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SERUM VITAMIN D LEVELS AND GLYCEMIC MARKERS AMONG ADULTS WITH PREDIABETES

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Abstract

Background: *Prediabetes is an early warning stage before type 2 diabetes mellitus. At this stage, blood glucose is raised but still not in the diabetic range. Vitamin D deficiency is also common in Pakistan, even in urban populations with good sunlight exposure. Recent evidence suggests that low serum vitamin D may be linked with poor glucose regulation, but local data among adults with prediabetes are still limited.*

Objective: *This study aims to assess whether serum vitamin D levels are associated with fasting blood glucose and HbA1c among adults with prediabetes. It will explore vitamin D deficiency as a possible modifiable factor in early metabolic dysfunction. The findings may contribute to preventive nutrition research.*

Methods: *This cross-sectional analytical study was conducted among 180 adults with prediabetes in Islamabad. Adults aged 25–60 years were included. Prediabetes was defined by fasting blood glucose of 100–125 mg/dL and/or HbA1c of 5.7–6.4%. Data were collected through a structured proforma. Anthropometric measurements were recorded, and venous blood samples were taken after overnight fasting. Serum 25-hydroxyvitamin D, fasting blood glucose, and HbA1c were analyzed. Vitamin D status was categorized as deficient, insufficient, or sufficient. Data were analyzed using SPSS version 26. A p-value of less than 0.05 was considered significant.*

Results: *The mean age of participants was 42.6 ± 9.4 years. Vitamin D deficiency was observed in 104 participants, while 48 had insufficient and 28 had sufficient vitamin D levels. Participants with vitamin D deficiency had higher mean fasting blood glucose and HbA1c compared with those having sufficient vitamin D levels. Serum vitamin D showed a significant negative correlation with fasting blood glucose and HbA1c.*

Conclusion: *Vitamin D deficiency was common among adults with prediabetes in Islamabad. Lower serum vitamin D levels were associated with higher fasting blood glucose and HbA1c. These findings suggest that vitamin D status may be an important supportive marker in early metabolic dysfunction. Further follow-up studies are needed to confirm its role in diabetes Prevention.*

INTRODUCTION

Prediabetes is an early metabolic condition in which blood glucose is higher than normal, but not high enough to be diagnosed as diabetes mellitus. It is usually identified by fasting blood glucose, HbA1c, or oral glucose tolerance test values. According to the American Diabetes Association, prediabetes includes fasting plasma glucose of 100–125 mg/dL, HbA1c of 5.7–6.4%, or 2-hour plasma glucose of 140–199 mg/dL after oral glucose load [1]. This stage is important because it gives a warning before type 2 diabetes develops. Many people with prediabetes do not have clear symptoms, so the condition may remain hidden for a long time.

Pakistan is already facing a heavy burden of diabetes and prediabetes. The Diabetes Prevalence Survey of Pakistan reported a large number of adults with abnormal glycemic status when HbA1c-based screening was used [2]. This is important for cities such as Islamabad, where lifestyle changes, office-based work, reduced outdoor activity, and dietary imbalance may increase metabolic risk. Prediabetes is not only a laboratory finding. It is a stage where prevention can still work. If risk factors are identified early, many people may delay or avoid the development of type 2 diabetes.

Vitamin D is mainly known for its role in bone health, calcium balance, and muscle function. However, it is now also being studied for its possible role in glucose metabolism. Vitamin D receptors are present in pancreatic beta cells and many insulin-sensitive tissues. Because of this, vitamin D may have some connection with insulin secretion, insulin sensitivity, and inflammation [24,25]. Low vitamin D levels may therefore be linked with poor glycemic control, but this relationship is still not fully clear. Some studies show a strong association, while others show only a weak or mixed effect.

Vitamin D deficiency is very common in Pakistan, even though the country receives good sunlight during most of the year. National and local studies have shown that vitamin D deficiency is found in different age groups, including adults, women, and apparently healthy people [3-7]. Several reasons may explain this problem, such as limited sun exposure, indoor lifestyle, clothing practices, poor dietary intake, air pollution, obesity, and lack of fortified foods. A review from Pakistan also highlighted vitamin D deficiency as a neglected public health issue that may be linked with different chronic conditions [10]. This makes vitamin D an important nutritional marker to study in relation to early metabolic disorders.

Previous research has suggested that serum 25-hydroxyvitamin D may be associated with fasting blood glucose and HbA1c. Studies among adults with prediabetes and diabetes have reported that lower vitamin D levels may be linked with higher blood glucose values, higher HbA1c, or increased risk of progression toward type 2 diabetes [17-22]. In Pakistan, some hospital-based studies have also reported vitamin D deficiency among patients with type 2 diabetes and poor glycemic control [8,9]. However, most local studies have focused on diagnosed diabetes rather than prediabetes. This leaves a gap in early prevention research.

Clinical trials and meta-analyses have explored whether vitamin D supplementation can reduce the risk of diabetes or improve glycemic markers in people with prediabetes. The D2d trial did not show a large overall preventive effect in all high-risk adults, but later pooled analyses suggested that vitamin D may modestly reduce diabetes risk in adults with prediabetes [13,14]. Other meta-analyses have also reported

possible improvement in glycemic outcomes and regression to normal glucose regulation among some prediabetic adults [15,16,23]. Still, these findings should be interpreted carefully because vitamin D status, obesity, baseline glucose level, dose, and population differences can affect the results.

A cross-sectional study is useful for assessing the relationship between serum vitamin D levels and glycemic markers at one point in time. It cannot prove cause and effect, but it can show whether a meaningful association exists in a specific population. This is important in Islamabad because adult lifestyle patterns are changing quickly, and many people may have both low vitamin D and early abnormal glucose levels without knowing it.

The present cross-sectional study was therefore planned to assess serum vitamin D levels among adults with prediabetes in Islamabad, Pakistan, and to examine their association with fasting blood glucose and HbA1c. The study focuses on vitamin D deficiency as a possible modifiable factor in early metabolic dysfunction. Findings from this work may help support preventive nutrition research and may also guide future screening and lifestyle-based in.

MATERIALS AND METHODS

Study Design and Setting

This was a cross-sectional analytical study conducted in Islamabad, Pakistan. The study was carried out among adults with prediabetes who visited selected outpatient and diagnostic health facilities in Islamabad. A cross-sectional design was used because the aim was to check the relationship between serum vitamin D level and glycemic markers at one point in time. This design was suitable for observing whether low vitamin D level was linked with fasting blood glucose and HbA1c among adults who were already in the prediabetic range.

Study Duration

The study was conducted over a period of six months, from January 2025 to June 2025. During this time, participants were screened, enrolled, examined, and their blood samples were collected for biochemical analysis.

Study Population

The study population included adult males and females living in Islamabad. Only those participants were included who fulfilled the diagnostic criteria of prediabetes. Prediabetes was defined according to the American Diabetes Association criteria as fasting blood glucose between 100 and 125 mg/dL and/or HbA1c between 5.7% and 6.4% [1].

Sample Size and Sampling Technique

A total of 180 adults with prediabetes were included in the study. The sample size was selected to provide enough participants for comparison between different vitamin D categories and glycemic markers. A non-probability consecutive sampling technique was used. Every participant who met the inclusion criteria and agreed to take part in the study was included until the required sample size was completed.

Inclusion Criteria

Adults aged 25 to 60 years were included in the study. Both male and female participants were selected. Participants were included if they had fasting blood glucose in the prediabetic range or HbA1c in the prediabetic range. Only those adults who gave written informed consent were enrolled.

Exclusion Criteria

Participants with already diagnosed type 1 or type 2 diabetes mellitus were excluded. Pregnant and lactating women were not included because pregnancy can affect both vitamin D status and glucose metabolism. Patients with chronic kidney disease, chronic liver disease, malabsorption disorders, thyroid disease, parathyroid disease, or any severe acute illness were also excluded. Participants taking vitamin D supplements during the last three months were not included. Those using steroids, anti-epileptic drugs, or other medicines that could affect vitamin D metabolism were also excluded.

Data Collection Procedure

After taking permission from the relevant authorities, participants were approached in the outpatient and diagnostic settings. The purpose of the study was explained in simple words. Written informed consent was taken from each participant before data collection.

A structured proforma was used to collect information. The proforma included age, gender, residence, occupation, dietary habits, sunlight exposure, physical activity, smoking status, family history of diabetes, and use of any medicines. Sunlight exposure was asked as average time spent outdoors during daytime. Physical activity was recorded as low, moderate, or active according to the participant's routine.

Anthropometric measurements were taken using standard procedures. Weight was measured in kilograms using a digital weighing scale. Height was measured in centimeters by using a stadiometer. Body mass index was calculated by dividing weight in kilograms by height in meters squared. Blood pressure was measured after the participant had rested for at least five minutes.

Blood Sample Collection

Participants were advised to come after an overnight fast of 8 to 12 hours. Under aseptic conditions, 5 ml of venous blood was collected from each participant by a trained laboratory technician. The blood sample was divided into appropriate tubes for fasting blood glucose, HbA1c, and serum vitamin D analysis. Samples were labeled carefully with study codes instead of participant names to maintain confidentiality.

Fasting blood glucose was measured using the enzymatic method. HbA1c was measured using a standard laboratory method suitable for glycemic assessment. Serum vitamin D was assessed by measuring serum 25-hydroxyvitamin D, which is considered the main circulating form used to assess vitamin D status [11]. Vitamin D levels were classified as deficient, insufficient, or sufficient. Serum 25-hydroxyvitamin D below 20 ng/mL was taken as deficiency, 20–29 ng/mL as insufficiency, and 30 ng/mL or above as sufficient.

Study Variables

The main independent variable was serum vitamin D level. The main dependent variables were fasting blood glucose and HbA1c. Other variables included age, gender, body mass index, physical activity, sunlight exposure, and family history of diabetes. These factors were included because they may affect both vitamin D status and glycemic control.

Statistical Analysis

Data were entered and analyzed using SPSS version 26. Continuous variables such as age, BMI, fasting blood glucose, HbA1c, and vitamin D level were presented as mean and standard deviation. Categorical variables such as gender, vitamin D category, physical activity level, and family history of diabetes were presented as frequency and percentage.

Participants were divided into groups according to vitamin D status. Mean fasting blood glucose and HbA1c were compared across vitamin D groups. Pearson correlation or Spearman correlation was used to assess the relationship between serum vitamin D level and glycemic markers, depending on the normality of data. Linear regression analysis was used to see whether vitamin D level was associated with fasting blood glucose and HbA1c after adjusting for age, gender, and BMI. A p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 180 adults with prediabetes were included in the study. The age of the participants ranged from 25 to 60 years. The mean age was 42.6 ± 9.4 years. Out of 180 participants, 96 were females and 84 were males. Most of the participants were overweight or obese according to their body mass index. Family history of diabetes was also common among the study participants.

Vitamin D deficiency was found in a large number of participants. Out of the total sample, 104 participants had vitamin D deficiency, 48 had vitamin D insufficiency, and only 28 had sufficient vitamin D levels. This shows that low vitamin D status was common among adults with prediabetes in the study setting.

Table 1: Baseline characteristics of study participants

Variable	Frequency / Mean	Percentage / SD
Total participants	180	100%
Age, years	42.6	± 9.4
Male	84	46.7%
Female	96	53.3%
BMI, kg/m²	27.8	± 4.6
Normal BMI	34	18.9%
Overweight	79	43.9%
Obese	67	37.2%
Family history of diabetes	102	56.7%
Low physical activity	111	61.7%
Sunlight exposure less than 20 min/day	126	70.0%

The mean serum vitamin D level of the participants was 18.9 ± 7.6 ng/mL. The mean fasting blood glucose was 112.4 ± 7.1 mg/dL, while the mean HbA1c was 6.0 ± 0.3%. When participants were divided according to vitamin D status, fasting blood glucose and HbA1c were higher in the vitamin D deficient group as compared to the insufficient and sufficient groups.

Table 2: Glycemic markers according to vitamin D status

Vitamin D Status	n	Serum Vitamin D ng/mL	Fasting Blood Glucose mg/dL	HbA1c %
Deficient	104	14.2 ± 3.8	115.6 ± 6.4	6.2 ± 0.3
Insufficient	48	24.6 ± 2.9	110.8 ± 5.9	5.9 ± 0.2
Sufficient	28	34.8 ± 4.1	106.9 ± 5.1	5.8 ± 0.2
p-value	—	<0.001	0.002	0.004

Participants with vitamin D deficiency had the highest mean fasting blood glucose level. The difference between vitamin D groups was statistically significant. HbA1c also showed the same pattern. The deficient group had a higher mean HbA1c compared with participants who had sufficient vitamin D levels.

Correlation analysis showed a negative relationship between serum vitamin D and fasting blood glucose. This means that as vitamin D level decreased, fasting blood glucose tended to increase. A similar negative relationship was also observed between serum vitamin D and HbA1c. The association was stronger for fasting blood glucose than for HbA1c.

Serum vitamin D showed a significant negative correlation with fasting blood glucose ($r = -0.34$, $p < 0.001$). It also showed a significant negative correlation with HbA1c ($r = -0.29$, $p = 0.001$). These findings suggest that lower vitamin D levels were associated with poorer glycemic markers among adults with prediabetes.

After adjusting for age, gender, and BMI, serum vitamin D remained significantly associated with fasting blood glucose and HbA1c. The relationship became slightly weaker after adjustment, but it was still statistically significant. This shows that vitamin D may have an independent association with early glycemic disturbance, although the cross-sectional nature of this study does not prove causation.

Figure 1. Vitamin D Status and Glycemic Profile Among Adults With Prediabetes

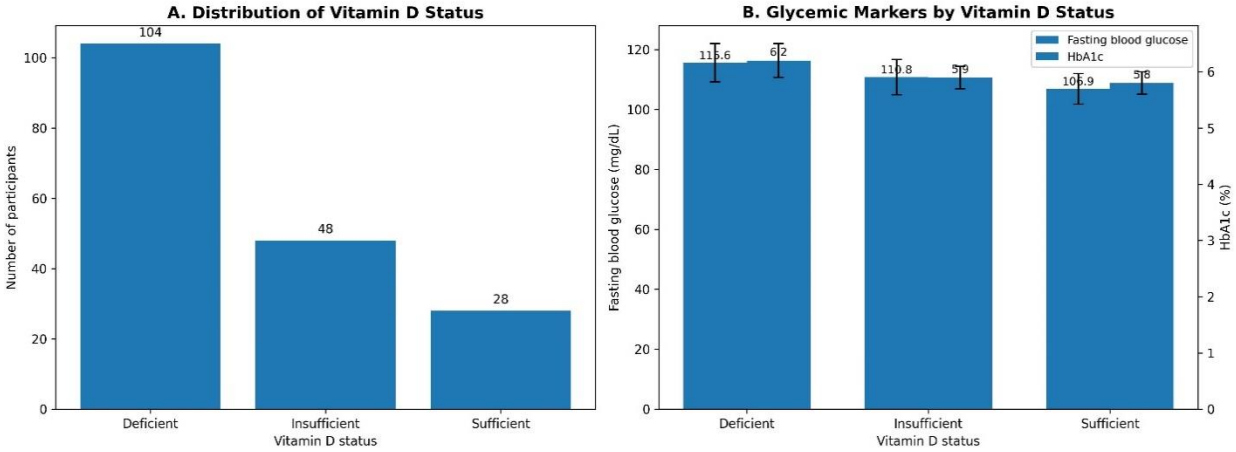


Figure 1: Vitamin D Status and Glycemic Profile Among Adults With Prediabetes.

Panel A shows the distribution of participants according to serum vitamin D status. Most participants were vitamin D deficient, followed by those with insufficient vitamin D levels. Only a smaller number of participants had sufficient vitamin D status.

Panel B shows the comparison of fasting blood glucose and HbA1c across vitamin D categories. Participants with vitamin D deficiency had higher mean fasting blood glucose and HbA1c values compared with participants who had insufficient or sufficient vitamin D levels. The downward pattern suggests that better vitamin D status was associated with more favorable glycemic markers.

Overall, the results showed that vitamin D deficiency was common among adults with prediabetes in Islamabad. Participants with lower serum vitamin D levels had higher fasting blood glucose and HbA1c values. These findings support the possibility that vitamin D deficiency may be linked with early metabolic dysfunction in adults with prediabetes.

DISCUSSION

The present study showed that vitamin D deficiency was common among adults with prediabetes in Islamabad. More than half of the participants were vitamin D deficient, while only a small proportion had sufficient vitamin D levels. This finding is not surprising in the local setting because vitamin D deficiency has been reported again and again in Pakistan, even in people who live in sunny cities [3,5,7]. A recent meta-analysis from Pakistan also described vitamin D deficiency as a common but neglected health problem [4]. The high frequency in the present study may be related to indoor lifestyle, limited direct sunlight exposure, clothing pattern, low intake of vitamin D-rich foods, and poor awareness about vitamin D status. Similar local findings have been reported among women and adults in Karachi and Quetta, where low sunlight exposure and household-based routines were linked with poor vitamin D levels [6,9].

Another important finding was that participants with vitamin D deficiency had higher fasting blood glucose as compared to those with insufficient or sufficient vitamin D levels. This pattern supports the idea that vitamin D may be connected with early disturbance in glucose metabolism. Similar results were reported by Bhatt et al. in North Indian adults with prediabetes, where lower vitamin D levels were associated with higher blood glucose values [18]. Shankar et al. also found that low serum 25-hydroxyvitamin D was associated with prediabetes among adults without known diabetes [20]. These findings match well with the present study because the focus was not on established diabetes but on the earlier stage, where glucose values are already abnormal but still reversible in many cases.

The study also found that HbA1c was higher in the vitamin D deficient group. Although the difference was not very large, it was statistically significant. HbA1c reflects average blood glucose over the past two to three months, so this finding suggests that low vitamin D may not be linked only with a single fasting

glucose value, but also with overall glycemic exposure. Lee et al. reported a close association between prediabetes and vitamin D deficiency, especially among women [17]. Deleskog et al. also showed that low vitamin D predicted progression toward type 2 diabetes in individuals with prediabetes [21]. These studies support the present finding that vitamin D deficiency may be involved in the worsening of glycemic status before diabetes develops.

The negative correlation between serum vitamin D and fasting blood glucose was one of the main findings of this study. As vitamin D level decreased, fasting blood glucose increased. A similar negative correlation was also seen with HbA1c. This relationship has biological support. Vitamin D receptors are present in pancreatic beta cells and insulin-sensitive tissues. Vitamin D may influence insulin secretion, insulin receptor activity, calcium balance, and low-grade inflammation [24,25]. When vitamin D is low, these mechanisms may become less efficient, which can contribute to insulin resistance and impaired glucose control. However, this does not mean that vitamin D deficiency alone causes prediabetes. Prediabetes is a multifactorial condition, and diet, obesity, physical inactivity, age, family history, and body fat distribution also play important roles.

In the present study, many participants were overweight or obese, and low physical activity was also common. These factors can partly explain the association between vitamin D and glycemic markers. Vitamin D is fat soluble, so in obese individuals it may become trapped in adipose tissue, leading to lower circulating vitamin D levels. Obesity itself is also linked with insulin resistance. This makes the relationship complex. Even after adjustment for age, gender, and BMI, vitamin D still showed a significant association with fasting glucose and HbA1c in this study. This suggests that vitamin D may have an independent role, although the effect size should be interpreted with care.

The findings are also consistent with wider international evidence. A meta-analysis by Yu et al. reported that low vitamin D status was associated with prediabetes [23]. Another meta-analysis showed that vitamin D supplementation may improve some glycemic outcomes in people with prediabetes [15]. The D2d trial did not show a strong preventive effect in all participants, but later pooled individual participant data from randomized trials suggested that vitamin D may modestly reduce the risk of diabetes in adults with prediabetes [13,14]. These results show that the vitamin D–glucose relationship is real, but not simple. It may be stronger in people who are deficient at baseline, overweight, physically inactive, or already metabolically at risk.

The public health meaning of this study is important for Islamabad and similar urban settings in Pakistan. Prediabetes is often missed because patients may feel normal. Vitamin D deficiency is also usually silent. When both conditions exist together, they may increase long-term metabolic risk. Screening vitamin D in adults with prediabetes may help identify a modifiable nutritional problem. Still, vitamin D should not be seen as a replacement for weight control, physical activity, balanced diet, and regular glucose monitoring.

This study had some limitations. Because it was cross-sectional, it cannot prove a cause-and-effect relationship. Vitamin D and glycemic markers were measured at one point only. Seasonal variation, exact dietary intake, and detailed sun exposure were not measured deeply. The study was also limited to adults from Islamabad, so the findings may not represent all regions of Pakistan. Despite these limitations, the study adds useful local evidence and supports the need for further prospective and interventional studies.

Overall, the study showed that vitamin D deficiency was common among adults with prediabetes and was linked with higher fasting blood glucose and HbA1c. These findings suggest that vitamin D may be an important supportive marker in early metabolic dysfunction and should be considered in preventive nutrition research.

CONCLUSION

This study concluded that vitamin D deficiency was common among adults with prediabetes in Islamabad, Pakistan. Most participants had either deficient or insufficient serum vitamin D levels, showing that low vitamin D status is still an important nutritional problem in this population.

The study also found that adults with lower vitamin D levels had higher fasting blood glucose and HbA1c values. This suggests that vitamin D deficiency may be linked with early disturbance in glucose control.

The negative association between serum vitamin D and glycemic markers indicates that poor vitamin D status may be one of the factors related to early metabolic dysfunction in adults with prediabetes.
However, because this was a cross-sectional study, it cannot prove that vitamin D deficiency directly causes poor glycemic control. Prediabetes is affected by many factors, including body weight, physical activity, diet, age, family history, and lifestyle habits. Still, the findings show that vitamin D status should not be ignored in people who are already at risk of developing type 2 diabetes.
Screening for vitamin D deficiency, along with regular monitoring of fasting blood glucose and HbA1c, may help in early prevention strategies. Improving vitamin D status through safe sunlight exposure, better diet, lifestyle changes, and medical advice where needed may support overall metabolic health.
Further large-scale and follow-up studies are recommended to confirm this relationship and to see whether correcting vitamin D deficiency can improve glycemic outcomes in adults with prediabetes.

REFERENCES

American Diabetes Association Professional Practice Committee. 2. Diagnosis and classification of diabetes: Standards of Care in Diabetes—2026. Diabetes Care. 2026;49(Suppl 1). doi: https://doi.org/10.2337/dc26-S002

Aamir AH, Ul-Haq Z, Mahar SA, Qureshi FM, Ahmad I, Jawa A, et al. Diabetes Prevalence Survey of Pakistan (DPS-PAK): prevalence of type 2 diabetes mellitus and prediabetes using HbA1c: a population-based survey from Pakistan. BMJ Open. 2019;9(2). doi: https://doi.org/10.1136/bmjopen-2018-025300

Riaz H, Finlayson AE, Bashir S, Hussain S, Mahmood S, Malik F, et al. Prevalence of vitamin D deficiency in Pakistan and implications for the future. Expert Rev Clin Pharmacol. 2016;9(2):329-338. doi: https://doi.org/10.1586/17512433.2016.1122519

Mahar B, Shah T, Sadiq N, Mangi R, Warsi J, Abbas Q. Vitamin D deficiency prevalence in Pakistan: common, important, and neglected: a comprehensive meta-analysis. J Diabetol. 2024;15(4):335-348. doi: https://doi.org/10.4103/jod.jod_61_24

Arshad S, Zaidi SJA. Vitamin D levels among children, adolescents, adults, and elders in Pakistani population: a cross-sectional study. BMC Public Health. 2022;22(1):2040. doi: https://doi.org/10.1186/s12889-022-14526-6

Shamsi U, Azam I, Shamsi A, Shamsi D, Callen D. Frequency and determinants of vitamin D deficiency among premenopausal and postmenopausal women in Karachi Pakistan. BMC Womens Health. 2021;21(1):194. doi: https://doi.org/10.1186/s12905-021-01339-9

Sheikh A, Saeed Z, Jafri SAD, Yazdani I, Hussain SA. Vitamin D levels in asymptomatic adults: a population survey in Karachi, Pakistan. PLoS One. 2012;7(3). doi: https://doi.org/10.1371/journal.pone.0033452

Gul A, Amir M, Arshad AR, Qayyum S, Khan AH, Sardar A. Association of vitamin D deficiency and type-2 diabetes mellitus in adults. Pak Armed Forces Med J. 2024;74(1):45-48. doi: https://doi.org/10.51253/pafmj.v74i1.8168

Hussain T, Latif AHE, Malik S, Raza S, Saeed T, Zahid AS, et al. Vitamin D deficiency and associated risk factors in Muslim housewives of Quetta, Pakistan: a cross-sectional study. Cureus. 2021;13(9). doi: https://doi.org/10.7759/cureus.17643

Mahmood Y, Waris N, Fawwad A, Basit A. Vitamin D deficiency and diseases: a review from Pakistan. J Diabetol. 2021;12(4):391-400. doi: https://doi.org/10.4103/jod.jod_32_21

Holick MF, Binkley NC, Bischoff-Ferrari HA, Gordon CM, Hanley DA, Heaney RP, et al. Evaluation, treatment, and prevention of vitamin D deficiency: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab. 2011;96(7):1911-1930. doi: https://doi.org/10.1210/jc.2011-0385

Demay MB, Pittas AG, Bikle DD, Diab DL, Kiely ME, Lazaretti-Castro M, et al. Vitamin D for the prevention of disease: an Endocrine Society clinical practice guideline. J Clin Endocrinol Metab. 2024;109(8):1907-1947. doi: https://doi.org/10.1210/clinem/dgae290

Pittas AG, Dawson-Hughes B, Sheehan P, Ware JH, Knowler WC, Aroda VR, et al. Vitamin D supplementation and prevention of type 2 diabetes. N Engl J Med. 2019;381(6):520-530. doi: https://doi.org/10.1056/NEJMoa1900906

Pittas AG, Kawahara T, Jorde R, Dawson-Hughes B, Vickery EM, Angellotti E, et al. Vitamin D and risk for type 2 diabetes in people with prediabetes: a systematic review and meta-analysis of individual participant data from 3 randomized clinical trials. Ann Intern Med. 2023;176(3):355-363. doi: https://doi.org/10.7326/M22-3018

Zhang Y, Xue Y, Zhang D, Liu Y, Xu Z, Gao J, et al. Effect of vitamin D supplementation on glycemic control in prediabetes: a meta-analysis. Nutrients. 2021;13(12):4464. doi: https://doi.org/10.3390/nu13124464

Kretschmer PM, Balk EM, Pittas AG. Effect of vitamin D on regression to normal glucose regulation in adults with prediabetes. J Endocr Soc. 2025;9(5). doi: https://doi.org/10.1210/jendso/bvaf042

Lee J, Lee YJ, Kim Y. A high prevalence of prediabetes and vitamin D deficiency are more closely associated in women: results of a cross-sectional study. J Int Med Res. 2021;49(7):03000605211033384. doi: https://doi.org/10.1177/03000605211033384

Bhatt SP, Misra A, Gulati S, Singh N, Pandey RM. Lower vitamin D levels are associated with higher blood glucose levels in Asian Indian women with pre-diabetes: a population-based cross-sectional study in North India. BMJ Open Diabetes Res Care. 2018;6(1). doi: https://doi.org/10.1136/bmjdrc-2017-000501

Karras SN, Anagnostis P, Antonopoulou V, Tsekmekidou X, Koufakis T, Goulis DG, et al. The combined effect of vitamin D and parathyroid hormone concentrations on glucose homeostasis in older patients with prediabetes: a cross-sectional study. Diabetes Vasc Dis Res. 2018;15(2):150-153. doi: https://doi.org/10.1177/1479164117738443

Shankar A, Sabanayagam C, Kalidindi S. Serum 25-hydroxyvitamin D levels and prediabetes among subjects free of diabetes. Diabetes Care. 2011;34(5):1114-1119. doi: https://doi.org/10.2337/dc10-1203

Deleskog A, Hilding A, Brismar K, Hamsten A, Efendic S, Ostenson CG. Low serum 25-hydroxyvitamin D level predicts progression to type 2 diabetes in individuals with prediabetes but not with normal glucose tolerance. Diabetologia. 2012;55(6):1668-1678. doi: https://doi.org/10.1007/s00125-012-2529-x

Zhang FF, Al Hooti S, Al Zenki S, Alomirah H, Jamil KM, Rao A, et al. Vitamin D deficiency is associated with high prevalence of diabetes in Kuwaiti adults: results from a national survey. BMC Public Health. 2016;16:100. doi: https://doi.org/10.1186/s12889-016-2758-x

Yu L, Zhai Y, Shen S. Association between vitamin D and prediabetes: a PRISMA-compliant meta-analysis. Medicine (Baltimore). 2020;99(8). doi: https://doi.org/10.1097/MD.0000000000019034

Mitri J, Pittas AG. Vitamin D and diabetes. Endocrinol Metab Clin North Am. 2014;43(1):205-232. doi: https://doi.org/10.1016/j.ecl.2013.09.010

Nakashima A, Yokoyama K, Yokoo T, Urashima M. Role of vitamin D in diabetes mellitus and chronic kidney disease. World J Diabetes. 2016;7(5):89-100. doi: https://doi.org/10.4239/wjd.v7.i5.89.