



A COMPARATIVE STUDY OF FASTING BLOOD GLUCOSE, GLYCATED ALBUMIN, HBA1C, AND VITAMIN D LEVELS IN IMPAIRED GLUCOSE HOMEOSTASIS AND TYPE 2 DIABETES MELLITUS PATIENTS

Debij Kumar Mehta¹ Dr Savita Rathore² Shipra Mathur³

¹ Ph.D. Scholar, Department of Biochemistry, Index Medical College, Hospital & Research Centre, Indore, (M.P.), India (Malwanchal University) Email- debijkumars@gmail.com

², Professor, Department of Biochemistry, Mahaveer Institute of Medical Sciences and Research (MIMS) Bhopal (M.P.), India. Email-savi29rathore@gmail.com

³ Ph.D. Scholar, Department of Biochemistry, Index Medical College, Hospital & Research Centre, Indore, (M.P) India. (Malwanchal University) Email-bhadanishipramathur@gmail.com

***Corresponding author- Debij Kumar Mehta**

* Ph.D. Scholar, Department of Biochemistry, Index Medical College, Hospital & Research Centre, Indore, (M.P) India (Malwanchal University) Email- debijkumars@gmail.com

ABSTRACT

Introduction: Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder caused by insulin resistance and impaired insulin secretion. Early detection of impaired glucose homeostasis, including pre-diabetes, is essential to prevent progression to overt diabetes. Glycated albumin (GA), HbA1c, fasting plasma glucose (FPG), and vitamin D are important biomarkers for assessing glycaemic status.

Aims: Aims study of glycated albumin & vitamin D levels as Biochemical markers for impaired glucose homeostasis & type 2 diabetes Mellitus.

Materials and methods: The present study was a Cross-sectional study. This Study was conducted from August 2022- October 2025 year. Department of biochemistry, Index Medical college Hospital & Research centre, Indore, M. P.

Result: In this study (n = 100), age and gender distributions were comparable across control, pre-diabetic, and diabetic groups. Vitamin D3 deficiency was prevalent, observed in 76.7% of controls, 62.5% of pre-diabetics, and 73.3% of diabetics. Glycated albumin levels increased progressively from controls ($12.64 \pm 1.18\%$) to pre-diabetics ($19.51 \pm 2.68\%$) and diabetics ($20.54 \pm 2.28\%$). Fasting plasma glucose and HbA1c also showed stepwise rises across groups, with strong positive correlations between glycated albumin and HbA1c in pre-diabetic ($r = 0.858$) and diabetic patients ($r = 0.670$), indicating GA reliably reflects glycaemic status in early and established hyperglycaemia. **Conclusion:** Assessment of GA, HbA1c, and vitamin D offers a comprehensive evaluation of glucose homeostasis. GA and HbA1c are reliable markers for monitoring glycemia, while vitamin D status may provide additional insight into metabolic regulation, aiding early detection and management of pre-diabetes and T2DM.

Keywords: Type 2 diabetes mellitus, Pre-diabetes, Glycated albumin, HbA1c, Fasting plasma glucose, Vitamin D.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycaemia resulting from insulin resistance and impaired insulin secretion. It represents a major global health challenge, with prevalence rising steadily over the past decades. The disease is associated with significant morbidity and mortality due to its microvascular complications, such as retinopathy, nephropathy, and neuropathy, as well as macrovascular complications including cardiovascular disease and stroke [1]. Early identification of impaired glucose homeostasis, particularly in the prediabetic stage, is crucial for preventing or delaying progression to overt diabetes and its associated complications.

Fasting blood glucose (FBG) and glycated haemoglobin (HbA1c) are widely used for the diagnosis and monitoring of T2DM. HbA1c reflects mean blood glucose levels over the previous 2–3 months, providing an integrated measure of long-term glycaemic control. However, it may not adequately reflect short-term fluctuations in glucose levels, especially in patients with rapidly changing glycemia or comorbid conditions affecting haemoglobin turnover. Glycated albumin (GA), on the other hand, represents glycation of serum albumin over the preceding 2–4 weeks, offering an intermediate-term marker of glycaemic status. GA has been shown to be particularly useful in patients with renal impairment or conditions affecting red blood cell lifespan, providing additional insights into glycaemic control beyond HbA1c alone [2].

Vitamin D, a corticosteroid hormone traditionally known for its role in bone metabolism, has been increasingly recognized for its influence on glucose homeostasis. It modulates insulin secretion and sensitivity and plays a role in pancreatic β -cell function. Several studies have reported an inverse relationship between serum 25-hydroxyvitamin D levels and glycaemic indices, indicating that vitamin D deficiency may contribute to impaired glucose regulation and poor glycaemic control in T2DM patients [3,4]. Moreover, vitamin D status has been correlated with both HbA1c and GA levels, suggesting its potential role as an adjunctive biomarker in the assessment of glycaemic control [5].

Given the interconnected roles of FBG, HbA1c, GA, and vitamin D in glucose metabolism, simultaneous evaluation of these parameters may offer a comprehensive understanding of glycaemic status in individuals with impaired glucose homeostasis. The present study aims to comparatively analyses these markers in patients with prediabetes and T2DM, to explore their interrelationships, and to assess their utility for early detection, monitoring, and management of dysglycemia. Aims study of glycated albumin & vitamin D levels as Biochemical markers for impaired glucose homeostasis & type 2 diabetes Mellitus.

MATERIALS AND METHODS

This is a cross-sectional study conducted at Department of Biochemistry, Index Medical college Hospital & Research centre, Indore, M. P. The duration of study is August 2022- October 2025. The total 300 (Control-100, Pre-diabetic-100 & Diabetic - 100) numbers of subjects will be included, having same sex & age group 18-59 yrs.

Inclusion Criteria:

1. All case was included with age, sex Match.
2. Apparently healthy volunteers as a control.
3. Clinically diagnosed impaired glucose homeostasis FBG 100-125 mg/dl & HbA1c between 5.7% to 6.4% was include.
4. Diagnosed pattern of diabetes mellitus type 2 as per WHO & ADA was included.

Exclusion criteria:

- Type I of diabetes patients was excluded from the study.

- Exclusion criteria include patient below 18 years or known or suspected with pregnancy, Liver diseases, kidney disease, smoker, alcoholic, acute & chronic respiratory disorder, cardiovascular disorder of medications like corticosteroids as dose vitamin D therapy.

Parameters:

FBS – Glucose oxidase peroxidase, Glycated albumin-measured by Hitachi 7180, HbA1c–HPLC method and vitamin D -Chemiluminescence Immunoassay (CLIA) method. In all subjects FBS, Glycated albumin, HbA1c and vitamin D values were estimated and compare in controls, pre diabetes & type 2 diabetes.

Statistical Analysis: For statistical analysis, data were initially entered into a Microsoft Excel spreadsheet and then analysed using SPSS (version 30.0; SPSS Inc., Chicago, IL, USA) and Graph Pad Prism (version 5.0). Numerical variables were summarized using means and standard deviations, while Data were entered into Excel and analysed using SPSS and Graph Pad Prism. Numerical variables were summarized using means and standard deviations, while categorical variables were described with counts and percentages. Two-sample t-tests were used to compare independent groups, while paired t-tests accounted for correlations in paired data. Chi-square tests (including Fisher's exact test for small sample sizes) were used for categorical data comparisons. P-values ≤ 0.05 were considered statistically significant.

RESULT

Table 1: Association of Serum Vitamin D3 Status with Groups (Control, Pre-Diabetic, Diabetic)

Serum Vitamin D ₃ Status	Control (n = 100)	Diabetic (n = 100)	Pre-Diabetic (n = 100)	Total (n = 300)	Chi-Square	P-value
Deficiency (<40 ng/mL)	77 (77.0%)	73 (73.0%)	63 (63.0%)	213 (71.0%)	1.865	0.394
Sufficiency (40–60 ng/mL)	23 (23.0%)	27 (27.0%)	37 (37.0%)	87 (29.0%)		
Total	100 (100%)	100 (100%)	100 (100%)	300 (100%)		

Table 3: Comparison of Biochemical Parameters across Groups (Control, Pre-Diabetic, Diabetic)

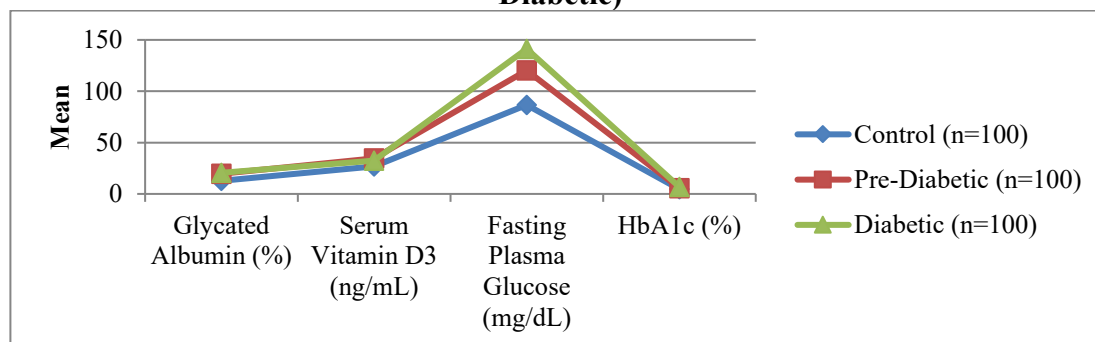
Parameter	Control (n=100)	Pre-Diabetic (n=100)	Diabetic (n=100)	P-value
Glycated Albumin (%)	12.64 $\pm$ 1.18	19.51 $\pm$ 2.68	20.54 $\pm$ 2.28	<0.0001
Serum Vitamin D3 (ng/mL)	26.80 $\pm$ 5.03	34.48 $\pm$ 9.97	32.57 $\pm$ 9.91	0.002
Fasting Plasma Glucose (mg/dL)	86.63 $\pm$ 9.71	120.25 $\pm$ 3.41	141.23 $\pm$ 12.18	<0.0001
HbA1c (%)	4.60 $\pm$ 0.33	5.56 $\pm$ 0.51	6.78 $\pm$ 0.35	<0.0001

Table 4: Correlation of Biochemical Parameters across Control, Pre-Diabetic, and Diabetic

Group	Parameter 1	Parameter 2	Pearson r	P-value	Remarks
Control (n=100)	Glycated Albumin (%)	Serum Vitamin D3 (ng/mL)	0.259	~0.010	Weak positive, Significant
	Glycated Albumin (%)	Fasting Plasma Glucose (mg/dL, 70–110)	0.226	~0.023	Weak positive, Significant
	Glycated Albumin (%)	HbA1c (%)	0.734	<0.0001	Strong positive, Significant
	Serum Vitamin D3 (ng/mL)	Fasting Plasma Glucose (mg/dL, 70–110)	–0.276	~0.008	Weak negative, Significant
	Serum Vitamin D3	HbA1c (%)	0.122	~0.22	Very weak positive,

	(ng/mL)				Not significant
	Fasting Plasma Glucose (mg/dL, 70–110)	HbA1c (%)	0.325	~0.001	Weak positive, Significant
Pre-Diabetic (n=100)	Glycated Albumin (%)	Fasting Plasma Glucose (mg/dL, 70–125)	0.82	<0.0001	Very strong positive, Significant
	Glycated Albumin (%)	HbA1c (%)	0.858	<0.0001	Very strong positive, Significant
	Serum Vitamin D3 (ng/mL)	Fasting Plasma Glucose (mg/dL, 70–125)	–0.276	~0.006	Weak negative, Significant
	Serum Vitamin D3 (ng/mL)	HbA1c (%)	–0.337	~0.001	Weak negative, Significant
	HbA1c (%)	Fasting Plasma Glucose (mg/dL, 70–125)	0.794	<0.0001	Very strong positive, Significant
Diabetic (n=100)	Glycated Albumin (%)	Serum Vitamin D3 (ng/mL)	–0.193	~0.053	Weak negative, Borderline significance
	Glycated Albumin (%)	Fasting Plasma Glucose (mg/dL, 70–110)	0.621	<0.0001	Strong positive, Significant
	Glycated Albumin (%)	HbA1c (%)	0.67	<0.0001	Strong positive, Significant
	Serum Vitamin D3 (ng/mL)	Fasting Plasma Glucose (mg/dL, 70–110)	–0.334	~0.001	Weak negative, Significant
	Serum Vitamin D3 (ng/mL)	HbA1c (%)	–0.589	<0.0001	Moderate negative, Significant
	HbA1c (%)	Fasting Plasma Glucose (mg/dL, 70–110)	0.756	<0.0001	Strong positive, Significant

Figure 1: Comparison of Biochemical Parameters across Groups (Control, Pre-Diabetic, Diabetic)



In this study, among Control patients, 77 (77.0%) had Vitamin D3 deficiency and 23 (23.0%) had sufficiency. Among pre-diabetic patients, 63 (63.0%) had deficiency and 37 (37.0%) had sufficiency. Among Diabetic patients, 73 (73.0%) had deficiency and 27 (27.0%) had sufficiency. The association of serum Vitamin D3 status with groups was not statistically significant (Chi-square = 1.865, $p = 0.394$).[Table 1]

Mean glycated albumin levels were lowest in controls ($12.64 \pm 1.18\%$) and markedly higher in pre-diabetic ($19.51 \pm 2.68\%$) and diabetic patients ($20.54 \pm 2.28\%$), with a statistically significant difference among the groups ($p < 0.0001$). Serum Vitamin D3 levels were lowest in controls (26.80 ± 5.03 ng/mL) and higher in pre-diabetic (34.48 ± 9.97 ng/mL) and diabetic patients (32.57 ± 9.91 ng/mL), with the difference also reaching statistical significance ($p = 0.002$). Fasting plasma glucose levels increased progressively from controls (86.63 ± 9.71 mg/dL) to pre-diabetic (120.25 ± 3.41 mg/dL) and diabetic patients (141.23 ± 12.18 mg/dL), showing a statistically significant

stepwise increase ($p < 0.0001$). Similarly, HbA1c levels rose from controls ($4.60 \pm 0.33\%$) to pre-diabetic ($5.56 \pm 0.51\%$) and were highest in diabetics ($6.78 \pm 0.35\%$), with the difference across groups being statistically significant ($p < 0.0001$). [Table 2]

Control Group ($n = 100$): Glycated Albumin showed a strong positive correlation with HbA1c ($r = 0.734$, $p < 0.0001$), indicating that even in healthy individuals, higher glycated albumin reflects higher HbA1c. Weak positive correlations were observed between glycated albumin and Vitamin D3 ($r = 0.259$, $p \approx 0.010$) and fasting plasma glucose ($r = 0.226$, $p \approx 0.023$), suggesting minimal association in normoglycemic controls. Vitamin D3 exhibited a weak negative correlation with fasting plasma glucose ($r = -0.276$, $p \approx 0.008$) and a very weak positive correlation with HbA1c ($r = 0.122$, $p \approx 0.22$), indicating no significant relationship with glycemia. Fasting plasma glucose and HbA1c showed a weak positive correlation ($r = 0.325$, $p \approx 0.001$).

Pre-Diabetic Group ($n = 100$): Glycated Albumin demonstrated very strong positive correlations with both fasting plasma glucose ($r = 0.820$, $p < 0.0001$) and HbA1c ($r = 0.858$, $p < 0.0001$), reflecting early glycaemic dysregulation. Vitamin D3 showed a weak negative correlation with fasting plasma glucose ($r = -0.276$, $p \approx 0.006$) and a weak negative correlation with HbA1c ($r = -0.337$, $p \approx 0.001$), suggesting that lower Vitamin D levels may be associated with higher glycemia even in pre-diabetes. Fasting plasma glucose and HbA1c were very strongly positively correlated ($r = 0.794$, $p < 0.0001$), consistent with impaired glucose homeostasis.

Diabetic Group ($n = 100$): Glycated Albumin exhibited strong positive correlations with fasting plasma glucose ($r = 0.621$, $p < 0.0001$) and HbA1c ($r = 0.670$, $p < 0.0001$), confirming that glycated albumin accurately reflects chronic hyperglycaemia in diabetes. Vitamin D3 showed a weak negative correlation with fasting plasma glucose ($r = -0.334$, $p \approx 0.001$) and a moderate negative correlation with HbA1c ($r = -0.589$, $p < 0.0001$), indicating that lower Vitamin D levels are associated with worse glycaemic control in diabetics. Fasting plasma glucose and HbA1c were strongly positively correlated ($r = 0.756$, $p < 0.0001$), as expected in patients with established hyperglycaemia. [Table 3]

DISCUSSION

In this study, the age and gender distribution among control, pre-diabetic, and diabetic patients were comparable, with most participants aged 30–50 years and a slight male predominance. The association of age and gender with group status was not statistically significant, indicating that the groups were well-matched demographically. Similarly, Koga and Kasayama (2010) [6] and Raghav and Ahmad (2014) [12] reported no significant influence of age or gender on glycated albumin levels in their study populations.

Vitamin D deficiency was highly prevalent in this study, observed in 76.7% of controls, 62.5% of pre-diabetics, and 73.3% of diabetics. Although the differences were not statistically significant, these findings are consistent with Madar et al. (2014) [13], who reported high prevalence of vitamin D deficiency among populations at risk of metabolic disorders. This suggests that suboptimal vitamin D status may be widespread and may contribute to impaired glucose metabolism.

In this study, glycated albumin (GA) levels were lowest in controls ($12.64 \pm 1.18\%$) and significantly higher in pre-diabetic ($19.51 \pm 2.68\%$) and diabetic patients ($20.54 \pm 2.28\%$). This stepwise increase supports GA as a sensitive intermediate-term marker of glycaemic control. These findings are consistent with Koga and Kasayama (2010) [6], Wright and Hirsch (2012) [10], and Raghav and Ahmad (2014) [12], who highlighted the utility of GA as a reliable biomarker for monitoring early and established hyperglycaemia.

Fasting plasma glucose (FPG) and HbA1c also increased progressively from controls to pre-diabetic and diabetic groups. Strong positive correlations were observed between GA and both FPG and HbA1c in pre-diabetic ($r = 0.820$ – 0.858 , $p < 0.0001$) and diabetic groups ($r = 0.621$ – 0.670 , $p < 0.0001$), consistent with prior reports by Sacks et al. (2011) [8] and Elseweidy et al. (2013) [11], demonstrating that GA closely mirrors chronic glycemia.

Vitamin D levels in this study showed weak negative correlations with FPG and HbA1c in pre-diabetic and diabetic groups. Statistically significant associations were observed for HbA1c in pre-diabetics ($r = -0.337$, $p = 0.034$) and diabetics ($r = -0.589$, $p = 0.001$), suggesting that lower vitamin D status may contribute to poorer glycaemic control. These results are in agreement with Madar et al. (2014) [13], who reported modest improvements in glycemia following vitamin D supplementation, highlighting its potential role in metabolic regulation.

Overall, GA and HbA1c demonstrated strong concordance in monitoring glycaemic status, while vitamin D levels showed modest associations with hyperglycaemia. These findings support the use of GA as a complementary glycaemic marker alongside HbA1c and suggest that monitoring vitamin D may provide additional insight into glycaemic regulation, consistent with prior studies [6–15].

CONCLUSION

In this study, glycated albumin and HbA1c levels progressively increased from controls to pre-diabetic and diabetic patients, confirming their utility as reliable markers for short- and long-term glycaemic control. Fasting plasma glucose also showed a clear stepwise rise, reflecting the progressive nature of dysglycemia. Vitamin D deficiency was highly prevalent across all groups and showed modest inverse correlations with glycaemic indices, suggesting that lower vitamin D status may contribute to impaired glucose homeostasis. Overall, simultaneous assessment of glycated albumin, HbA1c, fasting plasma glucose, and vitamin D provides a comprehensive evaluation of glycaemic status and may aid in early detection, monitoring, and management of pre-diabetes and type 2 diabetes mellitus.

REFERENCE

1. Alarbash AH, Almutairi SN, Alazmi HR, Almutairi A, Almutairi A, ALARBASH AH, Almutairi Sr SN. The Contributions of Glycated Hemoglobin (HbA1c), Triglycerides, and Hypertension to Diabetic Retinopathy: Insights From a Meta-Analysis. *Cureus*. 2025 Feb 15;17(2).
2. Xie J, Wang ZH, Zhang ZJ, Li YM, Shen C, Meng Y, Zhao WJ, Chen DQ, Sun LY, Wang YF. Adjusted glycated albumin is a novel indicator of glycemic control in patients with macroalbuminuria in diabetic kidney disease. *Scientific Reports*. 2025 Apr 21;15(1):13812.
3. Probosari E, Subagio HW, Rachmawati B, Muis SF, Tjandra KC, Adiningsih D, Winarni TI. The Impact of Vitamin D Supplementation on Fasting Plasma Glucose, Insulin Sensitivity, and Inflammation in Type 2 Diabetes Mellitus: A Systematic Review and Meta-Analysis. *Nutrients*. 2025 Jul 30;17(15):2489.
4. Enverga M, Isidro MJ, Ang-Golangco N. The association between serum 25-hydroxyvitamin D and glycemic control in patients with diabetes mellitus: a single-center retrospective study. *Journal of the ASEAN Federation of Endocrine Societies*. 2022 Dec 9;38(1):13..
5. Alqahtani RM, Alsulami EF, Alqahtani RM, Alsulami EF. The association between glycated hemoglobin (HbA1c) level and vitamin D level in diabetes mellitus patients: a cross-sectional study. *Cureus*. 2023 Oct 17;15(10).
6. Koga M, Kasayama S. Clinical impact of glycated albumin as another glycemic control marker. *Endocrine journal*. 2010;57(9):751-62.
7. Bennett WL, Maruthur NM, Singh S, Segal JB, Wilson LM, Chatterjee R, Marinopoulos SS, Puhon MA, Ranasinghe P, Block L, Nicholson WK. Comparative effectiveness and safety of medications for type 2 diabetes: an update including new drugs and 2-drug combinations. *Annals of internal medicine*. 2011 May 3;154(9):602-13.
8. Sacks DB, Arnold M, Bakris GL, Brun DE, Horvath AR, Kirkman MS, Lernmark A, Metzger BE, Nathan DM. Guidelines and recommendations for laboratory analysis in the diagnosis and management of diabetes mellitus. *Clinical chemistry*. 2011 Jun 1;57(6):e1-47.
9. Engelen L. The glycation pathway in type 2 diabetes and cardiovascular disease.(2012)

10. Wright LA, Hirsch IB. The challenge of the use of glycemic biomarkers in diabetes: reflecting on hemoglobin A1C, 1, 5-anhydroglucitol, and the glycated proteins fructosamine and glycated albumin. *Diabetes spectrum*. 2012 Jul 1;25(3):141.
11. Elseweidy MM, Elswefy SE, Younis NN, Zaghloul MS. Pyridoxamine, an inhibitor of protein glycation, in relation to microalbuminuria and proinflammatory cytokines in experimental diabetic nephropathy. *Experimental Biology and Medicine*. 2013 Aug;238(8):881-8.
12. Raghav A, Ahmad J. Glycated serum albumin: a potential disease marker and an intermediate index of diabetes control. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. 2014 Oct 1;8(4):245-51.
13. Madar AA, Knutsen KV, Stene LC, Brekke M, Meyer HE, Lagerlöv P. Effect of vitamin D3 supplementation on glycated hemoglobin (HbA1c), fructosamine, serum lipids, and body mass index: a randomized, double-blinded, placebo-controlled trial among healthy immigrants living in Norway. *BMJ Open Diabetes Research and Care*. 2014 Oct 1;2(1):e000026.
14. Williams ME, Garg R. Glycemic management in ESRD and earlier stages of CKD. *American journal of kidney diseases*. 2014 Feb 1;63(2):S22-38.
15. Speeckaert M, Van Biesen W, Delanghe J, Slingerland R, Wiecek A, Heaf J, Drechsler C, Lacatus R, Vanholder R, Nistor I, Bilo H. Are there better alternatives than haemoglobin A1c to estimate glycaemic control in the chronic kidney disease population?. *Nephrology Dialysis Transplantation*. 2014 Dec 1;29(12):2167-77.