

Research Article

Correlation of Serum Vitamin D Levels with Glycemic Control and Insulin Resistance in Type 2 Diabetes Mellitus

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ABSTRACT

Background: Vitamin D may influence glucose metabolism and insulin sensitivity; however, its association with glycemic control and insulin resistance in type 2 diabetes mellitus (T2DM) remains unclear.

Aim: To evaluate the correlation of serum vitamin D levels with glycemic control and insulin resistance in patients with T2DM.

Materials and Methods: This hospital-based, cross-sectional study included 120 patients with T2DM. Serum vitamin D, fasting blood glucose (FBG), postprandial blood glucose (PPBG), HbA1c, and fasting insulin were assessed. Insulin resistance was estimated using HOMA-IR. Correlation analysis was performed to evaluate associations between vitamin D and metabolic parameters.

Results: The mean age was 52.46 ± 10.28 years, with 55% males. Vitamin D deficiency was observed in 48.3% of patients. Mean vitamin D and HbA1c levels were 21.64 ± 9.28 ng/mL and $8.24 \pm 1.46\%$, respectively. Patients with vitamin D deficiency had higher HbA1c ($8.92 \pm 1.42\%$) and HOMA-IR (8.12 ± 3.42) compared with vitamin D-sufficient patients ($6.88 \pm 0.82\%$ and 3.32 ± 1.24 , respectively). Serum vitamin D showed inverse correlations with HbA1c ($r=-0.51$) and HOMA-IR ($r=-0.56$).

Conclusion: Lower serum vitamin D concentrations were associated with poorer glycemic control and greater insulin resistance in the T2DM cohort.

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

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from insulin resistance and progressive pancreatic β -cell dysfunction. It represents a major global public health concern owing to its increasing prevalence and associated microvascular and macrovascular complications [1]. The pathogenesis of T2DM involves complex interactions between genetic susceptibility, obesity, physical inactivity, dietary factors, and chronic low-grade inflammation [1,2]. In recent years, increasing attention has been directed towards identifying additional modifiable factors influencing glucose homeostasis, among which vitamin D has emerged as a potential contributor to metabolic regulation [3]. Vitamin D is a fat-soluble secosteroid hormone traditionally recognized for its role in calcium and phosphorus homeostasis. However, the presence of vitamin D receptors (VDRs) in pancreatic β -cells, skeletal muscle, and adipose tissue suggests its involvement in glucose

metabolism and insulin sensitivity [3,4]. Serum 25-hydroxyvitamin D [25(OH)D] is considered the most reliable circulating marker for assessing vitamin D status [4]. Experimental evidence suggests that vitamin D may influence insulin secretion through regulation of intracellular calcium concentrations and improve peripheral insulin sensitivity by modulating insulin receptor expression. Its anti-inflammatory and immunomodulatory properties may also contribute to metabolic regulation [3,5]. Insulin resistance is a central pathophysiological feature of T2DM, characterized by a diminished response of peripheral tissues to circulating insulin, resulting in impaired glucose uptake and compensatory hyperinsulinemia. The Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), derived from fasting glucose and insulin concentrations, is commonly employed to estimate insulin resistance in clinical research [6]. Several observational studies have reported an inverse association between serum vitamin D levels and

insulin resistance, suggesting that inadequate vitamin D status may coexist with greater metabolic dysfunction [7,8]. However, this association may be influenced by obesity, physical activity, dietary habits, and other metabolic factors.

Glycemic control is routinely assessed using fasting blood glucose, postprandial blood glucose, and glycated hemoglobin (HbA1c), with HbA1c reflecting average glycemic status over the preceding two to three months. Previous investigations have suggested that lower serum vitamin D concentrations may be associated with elevated HbA1c, fasting glucose, and insulin resistance [8,9]. Nevertheless, findings remain inconsistent across populations. Although some interventional studies have demonstrated improvements in glycemic parameters following vitamin D supplementation, others have reported limited or insignificant benefits, indicating that the relationship may depend on baseline vitamin D status, diabetes duration, body mass index, and other clinical characteristics [9,10]. The coexistence of vitamin D deficiency and T2DM is particularly relevant in the Indian population, where inadequate vitamin D status remains common despite abundant sunlight availability [11]. Variations in dietary patterns, lifestyle, body composition, and metabolic characteristics may further influence this association. Simultaneous evaluation of serum vitamin D concentrations, glycemic parameters, and HOMA-IR may therefore provide a better understanding of the relationship between vitamin D status and metabolic dysfunction in patients with T2DM. Therefore, the present study was undertaken to evaluate serum vitamin D levels and determine their correlation with glycemic control and insulin resistance in patients with type 2 diabetes mellitus.

MATERIALS AND METHODS

The present hospital-based, observational, cross-sectional study was conducted in the Department of Biochemistry at a tertiary care teaching hospital to evaluate the correlation of serum vitamin D levels with glycemic control and insulin resistance in patients with type 2 diabetes mellitus (T2DM). A total of 120 patients with established T2DM attending the outpatient and inpatient services were included using consecutive sampling after obtaining written informed consent.

Inclusion Criteria

1. Patients aged 30–70 years of either sex.
2. Patients with previously diagnosed T2DM.
3. Patients willing to provide written informed consent.

Exclusion Criteria

1. Patients with type 1 or gestational diabetes mellitus.
2. Patients receiving vitamin D or calcium supplementation within the preceding three months.
3. Patients with chronic kidney disease, chronic liver disease, malabsorption syndromes, or parathyroid disorders.
4. Patients receiving medications affecting vitamin D metabolism, including corticosteroids and anticonvulsants.
5. Pregnant and lactating women.
6. Patients with acute infections or critical illness.

Data Collection and Clinical Assessment

Demographic and clinical information, including age, sex, duration of diabetes, family history, treatment history, comorbidities, and lifestyle factors, was recorded using a structured proforma. Height and weight were measured, and body mass index (BMI) was calculated in kg/m².

Biochemical Investigations

Following an overnight fast of 8–12 hours, approximately 5–7 mL of venous blood was collected under aseptic precautions. The following parameters were assessed:

1. Serum 25-hydroxyvitamin D [25(OH)D] using a standardized immunoassay (ng/mL).
2. Fasting blood glucose (FBG) using the glucose oxidase–peroxidase method (mg/dL).
3. Postprandial blood glucose (PPBG), measured approximately two hours after a meal (mg/dL).
4. Glycated hemoglobin (HbA1c), expressed as a percentage (%).
5. Fasting serum insulin using a standardized immunoassay (μIU/mL).

Assessment of Vitamin D Status and Study Grouping

Based on serum 25(OH)D concentrations, participants were categorized into three groups:

Group	Vitamin D status	Serum 25(OH)D level
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Group I	Deficient	Below 20 ng/mL
Group II	Insufficient	20–29.9 ng/mL
Group III	Sufficient	≥30 ng/mL

Group allocation was based on measured vitamin D concentrations, without predefined equal distribution.

Assessment of Insulin Resistance

Insulin resistance was estimated using the Homeostatic Model Assessment of Insulin Resistance (HOMA-IR), calculated as:

$$\text{HOMA-IR} = \frac{\text{Fasting Insulin } (\mu\text{IU/mL})}{405}$$

Higher HOMA-IR values indicated greater insulin resistance.

Assessment of Glycemic Control

Glycemic control was evaluated using FBG, PPBG, and HbA1c. HbA1c was considered the principal marker of long-term glycemic control. Participants were additionally classified as having controlled (HbA1c below 7%) or uncontrolled diabetes (HbA1c ≥7%) for comparative analysis.

Outcome Measures

The primary outcomes were the correlations of serum vitamin D concentrations with HbA1c and HOMA-IR. Secondary outcomes included associations with FBG, PPBG, fasting insulin, BMI, and duration of diabetes, along with comparisons across vitamin D status groups.

Statistical Analysis

Data were analysed using SPSS.21 statistical software. Continuous variables were expressed as mean ± SD or median (IQR), while categorical variables were presented as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Comparisons were performed using the independent t-test, Mann–Whitney U test, one-way ANOVA, Kruskal–Wallis test, Chi-square test, or Fisher's exact test, as appropriate.

Pearson's or Spearman's correlation coefficient was used to assess associations between serum vitamin D and glycemic parameters, fasting insulin, and HOMA-IR. Multivariable linear regression was planned to assess independent associations after adjustment for relevant confounders, including age, sex, BMI, and

duration of diabetes. A p-value below 0.05 was considered statistically significant.

RESULTS

A total of 120 patients with type 2 diabetes mellitus were included in the study. The mean age was 52.46 ± 10.28 years, with the majority belonging to the 51–60-year age group (35.0%). Males constituted 55.0% of the study population. The mean duration of diabetes and BMI were 7.42 ± 4.16 years and 26.84 ± 3.72 kg/m², respectively. Family history of diabetes and hypertension were present in 43.3% and 38.3% of patients, respectively (Table 1).

Vitamin D deficiency was observed in 58 (48.3%) patients, insufficiency in 39 (32.5%), and sufficiency in 23 (19.2%). The mean serum vitamin D level was 21.64 ± 9.28 ng/mL. Mean FBG, PPBG, HbA1c, fasting insulin, and HOMA-IR were 158.42 ± 42.36 mg/dL, 236.58 ± 61.24 mg/dL, 8.24 ± 1.46%, 15.82 ± 6.42 μIU/mL, and 6.28 ± 3.14, respectively (Table 2).

Comparison across vitamin D categories revealed significantly higher FBG, PPBG, HbA1c, fasting insulin, and HOMA-IR in vitamin D-deficient patients compared with insufficient and sufficient groups (p<0.001 for all parameters). Mean HbA1c decreased from 8.92 ± 1.42% in the deficient group to 6.88 ± 0.82% in the sufficient group, while HOMA-IR decreased from 8.12 ± 3.42 to 3.32 ± 1.24, respectively (Table 3).

Pearson's correlation analysis demonstrated significant inverse correlations between serum vitamin D levels and FBG (r=−0.42), PPBG (r=−0.39), and HbA1c (r=−0.51), with p<0.001 for all parameters (Table 4, Figure 1). Similarly, vitamin D levels were negatively correlated with fasting insulin (r=−0.44, p<0.001), HOMA-IR (r=−0.56, p<0.001), BMI (r=−0.28, p=0.002), and duration of diabetes (r=−0.21, p=0.021). The strongest inverse correlation was observed with HOMA-IR (Table 5, Figure 2).

A significant association was observed between vitamin D status and glycemic control (p<0.001). Among patients with controlled diabetes (HbA1c <7%), 61.5% had sufficient vitamin D levels, whereas 58.5% of patients with uncontrolled diabetes (HbA1c ≥7%) were vitamin D deficient (Table 6, Figure 3).

Table 1. Baseline Demographic and Clinical Characteristics of the Study Population (N=120)

Parameter	Frequency (%) / Mean $\pm$ SD
Age (years)	52.46 $\pm$ 10.28
30–40 years	17 (14.2%)
41–50 years	32 (26.7%)
51–60 years	42 (35.0%)
61–70 years	29 (24.2%)
Male	66 (55.0%)
Female	54 (45.0%)
Duration of diabetes (years)	7.42 $\pm$ 4.16
BMI (kg/m ²)	26.84 $\pm$ 3.72
Family history of diabetes	52 (43.3%)
Hypertension	46 (38.3%)

Table 2. Distribution of Serum Vitamin D Status and Overall Biochemical Parameters (N=120)

Parameter	Value
Vitamin D deficient (below 20 ng/mL)	58 (48.3%)
Vitamin D insufficient (20–29.9 ng/mL)	39 (32.5%)
Vitamin D sufficient ($\geq$ 30 ng/mL)	23 (19.2%)
Serum vitamin D (ng/mL)	21.64 $\pm$ 9.28
Fasting blood glucose (mg/dL)	158.42 $\pm$ 42.36
Postprandial blood glucose (mg/dL)	236.58 $\pm$ 61.24
HbA1c (%)	8.24 $\pm$ 1.46
Fasting insulin (μ IU/mL)	15.82 $\pm$ 6.42
HOMA-IR	6.28 $\pm$ 3.14

Table 3. Comparison of Glycemic Parameters and Insulin Resistance According to Vitamin D Status

Parameter	Deficient (n=58)	Insufficient (n=39)	Sufficient (n=23)	p-value	Statistical test
FBG (mg/dL)	178.4 $\pm$ 43.2	151.6 $\pm$ 34.8	119.6 $\pm$ 24.5	<0.001	One-way ANOVA
PPBG (mg/dL)	264.8 $\pm$ 63.4	226.4 $\pm$ 48.6	182.6 $\pm$ 39.2	<0.001	
HbA1c (%)	8.92 $\pm$ 1.42	8.02 $\pm$ 1.12	6.88 $\pm$ 0.82	<0.001	
Fasting insulin (μ IU/mL)	18.42 $\pm$ 6.84	14.62 $\pm$ 5.12	11.28 $\pm$ 3.86	<0.001	
HOMA-IR	8.12 $\pm$ 3.42	5.48 $\pm$ 2.18	3.32 $\pm$ 1.24	<0.001	

Table 4. Correlation of Serum Vitamin D Levels with Glycemic Parameters (N=120)

Glycemic parameter	Pearson's r	p-value	Statistical test
Fasting blood glucose	−0.42	<0.001	Pearson's correlation
Postprandial blood glucose	−0.39	<0.001	
HbA1c	−0.51	<0.001	

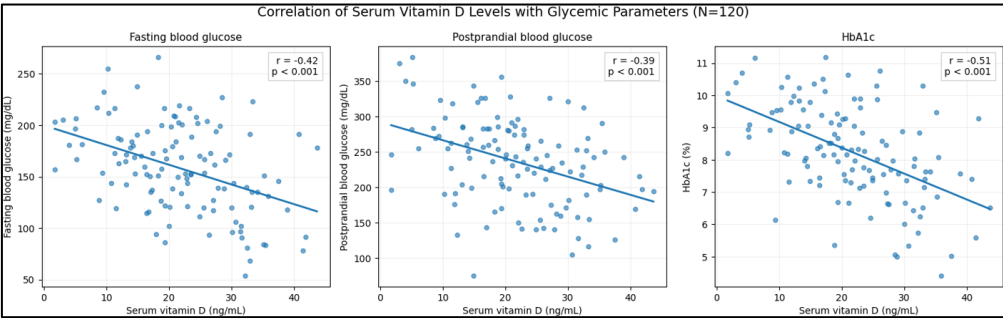


Figure 1. Correlation of Serum Vitamin D Levels with Glycemic Parameters (N=120)

Table 5. Correlation of Serum Vitamin D Levels with Insulin Resistance and Other Clinical Parameters (N=120)

Parameter	Pearson's r	p-value	Statistical test
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Fasting insulin	-0.44	<0.001	Pearson's correlation
HOMA-IR	-0.56	<0.001	
BMI	-0.28	0.002	
Duration of diabetes	-0.21	0.021	

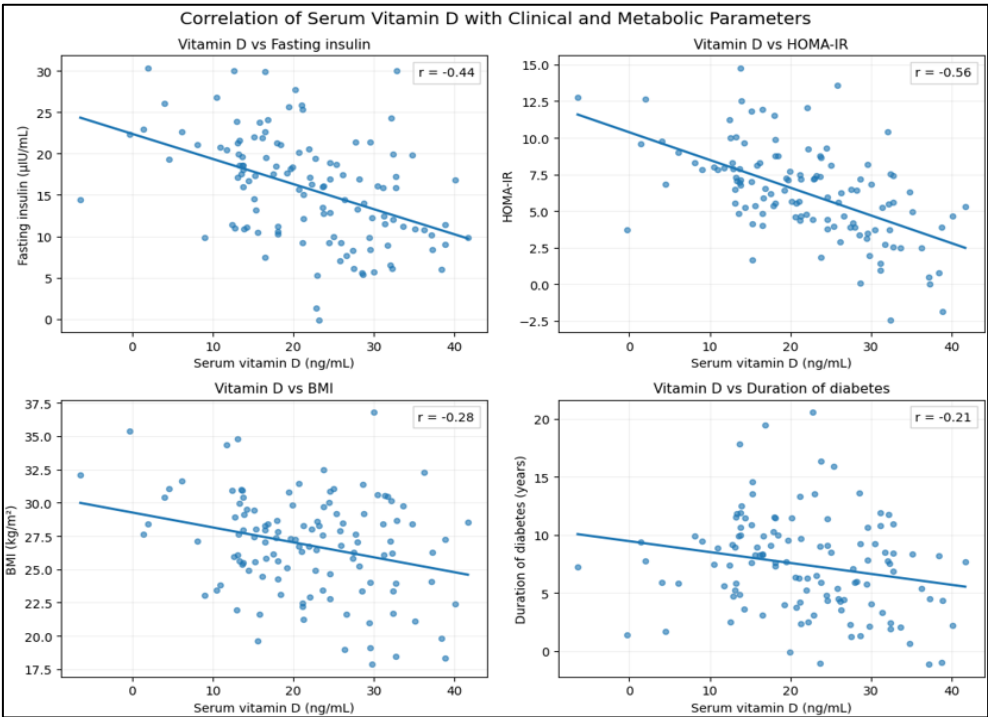


Figure 2. Correlation of Serum Vitamin D Levels with Insulin Resistance and Other Clinical Parameters (N=120)

Table 6. Association between Vitamin D Status and Glycemic Control (N=120)

Vitamin D status	Controlled diabetes (HbA1c below 7%) n=26	Uncontrolled diabetes (HbA1c ≥7%) n=94	Total	p-value	Statistical test
Deficient	3 (11.5%)	55 (58.5%)	58	<0.001	Chi-square test
Insufficient	7 (26.9%)	32 (34.0%)	39		
Sufficient	16 (61.5%)	7 (7.4%)	23		
Total	26 (100%)	94 (100%)	120		

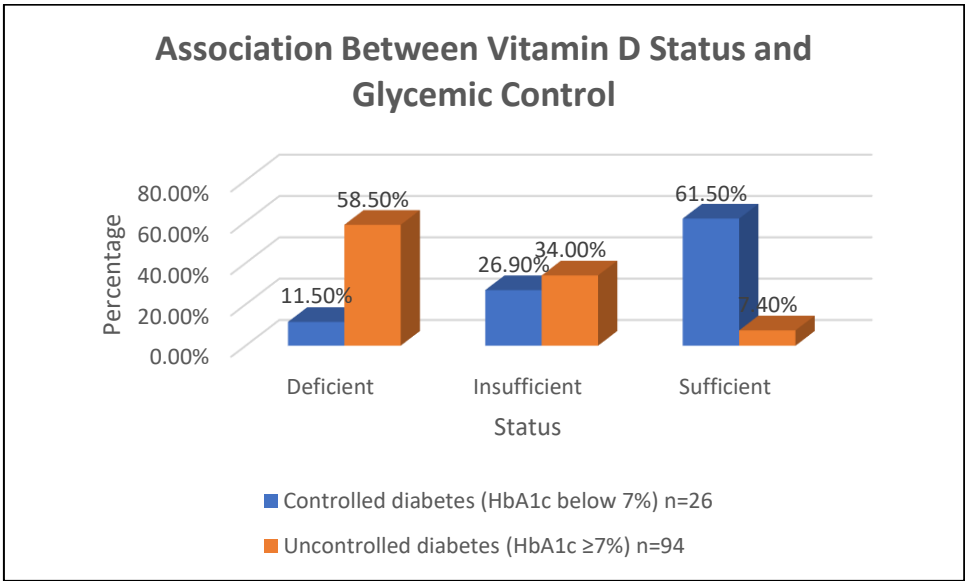


Figure 3. Association between Vitamin D Status and Glycemic Control (N=120)

DISCUSSION

The present study included 120 patients with type 2 diabetes mellitus (T2DM), with a mean age of 52.46 ± 10.28 years and male predominance (55.0%). The mean duration of diabetes was 7.42 ± 4.16 years, while the mean BMI was 26.84 ± 3.72 kg/m². Need et al. (2005) [12] evaluated 753 postmenopausal women to investigate the relationship between fasting serum glucose, age, BMI, and serum 25-hydroxyvitamin D. Their study highlighted the relevance of demographic and anthropometric characteristics when examining vitamin D and glucose metabolism. However, unlike their exclusively postmenopausal population, the present study included both sexes with established T2DM. In the present study, vitamin D deficiency was observed in 58 patients (48.3%), insufficiency in 39 (32.5%), and sufficiency in 23 (19.2%), with a mean serum vitamin D concentration of 21.64 ± 9.28 ng/mL. Overall, 80.8% of patients had vitamin D levels below 30 ng/mL. Mattila et al. (2007) [13] investigated the association between serum 25-hydroxyvitamin D concentrations and subsequent T2DM risk in a Finnish population. Their prospective findings provided evidence regarding the relationship between baseline vitamin D status and future diabetes development. Although the present study evaluated patients with established T2DM rather than incident diabetes, both investigations examined the metabolic relevance of circulating vitamin D concentrations.

The mean fasting blood glucose, postprandial blood glucose, and HbA1c in the present study were 158.42 ± 42.36 mg/dL, 236.58 ± 61.24 mg/dL, and $8.24 \pm 1.46\%$, respectively. Patients with vitamin D deficiency demonstrated higher HbA1c ($8.92 \pm 1.42\%$) compared with those having insufficient ($8.02 \pm 1.12\%$) and sufficient vitamin D levels ($6.88 \pm 0.82\%$). Serum vitamin D also showed inverse correlations with fasting glucose ($r=-0.42$), postprandial glucose ($r=-0.39$), and HbA1c ($r=-0.51$).

Need et al. (2005) [12] similarly examined the relationship between serum vitamin D and fasting glucose while considering age and BMI. Pittas et al. (2006) [14], in a prospective study involving 83,779 women, documented 4,843 incident cases of T2DM over 20 years. They reported a relative risk of 0.67 (95% CI: 0.49–0.90) among women consuming more than 1,200 mg calcium and 800 IU vitamin D daily

compared with lower intake categories. These findings provide supporting context for the relationship between vitamin D-related measures and glucose metabolism, although dietary intake and circulating vitamin D concentrations represent different exposures.

The mean fasting insulin and HOMA-IR in the present study were 15.82 ± 6.42 μ IU/mL and 6.28 ± 3.14 , respectively. Patients with vitamin D deficiency demonstrated higher HOMA-IR (8.12 ± 3.42) compared with insufficient (5.48 ± 2.18) and sufficient groups (3.32 ± 1.24). Serum vitamin D showed inverse correlations with fasting insulin ($r=-0.44$) and HOMA-IR ($r=-0.56$).

Wareham et al. (1999) [15], in a longitudinal investigation involving 1,122 individuals, reported that 26 participants developed diabetes during approximately 4.5 years of follow-up. The relative risk of diabetes comparing the highest with the lowest quartile was 17.6 (95% CI: 2.4–130.4) for fasting glucose, 16.4 (95% CI: 2.2–121.9) for fasting 32,33 split proinsulin, and 4.41 (95% CI: 1.5–12.9) for fasting insulin. Although vitamin D was not directly evaluated, their findings emphasized the importance of insulin-related metabolic abnormalities in diabetes development.

In the present study, 94 patients (78.3%) had uncontrolled diabetes (HbA1c $\geq 7\%$), while 26 (21.7%) had controlled diabetes. Vitamin D deficiency was observed in 58.5% of patients with uncontrolled diabetes compared with 11.5% of those with controlled diabetes. Conversely, vitamin D sufficiency was observed in 61.5% of the controlled group compared with only 7.4% of the uncontrolled group.

Pittas et al. (2006) [14] reported that higher supplemental vitamin D intake was associated with a relative risk of 0.87 (95% CI: 0.75–1.00) for incident T2DM. However, de Boer et al. (2008) [16], in the Women's Health Initiative trial involving 33,951 postmenopausal women, found no significant reduction in diabetes incidence following supplementation with 1,000 mg calcium and 400 IU vitamin D3 daily over a median follow-up of seven years (HR=1.01; 95% CI: 0.94–1.10). These contrasting findings indicate that observational associations between vitamin D and glycemic parameters do not necessarily establish a beneficial effect of supplementation.

CONCLUSION

The present study suggests an inverse correlation between serum vitamin D levels and glycemic parameters, particularly HbA1c, fasting blood glucose, and HOMA-IR, among patients with type 2 diabetes mellitus. Lower vitamin D concentrations were associated with poorer glycemic control and greater insulin resistance. These findings highlight the need for further prospective studies to clarify the potential metabolic significance of vitamin D in T2DM.

Limitations

The cross-sectional design and relatively small, hospital-based sample size limit causal interpretation and generalizability. Potential confounding factors, including dietary intake, sunlight exposure, physical activity, and antidiabetic medications, may have influenced the observed associations.

REFERENCES

1. DeFronzo RA. From the triumvirate to the ominous octet: a new paradigm for the treatment of type 2 diabetes mellitus. *Diabetes*. 2009;58(4):773-795.
2. Hu FB, Manson JE, Stampfer MJ, Colditz G, Liu S, Solomon CG, et al. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *N Engl J Med*. 2001;345(11):790-797.
3. Pittas AG, Lau J, Hu FB, Dawson-Hughes B. The role of vitamin D and calcium in type 2 diabetes: a systematic review and meta-analysis. *J Clin Endocrinol Metab*. 2007;92(6):2017-2029.
4. Holick MF. Vitamin D deficiency. *N Engl J Med*. 2007;357(3):266-281.
5. Chiu KC, Chu A, Go VLW, Saad MF. Hypovitaminosis D is associated with insulin resistance and B-cell dysfunction. *Am J Clin Nutr*. 2004;79(5):820-825.
6. Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*. 1985;28(7):412-419.
7. Kayaniyl S, Vieth R, Retnakaran R, Knight JA, Qi Y, Gerstein HC, et al. Association of vitamin D with insulin resistance and B-cell dysfunction in subjects at risk for type 2 diabetes. *Diabetes Care*. 2010;33(6):1379-1381.
8. Forouhi NG, Luan J, Cooper A, Boucher BJ, Wareham NJ. Baseline serum 25-hydroxy vitamin D is predictive of future glycemic status and insulin resistance: the Medical Research Council Ely Prospective Study 1990-2000. *Diabetes*. 2008;57(10):2619-2625.
9. Lei X, Zhou Q, Wang Y, Fu S, Li Z, Chen Q. Serum and supplemental vitamin D levels and insulin resistance in T2DM populations: a meta-analysis and systematic review. *Sci Rep*. 2023;13:12343.
10. Chen W, Liu L, Hu F. Efficacy of vitamin D supplementation on glycaemic control in type 2 diabetes: an updated systematic review and meta-analysis of randomized controlled trials. *Diabetes Obes Metab*. 2024;26(12):5713-5726.
11. Ritu G, Gupta A. Vitamin D deficiency in India: prevalence, causalities and interventions. *Nutrients*. 2014;6(2):729-775.
12. Need AG, O'Loughlin PD, Horowitz M, Nordin BE. Relationship between fasting serum glucose, age, body mass index and serum 25 hydroxyvitamin D in postmenopausal women. *Clin Endocrinol (Oxf)*. 2005;62(6):738-741.
13. Mattila C, Knekt P, Männistö S, Rissanen H, Laaksonen MA, Montonen J, et al. Serum 25-hydroxyvitamin D concentration and subsequent risk of type 2 diabetes. *Diabetes Care*. 2007;30(10):2569-2570.
14. Pittas AG, Dawson-Hughes B, Li T, van Dam RM, Willett WC, Manson JE, et al. Vitamin D and calcium intake in relation to type 2 diabetes in women. *Diabetes Care*. 2006;29(3):650-656.
15. Wareham NJ, Byrne CD, Williams R, Day NE, Hales CN. Fasting proinsulin concentrations predict the development of type 2 diabetes. *Diabetes Care*. 1999;22(2):262-270.
16. de Boer IH, Tinker LF, Connelly S, Curb JD, Howard BV, Kestenbaum B, et al. Calcium plus vitamin D supplementation and the risk of incident diabetes mellitus in the Women's Health Initiative. *Diabetes Care*. 2008;31(4):701-707.