former / Current, n (%)	75 (50.0) / 38 (25.3) / 37 (24.7)
Physical activity – Low / Moderate / High, n (%)	74 (49.3) / 40 (26.7) / 36 (24.0)

*SD: standard deviation.

The mean serum vitamin D level in the study population was 16.61 +/- 5.72 ng/mL (range 8.2-28.6 ng/mL). Notably, none of the participants had sufficient vitamin D levels (>=30 ng/mL). Vitamin D deficiency (<20 ng/mL) was observed in 105 patients (70.0%), while 45 patients (30.0%) had insufficient levels (20-29.9 ng/mL) [Table 2, Figure 1].

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

Vitamin D Status	n	%
Deficient (<20 ng/mL)	105	70.0
Insufficient (20–29.9 ng/mL)	45	30.0
Sufficient (≥30 ng/mL)	0	0.0
Total	150	100.0

Categorization per the Endocrine Society Clinical Practice Guideline.

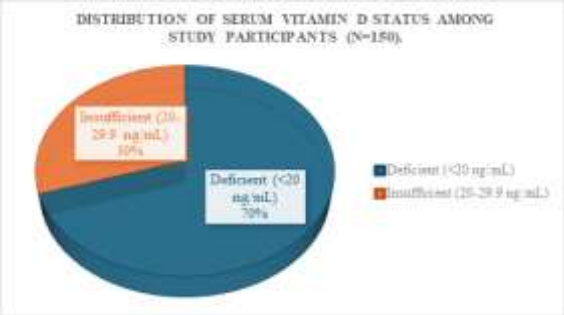

Figure 1: Distribution of serum vitamin D status among study participants (n=150).

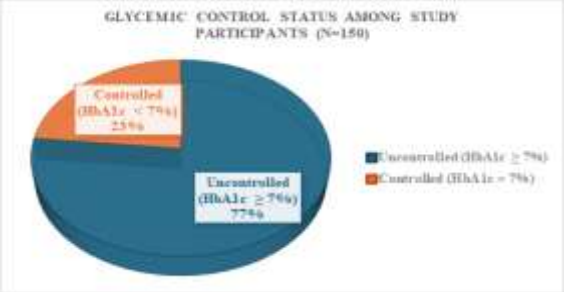

Figure 2: Glycemic control status among study participants (n=150).

Deficiency (<20 ng/mL) was present in 70.0% and insufficiency (20–29.9 ng/mL) in 30.0%; no participant had sufficient vitamin D levels (≥30 ng/mL).

The mean HbA1c of the study population was 7.95 +/- 1.08%, and the mean FBG was 161.15 +/- 30.97 mg/dL. Overall, 115 patients (76.7%) had uncontrolled glycemic status (HbA1c >=7%), while 35 patients (23.3%) had controlled glycemic status (HbA1c <7%) [Figure 2].

Controlled <7%; uncontrolled ≥7%

A strong, statistically significant negative correlation was observed between serum vitamin D and HbA1c (Pearson r = -0.966, p<0.001; Spearman rho = -0.995, p<0.001), and between serum vitamin D and FBG (Pearson r = -0.938, p<0.001; Spearman rho = -0.994, p<0.001), indicating that lower vitamin D levels were associated with poorer glycemic control.

On comparing glycemic parameters across vitamin D status categories, patients with vitamin D deficiency had a significantly higher mean HbA1c (8.47 +/- 0.84%) than those with insufficient levels (6.73 +/- 0.27%) (one-way ANOVA, F=184.32, p<0.001). Similarly, mean FBG was significantly higher in the deficient group (175.15 +/- 26.17 mg/dL) compared with the insufficient group (128.47 +/- 8.36 mg/dL) (F=136.76, p<0.001) (Table 3, Figures 3 and 4). On chi-square analysis, uncontrolled glycemic status was significantly more frequent among vitamin D-deficient patients (105 of 105, 100%) than among those with insufficient vitamin D (10 of 45, 22.2%) (chi-square=102.22, p<0.001).

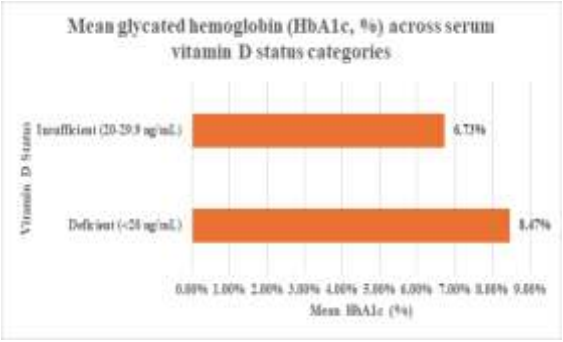

Figure 3: Mean glycated hemoglobin (HbA1c, %) across serum vitamin D status categories.

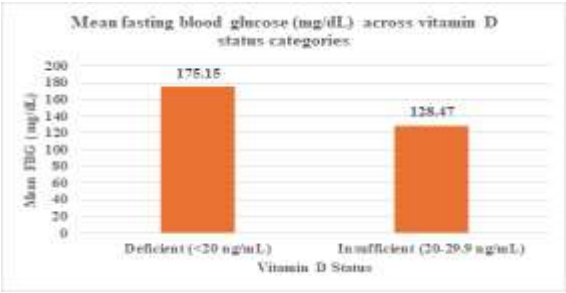

Figure 4: Mean fasting blood glucose (FBG, mg/dL) across serum vitamin D status categories.

Table 3: Comparison of Glycemic Parameters Across Serum Vitamin D Status Categories

Parameter	Deficient (n=105)	Insufficient (n=45)	p value
HbA1c, % (mean ± SD)	8.47 ± 0.84	6.73 ± 0.27	<0.001
FBG, mg/dL (mean ± SD)	175.15 ± 26.17	128.47 ± 8.36	<0.001
Uncontrolled glycemic status (HbA1c ≥7%), n (%)	105 (100.0)	10 (22.2)	<0.001

*SD: standard deviation; HbA1c and FBG were compared by one-way ANOVA; glycemic status was compared by chi-square test.

Serum vitamin D also correlated significantly with several other metabolic parameters [Table 4]: inversely with BMI (r=-0.972, p<0.001), duration of diabetes (r=-0.938, p<0.001), age (r=-0.981, p<0.001), total cholesterol (r=-0.977, p<0.001), LDL (r=-0.981, p<0.001), triglycerides (r=-0.957,

p<0.001), and albuminuria (r=-0.880, p<0.001); and positively with HDL (r=0.984, p<0.001) and serum calcium (r=0.961, p<0.001). Mean total cholesterol, LDL, and triglycerides were higher, and mean HDL lower, among vitamin D-deficient patients compared with the insufficient group, consistent with an atherogenic lipid pattern accompanying lower vitamin D status in this cohort.

Table 4: Correlation Between Serum Vitamin D and Metabolic/Biochemical Parameters (n=150)

Parameter	r value	p value
HbA1c, %	−0.966	<0.001
Fasting blood glucose, mg/dL	−0.938	<0.001
Body mass index, kg/m²	−0.972	<0.001
Duration of diabetes, years	−0.938	<0.001
Total cholesterol, mg/dL	−0.977	<0.001
LDL cholesterol, mg/dL	−0.981	<0.001
HDL cholesterol, mg/dL	+0.984	<0.001
Triglycerides, mg/dL	−0.957	<0.001
Albuminuria, mg/g	−0.880	<0.001
Serum calcium, mg/dL	+0.961	<0.001

*Pearson correlation coefficient; LDL: low-density lipoprotein; HDL: high-density lipoprotein.

About clinical and lifestyle factors (Table 5), mean vitamin D levels were significantly lower in males (11.94 +/- 2.93 ng/mL) than in females (21.29 +/- 3.62 ng/mL) (t=-17.38, p<0.001). Current smokers (12.79 +/- 1.00 ng/mL) and former smokers (10.57 +/- 2.09 ng/mL) had significantly lower vitamin D levels than non-smokers (21.56 +/- 3.53 ng/mL) (ANOVA F=247.52, p<0.001). Patients with low physical activity had the lowest mean vitamin D level (11.58 +/- 1.84 ng/mL), compared with moderate (18.66 +/- 1.87 ng/mL) and high activity groups (24.69 +/- 1.75 ng/mL) (F=657.43, p<0.001). Vitamin D levels also varied significantly by season of enrolment, being highest in spring (22.05 +/- 4.71 ng/mL) and lowest in monsoon (12.07 +/- 5.72 ng/mL) (F=24.20, p<0.001). Vitamin D-deficient patients also had significantly higher rates of hypertension, dyslipidemia, and insulin use compared with the insufficient group (all p<0.001) [Table 5].

Table 5: Association Between Serum Vitamin D Status and Clinical/Lifestyle Characteristics

Characteristic	Statistic	p value
Vitamin D, Male vs Female (mean ± SD, ng/mL)	11.94±2.93 vs 21.29±3.62	<0.001
Vitamin D by smoking status (Non/Former/Current, ng/mL)	21.56 / 10.57 / 12.79	<0.001
Vitamin D by physical activity (Low/Moderate/High, ng/mL)	11.58 / 18.66 / 24.69	<0.001
Vitamin D by season of enrolment (Spring highest, Monsoon lowest)	22.05 – 12.07 ng/mL	<0.001
Hypertension vs vitamin D category	χ^2=122.77	<0.001
Dyslipidemia vs vitamin D category	χ^2=92.89	<0.001
Insulin use vs vitamin D category	χ^2=19.20	<0.001

*SD: standard deviation; comparisons by independent t-test, one-way ANOVA, or chi-square test as appropriate.

Overall, the pattern of results indicated a consistent, statistically robust inverse gradient between serum vitamin D level and multiple markers of glycemic and metabolic derangement in this cohort. No participant in either vitamin D category recorded values falling within the sufficient range, underscoring the near-universal nature of hypovitaminosis D observed in this population of patients with type 2 diabetes mellitus, irrespective of the degree of glycemic control achieved.

DISCUSSION

In the present cross-sectional study of 150 patients with T2DM attending a tertiary care hospital in Jamshedpur, Jharkhand, vitamin D deficiency was highly prevalent, with 70% of participants classified as deficient and the remainder as insufficient; notably, no participant achieved a sufficient vitamin D level. This finding is consistent with earlier reports from diabetic populations across different regions, which have similarly described a high burden of hypovitaminosis D among patients with T2DM.[1,10,25] The near-universal inadequacy observed here, despite India's geographic position with abundant year-round sunlight, mirrors previous observations attributing widespread deficiency to predominantly indoor lifestyles, dietary insufficiency, and limited direct sun exposure among urban and semi-urban populations.[24,26]

The central finding of this study was a strong inverse correlation between serum vitamin D and both HbA1c and FBG, with patients in the deficient category demonstrating substantially poorer glycemic control than those with insufficient levels. This pattern aligns closely with several previous cross-sectional analyses that reported significant negative correlations between 25-hydroxyvitamin D and HbA1c,[2,8,12] as well as with fasting glucose.[11,23] The magnitude of correlation observed in the present cohort was higher than that reported in some of these studies, which may reflect differences in sample characteristics, laboratory methodology, or the relatively homogeneous regional population studied here; nonetheless, the direction of the association was consistent across studies, reinforcing the biological

plausibility of a link between vitamin D status and glycemic regulation. Mechanistically, this relationship has been attributed to the presence of vitamin D receptors on pancreatic beta cells, where vitamin D is thought to facilitate insulin synthesis and secretion, partly through modulation of intracellular calcium availability, and to enhance peripheral insulin sensitivity by influencing insulin receptor expression in target tissues.[3,4,6,17] Vitamin D has also been implicated in attenuating systemic inflammation and oxidative stress, both of which contribute to insulin resistance in T2DM.[6,17] While the present study, being cross-sectional, cannot establish causality, these proposed mechanisms provide biological plausibility for the observed inverse association and are consistent with data from interventional trials showing modest glycemic improvement following vitamin D supplementation, particularly among patients who were deficient at baseline.[4,6,20]

The inverse correlation observed between vitamin D and adverse lipid parameters, alongside a positive correlation with HDL, corroborates earlier reports linking vitamin D status to dyslipidemia in T2DM patients.[7,13,15] Similarly, the inverse relationship between vitamin D and albuminuria in this cohort is in agreement with previous work suggesting a protective association between adequate vitamin D status and diabetic nephropathy markers.[9] These associations, taken together, suggest that vitamin D deficiency may cluster with a broader adverse metabolic and microvascular risk profile in T2DM, rather than operating as an isolated abnormality. Lower vitamin D levels among males, current and former smokers, and physically inactive individuals in this study are consistent with previously described lifestyle determinants of vitamin D status,[14,16,18] and the seasonal variation observed, with higher levels in spring and lower levels during the monsoon, aligns with known patterns of cutaneous vitamin D synthesis dependent on sunlight exposure.[8] The higher prevalence of hypertension, dyslipidemia, and insulin requirement among vitamin D-deficient patients further supports observations that more severe vitamin D deficiency may accompany a more advanced or poorly controlled metabolic state.[13,23,24]

This study has certain limitations. Its cross-sectional design precludes causal inference regarding the direction of the vitamin D-glycemia relationship. The study was conducted at a single centre, which may limit generalizability, and factors such as dietary vitamin D intake and detailed sun-exposure duration were not directly quantified. Despite these limitations, the consistency of the present findings with existing literature strengthens confidence in the observed association and underscores the potential clinical relevance of vitamin D status assessment in patients with T2DM.

The findings of this study carry practical implications for clinical practice in similar settings. Given the near-universal prevalence of vitamin D deficiency observed in this cohort, opportunistic screening of serum vitamin D at the time of diabetes evaluation, particularly in patients with suboptimal glycemic control, hypertension, or dyslipidemia, may help identify individuals who could benefit from correction, in line with recommendations emerging from other regional studies.[1,10,12,25] Meta-analytic evidence suggests that supplementation may confer the greatest glycemic benefit in patients who are frankly deficient rather than merely insufficient,[4,5,6] a distinction that is directly relevant to the present cohort, in which the majority of patients fell into the deficient category. Future work incorporating dietary vitamin D intake, objective measures of sun exposure, and parathyroid hormone levels would help clarify the relative contribution of these factors to the deficiency observed, and interventional studies with pre-specified glycemic endpoints would be valuable in establishing whether correction of vitamin D deficiency yields measurable improvement in glycemic control in this population.

CONCLUSION

This cross-sectional study conducted among 150 patients with type 2 diabetes mellitus at a tertiary care hospital in Jamshedpur, Jharkhand, demonstrated a high prevalence of vitamin D deficiency, with 70% of patients deficient and none achieving sufficient levels. Serum vitamin D showed a strong, statistically significant inverse correlation with both HbA1c and fasting blood glucose, indicating that patients with lower vitamin D levels tended to have poorer glycemic control. Vitamin D status was also significantly associated with BMI, duration of diabetes, lipid parameters, albuminuria, and lifestyle factors such as smoking and physical activity, suggesting that vitamin D deficiency may be part of a wider adverse metabolic profile in this population. These findings suggest that routine screening for vitamin D deficiency could be considered in the clinical evaluation of patients with T2DM, particularly those with poor glycemic control, so that appropriate correction can be undertaken as part of comprehensive diabetes care. However, given the cross-sectional design of this study, causal relationships cannot be established, and the direction and clinical benefit of vitamin D correction on glycemic outcomes warrant further evaluation. Larger, multicentric, and longitudinal studies, including randomized controlled trials of vitamin D supplementation with glycemic endpoints, are recommended to confirm these associations and to determine whether correcting vitamin D deficiency translates into meaningful improvement in glycemic control among patients with type 2 diabetes mellitus. In the interim, the magnitude and consistency of the association observed in this cohort support the inclusion of serum vitamin D assessment as a low-cost, readily available addition to the routine metabolic work-up of patients with T2DM in this region, particularly those presenting with poor

glycemic control, so that coexisting deficiency is not overlooked in the broader effort to optimize diabetes management.

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