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Vitamin D level and glycemic control in type 2 diabetes mellitus

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Vitamin D's effects outside the skeleton have garnered a lot of attention. A lack of vitamin D seems to be linked to the onset of type 2 diabetes and the metabolic syndrome. It has been shown that mild to severe vitamin D insufficiency raises the risk of type 2 diabetes. This study aimed to study vitamin D levels in a group of T2DM patients and to investigate its relation with the degree of glycemic control. A case-control study was conducted in Mosul, Iraq, between October 2024 and January 2025, including 160 participants aged 35–60 years. Eighty individuals diagnosed with T2DM were compared with 80 age- and sex-matched healthy persons. Blood samples were collected after overnight fasting to determine levels of 25-hydroxyvitamin D [25(OH)D], fasting plasma glucose (FPG), hemoglobin A1c (HbA1c), parathyroid hormone (PTH), calcium, and phosphate. Vitamin D levels were substantially lower in T2DM patients (6.86 ± 2.30 ng/mL) than in controls. PTH levels were higher in T2DM patients. The levels of serum calcium and phosphate were lower in the diabetic group. We observed relationships between Vitamin D and both HbA1C and FPG in the T2DM group. Similar inverse connections were seen between calcium and blood sugar levels. The research highlights a reverse link between vitamin D and calcium levels with indicators of blood sugar control in patients with type 2 diabetes. The results emphasize how term high blood sugar levels can affect the metabolism of bone minerals and stress the need to keep track of indicators of bone health in people with diabetes.

Keywords: diabetes mellitus type 2; T2DM; fasting plasma glucose; HbA1c; vitamin D; parathyroid hormon.

Introduction

Type 2 diabetes mellitus (T2DM) is a long term metabolizing situation that poses a health concern on a scale and impacts numerous people from various backgrounds (Motala et al., 2022). It is mainly identified by the body's resistance to insulin action and high blood sugar levels due to the dysfunction of beta cells over time. The rising occurrence of T2DM is largely linked to lifestyle elements, such as eating habits, lack of activity and being overweight or obese, alongside factors related to genetic inheritance (Nadhiya et al., 2024). Tying it all together is the fact that T2DM has been associated with issues such as heart disease and kidney problems. These factors add to the health risks and fatality rates (Samant et al., 2025). Dealing with T2DM usually requires changes in lifestyle habits along, with medications and regular monitoring of blood sugar levels (Williams et al., 2022). Despite the progress made in diabetes management methods today, maintaining blood sugar levels continues to pose difficulties for people. This has prompted researchers to delve into elements that might impact how the body processes glucose and responds to insulin. As a result there is an increasing curiosity regarding the importance of vitamins in understanding the development of diabetes (Abed et al., 2024). People widely recognize vitamin D as a fat soluble vitamin that is essential for preserving the balance of calcium and phosphate in the body to support healthy bones. Recent findings indicate that vitamin D also plays a part in regulating metabolic functions such as glucose balance and insulin activity (Argano et al., 2023). The existence of vitamin D receptors (known as VDR), in beta cells and insulin responsive tissues suggests a link between vitamin D levels and metabolic indicators associated with diabetes. Research from both intervention studies has hinted at the effects of sufficient vitamin D levels in boosting insulin secretion and sensitivity while decreasing overall inflammation – all essential factors, in managing diabetes effectively (Pieńkowska et al., 2023). This research is focused on how vitamin D level correlated with the glycemic markers in people with type 2 diabetes.

Materials and methods

The Medical Ethics Committee at the University of Mosul College of Medicine approved the study. The research complied with the Declaration of Helsinki's rules for studies with human subjects. The study's objectives and methods were explained to participants prior to their participation.

A case-control study was conducted between October 2024 and January 2025 with 160 participants aged between 35 and 60 years recruited for the study from Ibn Sina Teaching Hospital and Al Wafaa Center for Diabetes Management. The participants were divided into two groups, for the study population analysis; Case group: included 80 people with type 2 diabetes and the control comprised of 80 persons who were evidently healthy and had no medical conditions.

Inclusion criteria for cases: diagnosis of type 2 diabetes has been confirmed, regardless of how it has been present. The age group falls within the range of 35 to 60 years old. The individuals involved in the study agreed in writing to take part in the research project.

Exclusion criteria for cases: type 1 diabetes mellitus; type 2 diabetes mellitus on insulin treatment; Having liver, kidney, thyroid or parathyroid diseases; current use of vitamin D supplements; taking medications that impact the way vitamin D works in the body such, as corticosteroids or hormonal treatments that can affect bone strength; Pregnant women.

The controls were similar in age and gender to the cases, had no issues with their liver, kidneys, thyroid or parathyroid glands. They did not use any vitamin D supplements.

Data was collected by conducting interviews before gathering samples. Anthropometric assessments involved analyzing factors such, as body mass index (BMI) weight measurements and height details. Fasting blood samples were taken for testing purposes. Each individual had 7 mL of blood taken and distributed into three different tubes for further analysis. Four milliliters of blood were carefully placed into a tube with a gel that separates the serum from the rest of the blood components after clotting for half an hour at room temperature and spinning at 3000 rotations per minute for 10 minutes in a centrifuge machine. The resulting serum was divided into tubes, kept frozen at 20 °C for testing vitamin D levels along with PTH calcium and phosphate. Two mL of blood was put into an (EDTA) test tube, for measurement of HbA1c. One ml was put in to a sodium fluoride / potassium oxalate tube to obtain plasma that separated after centrifugation and was stored frozen at –20 °C, used for plasma glucose assessment. The Cobas c 311 analyzer was used to measure vitamin D

levels, fasting plasma glucose, hemoglobin A1c, PTH, calcium levels and phosphate level.

The data gathered was analysed using SPSS. The T-test was conducted to compare the means ± standard deviation (SD) between the case and control groups for the studied parameters (significant at $P < 0.05$). The relationship between vitamin D levels, calcium, phosphate, and parathyroid hormone and FPG and HbA1c was examined using the Pearson correlation test.

Results

The data in Table 1 stands the mean ± (SD) values of the biochemical parameters in the studied groups. A substantial difference was observed among the two groups for all parameters.

Vitamin D in the case group (6.86 ± 2.3 ng/mL) was substantially lower than that in the control group (32.3 ± 12.14 ng/mL).

Fasting plasma glucose (FPG) level was considerably higher in the case group (167.6 ± 40.4 mg/dL) than in the control group (81.3 ± 13.6 mg/dL).

HbA1c levels in the case group (10.8 ± 2.1%) were considerably higher than in the control group (5.6 ± 0.6%), indicating poor glycemic control in diabetic individuals.

Parathyroid hormone (PTH) levels were significantly elevated in the case group (81.1 ± 14.4 pg/mL) compared to the control (34.8 ± 10.7 pg/mL).

The serum calcium level was considerably reduced in the case group (9.23 ± 0.72 mg/dL) compared to the control group (9.93 ± 0.37 mg/dL).

Phosphate levels were considerably lower in the case group (2.53 ± 0.74 mg/dL) compared to the control (4.26 ± 0.58 mg/dL).

Table 1
Values of the studied parameters in the diabetes mellitus (DM) and control groups

Parameters	Group 1 (case) n = 80	Group 2 (control) n = 80	P-value
Vitamin D, ng/mL	6.86 ± 2.30	32.3 ± 12.14	<0.001
FPG, mg/dL	167.6 ± 40.4	81.3 ± 13.6	<0.001
HbA1c, %	10.78 ± 2.09	5.55 ± 0.59	<0.001
PTH, pg/mL	81.1 ± 14.4	34.8 ± 10.7	<0.001
Calcium, mg/dL	9.23 ± 0.72	9.93± 0.37	<0.001
Phosphate, mg/dL	2.53 ± 0.74	3.88 ± 0.84	<0.001

The correlation analysis in Table 2 shows the relationships between vitamin D levels (ng/ml) with HbA1c (%) and fasting plasma glucose (FPG, mg/dL) among the studied groups:

– Vitamin D and HbA1c: an inverse relationship between vitamin D levels and HbA1c ($r = –0.724$, $P = 0.038$), which is statistically significant in the T2DM group (Table 2, Fig. 1) but there is non-significant inverse correlation in the control group ($r = –0.863$, $P = 0.07$, Table 2);

– Vitamin D and FPG: a statistically inverse link between vitamin D and fasting plasma glucose levels ($r = –0.580$, $P = <0.001$, Table 2, Fig. 1) and non-significant inverse relation in the control group ($r = –0.754$, $P = 0.06$).

Table 2
Relation between vitamin D with HbA1c and fasting plasma glucose (FPG)

Glucose	T2DM group 1		Control group 2	
	r	probability	r	probability
HbA1c, %	–0.724	0.038	–0.863	0.07
FPG, mg/dL	–0.580	<0.001	–0.754	0.06

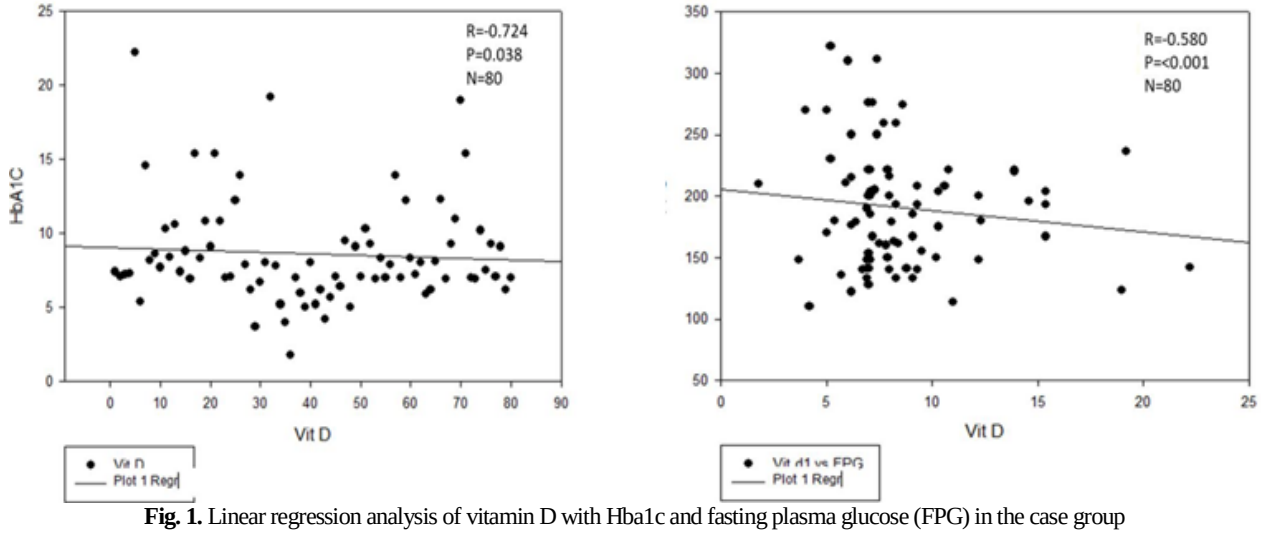

Fig. 1. Linear regression analysis of vitamin D with Hba1c and fasting plasma glucose (FPG) in the case group

Table 3 presents the correlation between the calcium levels with HbA1c and FPG:

– HbA1c and calcium had a negative connection in the T2DM group ($r = –0.753$, $P = 0.0062$, Table 4, Fig. 2); the control group also has a significant and inverse connection ($r = –0.828$, $P = <0.001$, Table 4);

– Calcium and FPG: in the T2DM group, there was a significant negative connection ($r = –0.0813$, $P = 0.007$) between calcium and fasting plasma glucose (Table 4, Fig. 2); in the control group, the association is likewise significant and inverse (Table 4).

Table 3
The association between calcium with Hba1c and FPG

Glucose	T2DM group 1		Control group 1	
	r	probability	r	probability
HbA1c, %	–0.753	0.0062	–0.828	<0.001
FPG, mg/dL	–0.717	0.0070	–0.659	<0.001

Table 4 and Figure 3 recorded the correlation of the phosphate levels with HbA1c and FPG:

– phosphate levels and HbA1c in the T2DM group showed a strong negative connection ($r = –0.870$, $P = <0.001$, Table 5, Fig. 3) in the case group; also an inverse connection were seen in the control group ($r = –0.666$, $P = <0.001$);

– phosphate and FPG: there is a significant negative association between fasting plasma glucose and phosphate levels in the T2DM group ($r = –0.710$, $P = <0.001$, Table 5, Fig. 3).

Table 4
Relationship between phosphate level with Hba1c and fasting plasma glucose (FPG)

Glucose	T2DM group 1 (n = 80)		Control group 1 (n = 80)	
	r	probability	r	probability
HbA1c	–0.870	<0.001	–0.666	<0.001
FPG	–0.710	<0.001	–0.510	<0.001

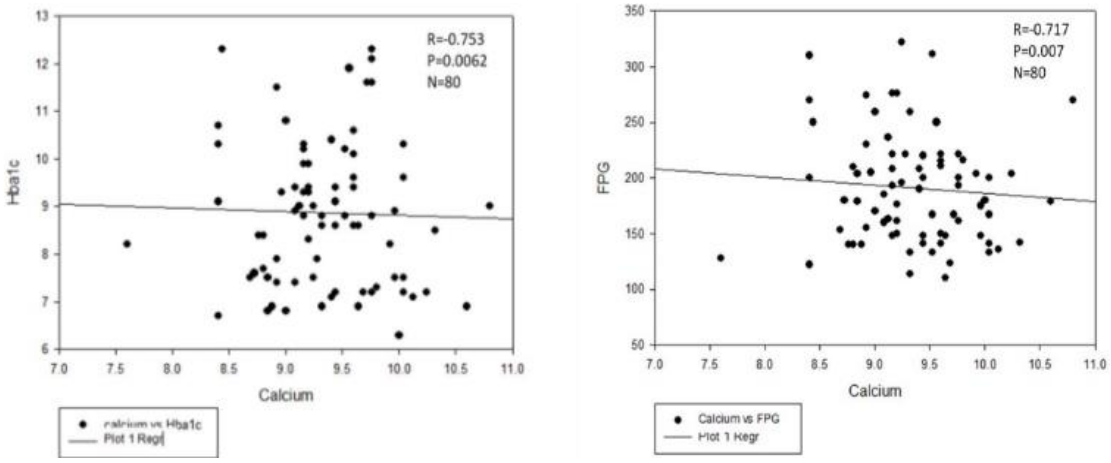

Fig. 2. Linear regression analysis of calcium level with Hba1c and fasting plasma glucose (FPG) in the case group

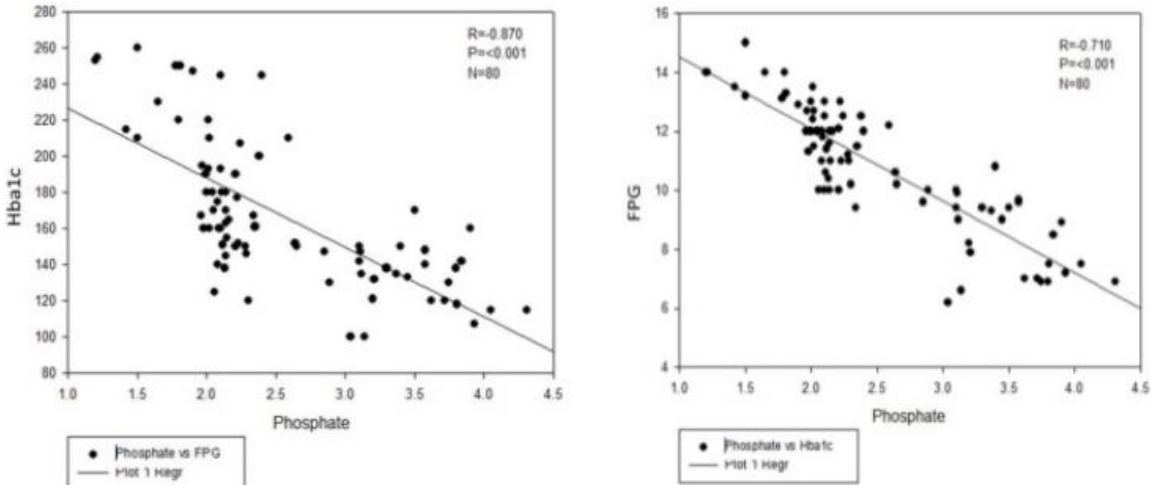

Fig. 3. Linear regression analysis of the phosphate level with Hba1c and fasting plasma glucose (FPG) in the case group

Table 5 and Figure 4 presents the correlation between the parathyroid hormone with HbA1c and FPG:

– parathyroid hormone level and HbA1c in the T2DM group exhibit a substantial direct connection with HbA1c (r = 0.476, P = <0.001, Table 6) in the case group, but in the control group displayed non-significant direct correlation with HbA1c (r = 0.197, P = 0.08);

– there is a significant positive relationship between fasting plasma glucose and parathyroid hormone levels in the T2DM group (r = 0.443, P = <0.001, Table 6); Table 6 shows a non-significant direct relation in the control as well (r = 0.206, P = 0.067).

Table 5
Connection between parathyroid hormone with Hba1c and fasting plasma glucose (FPG)

Glucose	T2DM group 1 (n = 80)		Control group 1 (n = 80)	
	r	probability	r	Probability
HbA1c	0.476	<0.001	0.197	0.080
FPG	0.443	<0.001	0.206	0.067

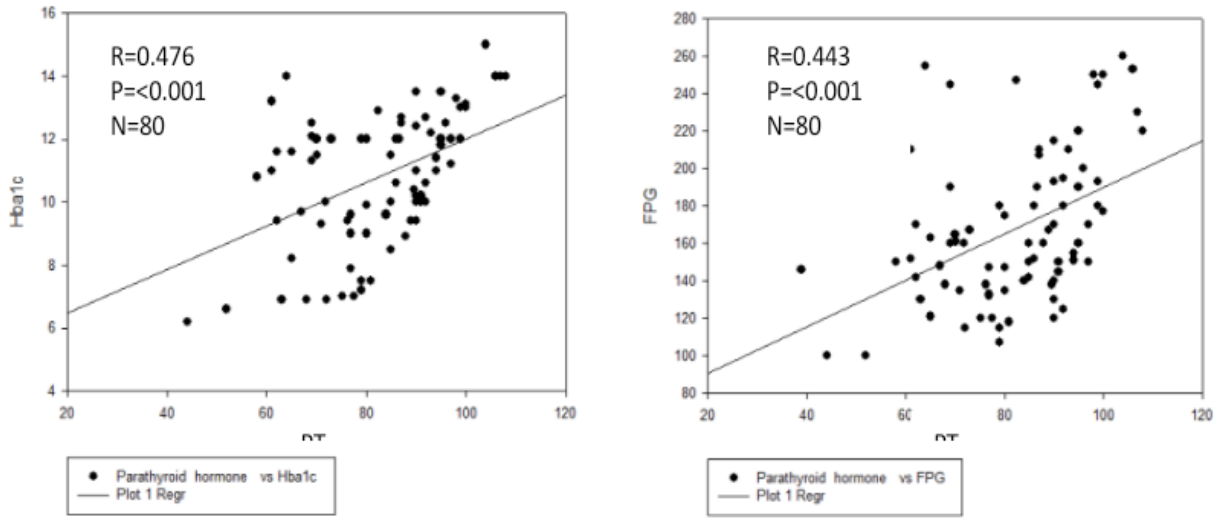

Fig. 4. Linear regression analysis of the parathyroid hormone with Hba1c and fasting plasma glucose (FPG) in the case group

Discussion

According to the study's findings, persons with type 2 diabetes mellitus (T2DM) have notable biochemical changes when compared to healthy controls, especially when it comes to vitamin D levels and indicators of bone metabolism and glycemic management.

A marked vitamin D deficiency was observed in diabetic group, with serum 25(OH)D levels considerably lower than those in the control (6.86 ± 2.3 vs. 32.3 ± 12.14 ng/mL; $P < 0.05$). This result aligns with several previous reports suggesting that vitamin D deficiency is prevailing among people with T2DM and may contribute to insulin resistance, impairment β-cell function, and systematic inflammation (Kayaniyil et al., 2010; Pittas et al., 2023). The underlying mechanisms may involve the character of vitamin D in modulating insulin secretion through its receptor expression in pancreatic β-cells and its influence on calcium flux, which is crucial for insulin exocytosis (Mendes et al., 2022).

Consistent with the diagnostic features of T2DM, FPG and HbA1c levels were significantly higher in the diabetic patients. Elevated HbA1c levels (10.78 ± 2.09%) indicate chronic hyperglycemia and poor glycemic control, which has deleterious effects on various tissues, including the bone. Hyperglycemia promotes oxidative stress and glycation of collagen in bone matrix, reducing bone strength and increasing the risk of fractures (Vestergaard et al., 2007). Importantly, parathyroid hormone (PTH) levels were significantly elevated in the T2DM group (81.12 ± 14.43 pg/mL), possibly as a compensatory response to hypovitaminosis D and reduced calcium levels. Elevated PTH is known to increase bone turnover which, when unbalanced by vitamin D and calcium, can result in bone resorption and osteoporosis (Cheng et al., 2022). Correspondingly, serum calcium levels were lower in the diabetic group than in controls. Hypocalcemia in T2DM may be multifactorial, stemming from poor intestinal absorption due to low vitamin D levels, renal losses, or altered PTH activity. The disruption in calcium homeostasis further supports the notion of compromised bone metabolism in diabetic patients(Tinawi et al., 2022). Additionally the diabetic group showed a decrease, in serum phosphate levels compared to the control group. Phosphorus plays a role in bone mineralization along with calcium and vitamin D. The low phosphorus levels could be due to excretion of phosphates, through the kidneys, which is often observed in kidney disease, or it could be linked to phosphaturia mediated by parathyroid hormone (PTH) (Akimbekov et al., 2022). When all the findings are taken into consideration, it is evident that there is a link between vitamin D deficiency and problems controlling blood sugar levels as well as abnormalities in bone health in people with type 2 diabetes. These patients may be at risk of bone disorders such as osteoporosis or osteomalacia due to the significant alterations in the balance of calcium and phosphorus and the elevated levels of PTH. It is possible to improve bone strength by routinely measuring vitamin D levels and quickly correcting any shortages with supplements, which also assists in better blood sugar control and the avoidance of diabetic complications. (Fuentes-Barría et al., 2025).

The results suggest that vitamin D could impact how the body handles glucose levels and insulin sensitiveness in individuals with type 2 diabetes. The findings show a link between the serum levels of calcium and both HbAlc and fasting plasma glucose observed in both the T2DM group and the control group. Calcium levels were inversely related to HBA1c and fasting glucose levels in the studied groups, suggest a potential role of calcium in regulating glucose even in non-diabetic individuals (Rawat et al., 2023). The results suggest that calcium balance is connected to how the body regulates sugar grade by affecting insulin liberation and the function of β cells. Problems with maintaining calcium levels could play a part in causing issues, with how the body processes glucose and in the development of diabetes (Campbell & Newgard, 2021; Weiser et al., 2021).

The present study demonstrates a significant inverse correlation between serum phosphate levels and both glycemic control indicators – HbA1c and fasting plasma glucose (FPG) – in both T2DM patients and healthy controls, as shown in Table 5 and Figure 3. These findings align with emerging evidence that disturbances in phosphate homeostasis may be linked to glucose metabolism and diabetes pathophysiology. In the T2DM group, phosphate levels exhibited a strong negative correlation with HbA1c ($r = 0.870$, $P < 0.001$) and FPG ($r = 0.710$, $P < 0.001$), indicating that lower phosphate concentrations are associated with poorer glycemic control. Similar, though slightly weaker, inverse correlations were also observed in the control group ($r = 0.666$ for HbA1c and $r = –0.510$ for FPG; $P < 0.001$ for both). These associations suggest that phosphate depletion may not only be a consequence of hyperglycemia but could also contribute to impaired glucose regulation.

Hypophosphatemia is a known complication in individuals with poorly controlled diabetes and has been attributed to several mechanisms, including increased urinary phosphate loss due to osmotic diuresis and insulin deficiency or resistance affecting renal phosphate handling. Furthermore, phosphate plays a vital role in glucose metabolism, particularly in ATP generation and glycolysis, processes that are essential for proper cellular glucose utilization (Palacios, 2006). Therefore, low phosphate availability may impair glucose uptake and metabolism, exacerbating hyperglycemia.

The observed correlations in the control group, though less pronounced, still support the broader physiological relationship between phosphate status and glycemic parameters. These findings emphasize the potential value of monitoring phosphate levels not only in patients with T2DM but also in individuals at risk of metabolic dysregulation. Moreover, chronic low phosphate levels may have implications for long-term diabetes complications, as phosphate imbalances have been linked to cardiovascular disease, insulin resistance, and bone mineral disorders, which are common comorbidities in diabetic patients (Kalantar-Zadeh et al., 2010).

Conclusion

Vitamin D levels were linked to glycemic control in individuals with type 2 diabetes, and they seemed to be lower in these patients than in the control group. These results may have therapeutic significance because careful vitamin D treatment may help individuals with type 2 diabetes handle blood sugar level.

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References

Abed, M. N., Alassaf, F. A., & Qazzaz, M. E. (2024). Exploring the interplay between vitamin D, insulin resistance, obesity and skeletal health. Journal of Bone Metabolism, 31(2), 75–89.

Akimbekov, N. S., Digel, I., Sherelkhan, D. K., & Razzaque, M. S. (2022). Vitamin D and phosphate interactions in health and disease. In: Razzaque, M. S. (Ed.). Phosphate metabolism: From physiology to toxicity. Springer, Cham. Pp. 37–46.

Argano, C., Mirarchi, L., Amodeo, S., Orlando, V., Torres, A., & Corrao, S. (2023). The role of vitamin D and its molecular bases in insulin resistance, diabetes, metabolic syndrome, and cardiovascular disease: State of the art. International Journal of Molecular Sciences, 24(20), 15485.

Campbell, J. E., & Newgard, C. B. (2021). Mechanisms controlling pancreatic islet cell function in insulin secretion. Nature Reviews Molecular Cell Biology, 22(2), 142–158.

Cheng, C.-H., Chen, L.-R., & Chen, K.-H. (2022). Osteoporosis due to hormone imbalance: An overview of the effects of estrogen deficiency and glucocorticoid overuse on bone turnover. International Journal of Molecular Sciences, 23(3), 1376.

Fuentes-Barría, H., Aguilera-Eguía, R., Flores-Fernández, C., Angarita-Davila, L., Rojas-Gómez, D., Alarcón-Rivera, M., López-Soto, O., & Maureira-Sánchez, J. (2025). Vitamin D and type 2 diabetes mellitus: Molecular mechanisms and clinical implications – a narrative review. International Journal of Molecular Sciences, 26(5), 2153.

Kalantar-Zadeh, K., Gutekunst, L., Mehrotra, R., Kovesdy, C. P., Bross, R., Shinaberger, C. S., Noori, N., Hirschberg, R., Benner, D., Nissenson, A. R., & Kopple, J. D. (2010). Understanding sources of dietary phosphorus in the treatment of patients with chronic kidney disease. Clinical Journal of the American Society of Nephrology, 5(3), 519–530.

Kayaniyil, S., Vieth, R., Retnakaran, R., Knight, J. A., Qi, Y., Gerstein, H. C., Perkins, B. A., Harris, S. B., Zinman, B., & Hanley, A. J. (2010). Association of vitamin D with insulin resistance and β-cell dysfunction in subjects at risk for type 2 diabetes. Diabetes Care, 33(6), 1379–1381.

Mendes, A. K. B., Sulis, P. M., Cavalari, F. C., Padilla, D. P. R., Aragón, M., Gaspar, J. M., & Silva, F. R. M. B. (2022). 1α,25-$(OH)_2$ vitamin D_3 prevents insulin resistance and regulates coordinated exocytosis and insulin secretion. The Journal of Nutritional Biochemistry, 99, 108864.

Motala, A. A., Mbanya, J. C., Ramaiya, K., Pirie, F. J., & Ekoru, K. (2022). Type 2 diabetes mellitus in sub-Saharan Africa: Challenges and opportunities. Nature Reviews Endocrinology, 18(4), 219–229.

Nadhiya, J., Vijayalakshmi, M. K., & Showbharnikhaa, S. (2024). A brief review on diabetes mellitus. Journal of Pharma Insights and Research, 2(1), 117–121.

Palacios, C. (2006). The role of nutrients in bone health, from A to Z. Critical Reviews in Food Science and Nutrition, 46(8), 621–628.

Pieńkowska, A., Janicka, J., Duda, M., Dzwonnik, K., Lip, K., Mędza, A., Szlagatys-Sidorkiewicz, A., & Brzeziński, M. (2023). Controversial impact of vitamin D supplementation on reducing insulin resistance and prevention of type 2 diabetes in patients with prediabetes: A systematic review. Nutrients, 15(4), 983.

Pittas, A. G., Kawahara, T., Jorde, R., Dawson-Hughes, B., Vickery, E. M., Angellotti, E., Nelson, J., Trikalinos, T. A., & Balk, E. M. (2023). Vitamin D and risk for type 2 diabetes in people with prediabetes. Annals of Internal Medicine, 176(3), 355–363.

Rawat, A., Grover, M., Kataria, T., Samdhani, S., Mathur, S., & Sharma, B. (2022). Minimally invasive parathyroidectomy as the surgical management of single parathyroid adenomas: A tertiary care experience. Indian Journal of Otolaryngology and Head and Neck Surgery, 75(2), 271–277.

Samant, A. C., Jha, H., & Kamal, P. (2025). Systematic review: Risk factors for developing type 2 diabetes mellitus. European Journal of Cardiovascular Medicine, 15(1), 382–390.

Tinawi, M. (2021). Disorders of calcium metabolism: Hypocalcemia and hypercalcemia. Cureus, 13(1), e12420.

Vestergaard, P., Jorgensen, N. R., Mosekilde, L., & Schwarz, P. (2006). Effects of parathyroid hormone alone or in combination with antiresorptive therapy on bone mineral density and fracture risk – a meta-analysis. Osteoporosis International, 18(1), 45–57.

Weiser, A., Feige, J. N., & De Marchi, U. (2021). Mitochondrial calcium signaling in pancreatic β-cell. International Journal of Molecular Sciences, 22(5), 2515.

Williams, D. M., Jones, H., & Stephens, J. W. (2022). Personalized type 2 diabetes management: An update on recent advances and recommendations. Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy, 15, 281–295.