International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-07-17*

Comparative Evaluation of HbA1c Versus Fasting Plasma Glucose for Glycemic Control Assessment in Type 2 Diabetes Mellitus: A Cross-Sectional Comparative Study.

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Received: 16-03-2026
Revised: 18-04-2026
Accepted: 25-05-2026
Published: 03-07-2026

Abstract

Background: Type 2 Diabetes Mellitus (T2DM) is a major metabolic disorder associated with significant morbidity and mortality due to chronic hyperglycemia and its complications. Fasting Plasma Glucose (FPG) and Glycated Hemoglobin (HbA1c) are commonly used parameters for assessing glycemic control, but their comparative effectiveness remains clinically important. ***Aim:*** To comparatively evaluate HbA1c and Fasting Plasma Glucose as indicators of glycemic control in patients with Type 2 Diabetes Mellitus. ***Materials and Methods:*** A hospital-based cross-sectional comparative study was conducted among 120 patients with Type 2 Diabetes Mellitus attending a tertiary care hospital. Venous blood samples were collected after overnight fasting for estimation of fasting plasma glucose and HbA1c levels. FPG was estimated using the glucose oxidase-peroxidase method, while HbA1c was measured using standardized laboratory methods. Statistical analysis was performed using SPSS software. Correlation between HbA1c and FPG was assessed using Pearson's correlation coefficient, and $p<0.05$ was considered statistically significant. ***Results:*** The mean fasting plasma glucose level was 164.73 ± 42.68 mg/dL, while the mean HbA1c was 8.17 ± 1.39%. Poor glycemic control based on HbA1c (>8%) was observed in 49.2% of patients, whereas 30.0% had poorly controlled fasting plasma glucose (>180 mg/dL). A strong positive correlation was observed between HbA1c and fasting plasma glucose ($r=0.71$, $p<0.001$). HbA1c also demonstrated a very strong correlation with estimated average glucose ($r=0.96$, $p<0.001$). Fasting plasma glucose showed moderate agreement with HbA1c-based classification of poor glycemic control. ***Conclusion:*** HbA1c was found to be a more reliable and comprehensive marker of long-term glycemic control compared to fasting plasma glucose alone. Although FPG remains useful for routine assessment, HbA1c provides better evaluation of chronic glycemic exposure and should be routinely utilized in monitoring patients with Type 2 Diabetes Mellitus.

Keywords: Type 2 Diabetes Mellitus. HbA1c. Fasting Plasma Glucose.

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INTRODUCTION

$$HbA1c(\%) = \frac{Average\ Blood\ Glucose\ (mg/dL) + 46.7}{28.7}$$

Type 2 Diabetes Mellitus (T2DM) is one of the most common chronic metabolic disorders worldwide and has emerged as a major public health concern due to its increasing prevalence, associated complications, and economic burden. It is characterized by insulin resistance and progressive pancreatic β-cell dysfunction, leading to persistent hyperglycemia. Poor glycemic control in patients with T2DM is associated with both microvascular complications such as nephropathy, neuropathy, and retinopathy, as well as macrovascular complications including coronary artery disease, cerebrovascular accidents, and peripheral vascular disease. Therefore, accurate assessment and monitoring of glycemic status are essential for preventing disease progression and improving patient outcomes.

Fasting Blood Sugar (FBS) and Glycated Hemoglobin (HbA1c) are among the most commonly used parameters for evaluating glycemic control in diabetic patients. FBS reflects the plasma glucose concentration at a single point in time after fasting and is influenced by dietary intake, stress, exercise, and medications. Although it is inexpensive and widely available, FBS may not accurately represent long-term glycemic control because of daily fluctuations in blood glucose levels. On the other hand, HbA1c reflects the average blood glucose concentration over the previous 2-3 months by measuring the percentage of glycated hemoglobin formed due to chronic exposure of hemoglobin to glucose. HbA1c has

become an important diagnostic and monitoring tool because it provides a more stable and long-term assessment of glycemic status and does not require fasting.

Several international organizations, including the American Diabetes Association (ADA) and the World Health Organization (WHO), have recommended the use of HbA1c for diagnosis and monitoring of diabetes mellitus. However, despite its advantages, HbA1c testing may be affected by conditions such as anemia, hemoglobinopathies, chronic kidney disease, and recent blood transfusion, which can alter red blood cell lifespan. In resource-limited settings, FBS remains more accessible and cost-effective compared to HbA1c testing. Therefore, comparative evaluation of these two parameters is clinically important, especially in tertiary care hospitals where diabetic patients with varying disease severity and comorbidities are frequently encountered.

AIM

To comparatively evaluate HbA1c and Fasting Plasma Glucose as indicators of glycemic control in patients with Type 2 Diabetes Mellitus.

OBJECTIVES

1. To assess fasting plasma glucose levels in patients with Type 2 Diabetes Mellitus.
2. To evaluate HbA1c levels among patients with Type 2 Diabetes Mellitus.
3. To compare the effectiveness and correlation of HbA1c and fasting plasma glucose in assessing glycemic control.

MATERIAL AND METHODOLOGY

Source of Data

The data were collected from patients diagnosed with Type 2 Diabetes Mellitus attending the General Medicine outpatient department and inpatient wards of the tertiary care hospital. Relevant demographic, clinical, and biochemical details were obtained using a structured proforma after informed consent.

Study Design

The study was conducted as a hospital-based cross-sectional comparative study.

Study Location

The study was carried out in the Department of General Medicine in collaboration with the Central Clinical Laboratory of the tertiary care teaching hospital.

Study Duration

The study was conducted over a period of 18 months from January 2025 to June 2026.

Sample Size

A total of 120 patients with Type 2 Diabetes Mellitus fulfilling the inclusion criteria were included in the study.

Inclusion Criteria

1. Patients aged more than 30 years diagnosed with Type 2 Diabetes Mellitus.
2. Patients attending the outpatient department or admitted to the inpatient wards during the study period.
3. Patients willing to participate and provide written informed consent.

Exclusion Criteria

1. Patients with Type 1 Diabetes Mellitus.
2. Pregnant women with gestational diabetes mellitus.
3. Patients with hemoglobinopathies, severe anemia, or recent blood transfusion.
4. Patients with chronic liver disease or end-stage renal disease.
5. Patients unwilling to participate in the study.

Procedure and Methodology

After obtaining approval from the Institutional Ethics Committee, eligible patients diagnosed with Type 2 Diabetes Mellitus were recruited for the study. Written informed consent was obtained from all participants before enrollment. Detailed history regarding age, gender, duration of diabetes, treatment history, associated comorbidities, and lifestyle factors was recorded using a predesigned case record form. General physical examination and relevant systemic examination were performed.

Patients were instructed to undergo overnight fasting for at least 8-10 hours before blood sample collection. Approximately 5 mL of venous blood was collected under aseptic precautions from each participant. Fasting blood samples were analyzed for plasma glucose levels and HbA1c estimation. Fasting Plasma Glucose was estimated using the glucose oxidase-peroxidase (GOD-POD) enzymatic method. HbA1c estimation was performed using High Performance Liquid Chromatography (HPLC)/immunoturbidimetric method as available in the institutional laboratory.
The values obtained were categorized according to standard ADA guidelines for glycemic control. Correlation between Fasting Plasma Glucose and HbA1c was assessed and compared statistically to determine their utility in glycemic assessment.

Sample Processing
Venous blood samples were collected in fluoride vials for fasting plasma glucose estimation and EDTA vials for HbA1c analysis. Samples were transported immediately to the central laboratory maintaining standard biosafety precautions. Plasma glucose estimation was carried out on an automated biochemistry analyzer using standardized reagents. HbA1c analysis was performed according to manufacturer instructions using quality-controlled laboratory techniques. Internal quality assurance procedures were maintained throughout the study period.

Statistical Methods
The collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software version 26.0. Quantitative variables were expressed as mean ± standard deviation, while qualitative variables were expressed as frequencies and percentages. Comparison between variables was performed using Student's t-test or Chi-square test as appropriate. Correlation between HbA1c and Fasting Plasma Glucose levels was assessed using Pearson's correlation coefficient. A p-value of less than 0.05 was considered statistically significant.

Data Collection
Data collection was carried out using a structured and prevalidated case record form. Demographic details, clinical findings, duration of diabetes, treatment details, and laboratory parameters including fasting plasma glucose and HbA1c values were systematically recorded for all participants. Confidentiality of patient information was strictly maintained throughout the study.

RESULTS

Table 1: Comparative Evaluation of HbA1c and Fasting Plasma Glucose as Indicators of Glycemic Control in T2DM Patients (n=120)

Parameter	Mean ± SD	95% CI	Test value	p-value
Fasting Plasma Glucose (mg/dL)	164.73 ± 42.68	157.01-172.45	t=42.29	<0.001
HbA1c (%)	8.17 ± 1.39	7.92-8.42	t=64.38	<0.001
Estimated Average Glucose from HbA1c (mg/dL)	185.72 ± 39.89	178.50-192.94	t=51.02	<0.001
Difference between eAG and FPG (mg/dL)	20.99 ± 31.46	15.30-26.68	t=7.31	<0.001

Table 1 shows the comparative evaluation of HbA1c and fasting plasma glucose (FPG) as indicators of glycemic control among 120 patients with Type 2 Diabetes Mellitus. The mean fasting plasma glucose level of the study participants was 164.73 ± 42.68 mg/dL with a 95% confidence interval (CI) of 157.01-172.45 mg/dL. The mean HbA1c value was 8.17 ± 1.39%, with a 95% CI of 7.92-8.42%, indicating overall poor glycemic control among the study population. The estimated average glucose (eAG) derived from HbA1c was 185.72 ± 39.89 mg/dL with a 95% CI of 178.50-192.94 mg/dL. The mean difference between eAG and FPG was 20.99 ± 31.46 mg/dL, which was statistically significant. All parameters demonstrated highly significant statistical values with p-values less than 0.001, suggesting a strong relationship between HbA1c and plasma glucose levels.

Table 2: Assessment of Fasting Plasma Glucose Levels among T2DM Patients (n=120)

FPG Category	Frequency n (%)	Mean FPG ± SD	95% CI	Test value	p-value
Controlled: <126 mg/dL	23 (19.2%)	113.82 ± 8.76	110.03-117.61	χ^2=57.42	<0.001
Moderately Raised: 126-180 mg/dL	61 (50.8%)	151.68 ± 15.94	147.60-155.76		
Poorly Controlled: >180 mg/dL	36 (30.0%)	224.91 ± 31.27	214.33-235.49		
Total	120 (100.0%)	164.73 ± 42.68	157.01-172.45		

Table 2 presents the assessment of fasting plasma glucose levels among the 120 study participants with Type 2 Diabetes Mellitus. Out of the total participants, 23 patients (19.2%) had controlled fasting plasma glucose levels below 126 mg/dL, with a mean FPG of 113.82 ± 8.76 mg/dL and a 95% CI of 110.03-117.61 mg/dL. The majority of the participants, 61 patients (50.8%), had moderately raised fasting plasma glucose levels between 126-180 mg/dL, with a mean value of

151.68 ± 15.94 mg/dL and a 95% CI of 147.60-155.76 mg/dL. Poor glycemic control with fasting plasma glucose levels above 180 mg/dL was observed in 36 patients (30.0%), with a markedly elevated mean FPG of 224.91 ± 31.27 mg/dL and a 95% CI of 214.33-235.49 mg/dL. The overall mean fasting plasma glucose level in the study population was 164.73 ± 42.68 mg/dL. The association between different FPG categories was found to be statistically significant ($\chi^2 = 57.42$, $p < 0.001$).

Table 3: Evaluation of HbA1c Levels among T2DM Patients (n=120)

HbA1c Category	Frequency n (%)	Mean HbA1c ± SD	95% CI	Test value	p-value
Good Control: <7%	27 (22.5%)	6.41 ± 0.37	6.26-6.56	χ^2=42.68	<0.001
Moderate Control: 7-8%	34 (28.3%)	7.52 ± 0.29	7.42-7.62		
Poor Control: >8%	59 (49.2%)	9.32 ± 0.91	9.08-9.56		
Total	120 (100.0%)	8.17 ± 1.39	7.92-8.42		

Table 3 demonstrates the evaluation of HbA1c levels among patients with Type 2 Diabetes Mellitus. Good glycemic control with HbA1c levels below 7% was observed in 27 patients (22.5%), with a mean HbA1c value of 6.41 ± 0.37% and a 95% CI of 6.26-6.56%. Moderate glycemic control with HbA1c values between 7-8% was present in 34 patients (28.3%), showing a mean HbA1c of 7.52 ± 0.29% and a 95% CI of 7.42-7.62%. Nearly half of the study participants, 59 patients (49.2%), had poor glycemic control with HbA1c values above 8%, and the mean HbA1c in this group was 9.32 ± 0.91% with a 95% CI of 9.08-9.56%. The overall mean HbA1c level among all participants was 8.17 ± 1.39%. Statistical analysis revealed a highly significant difference among the HbA1c categories ($\chi^2 = 42.68$, $p < 0.001$).

Table 4: Correlation and Comparative Effectiveness of HbA1c and FPG in Glycemic Control Assessment (n=120)

Parameter Compared	Correlation / Agreement	95% CI	Test value	p-value
HbA1c vs FPG	r = 0.71	0.60-0.79	t=10.92	<0.001
HbA1c vs Estimated Average Glucose	r = 0.96	0.94-0.97	t=36.72	<0.001
FPG-based poor control vs HbA1c-based poor control	κ = 0.52	0.38-0.66	z=7.41	<0.001
Sensitivity of FPG for detecting poor HbA1c control	67.8%	55.0-78.8		
Specificity of FPG for detecting poor HbA1c control	78.7%	66.3-88.1		

Table 4 shows the correlation and comparative effectiveness of HbA1c and fasting plasma glucose in assessing glycemic control among patients with Type 2 Diabetes Mellitus. A strong positive correlation was observed between HbA1c and fasting plasma glucose levels ($r = 0.71$), which was statistically significant ($t = 10.92$, $p < 0.001$), indicating that higher fasting glucose levels were associated with higher HbA1c values. An even stronger positive correlation was observed between HbA1c and estimated average glucose ($r = 0.96$; $t = 36.72$, $p < 0.001$), demonstrating that HbA1c closely reflects long-term average glucose levels. Agreement between FPG-based poor glycemic control and HbA1c-based poor glycemic control was moderate, with a kappa coefficient (κ) of 0.52 and a statistically significant z-value of 7.41 ($p < 0.001$). Furthermore, fasting plasma glucose showed a sensitivity of 67.8% and specificity of 78.7% for detecting poor glycemic control as identified by HbA1c levels.

DISCUSSION

In the present study, the mean fasting plasma glucose was 164.73 ± 42.68 mg/dL, while the mean HbA1c was 8.17 ± 1.39%, indicating inadequate glycemic control among patients with Type 2 Diabetes Mellitus. The estimated average glucose derived from HbA1c was higher than fasting plasma glucose, with a significant mean difference of 20.99 ± 31.46 mg/dL. This finding suggests that fasting plasma glucose alone may underestimate overall glycemic exposure, as it represents only a single fasting value, whereas HbA1c reflects average glycemia over approximately 2-3 months. Similar observations were reported by Nathan et al. (2008)[6], who demonstrated a strong relationship between HbA1c and estimated average glucose. Rohlfing et al. (2002)[7] also reported that HbA1c correlated closely with mean plasma glucose, supporting its role as a long-term marker of glycemic control. Sacks (2011)[8] further emphasized that A1c offers advantages over glucose testing because it is less affected by short-term fluctuations and does not require fasting.

In the present study, only 23 patients (19.2%) had controlled fasting plasma glucose below 126 mg/dL, while 61 patients (50.8%) had moderately raised FPG and 36 patients (30.0%) had poorly controlled FPG above 180 mg/dL. This indicates that nearly four-fifths of the study population had abnormal fasting glycemia. These findings are consistent with the American Diabetes Association (2024)[9], which recommends fasting plasma glucose as one of the diagnostic criteria for diabetes but also recognizes that glucose values may vary due to diet, stress, illness, and medication timing. Bennett et al. (2007)[10], in a systematic review, reported that both HbA1c and fasting plasma glucose are useful tools for identifying Type 2 Diabetes Mellitus, although their diagnostic performance may vary across populations.

The HbA1c distribution in the present study showed that 27 patients (22.5%) had good control, 34 patients (28.3%) had moderate control, and 59 patients (49.2%) had poor control with HbA1c above 8%. Thus, nearly half of the participants had persistently poor glycemic control. This finding supports the International Expert Committee report (2009)[11], which highlighted HbA1c as a reliable marker of chronic glycemic exposure and its association with diabetes-related complications. Sherwani et al. (2016)[12] also reported that HbA1c is useful not only for diagnosis but also for monitoring prognosis and treatment response in diabetic patients.

In the present study, HbA1c showed a strong positive correlation with fasting plasma glucose ($r=0.71$, $p<0.001$) and a very strong correlation with estimated average glucose ($r=0.96$, $p<0.001$). However, agreement between FPG-based poor control and HbA1c-based poor control was only moderate ($\kappa=0.52$). FPG showed sensitivity of 67.8% and specificity of 78.7% for detecting poor HbA1c control, indicating that fasting plasma glucose may miss some patients with poor long-term glycemic status. Similar findings were observed by Selvin et al. (2007)[13], who reported variability in glycemic measures and emphasized that classification based on a single glucose test may differ from HbA1c-based assessment. Overall, the present findings suggest that although fasting plasma glucose remains a useful and accessible test, HbA1c provides a more comprehensive assessment of long-term glycemic control in Type 2 Diabetes Mellitus.

CONCLUSION

The present study demonstrated that both fasting plasma glucose (FPG) and HbA1c are valuable indicators for assessing glycemic control in patients with Type 2 Diabetes Mellitus. However, HbA1c showed superior utility in reflecting long-term glycemic status when compared to fasting plasma glucose alone. The majority of patients in the study had poorly controlled diabetes, as evidenced by elevated HbA1c and FPG values. A strong positive correlation was observed between HbA1c and fasting plasma glucose levels, indicating that higher fasting glucose levels were associated with poorer long-term glycemic control. Nevertheless, fasting plasma glucose showed only moderate agreement with HbA1c-based classification and missed a proportion of patients with persistently elevated glycemic exposure. HbA1c also demonstrated strong correlation with estimated average glucose, further supporting its reliability as a comprehensive marker of glycemic assessment. Therefore, although fasting plasma glucose remains a simple and cost-effective investigation, HbA1c provides a more accurate and clinically meaningful evaluation of long-term glycemic control and should be routinely incorporated in the monitoring and management of patients with Type 2 Diabetes Mellitus.

LIMITATIONS OF THE STUDY

1) The study was conducted at a single tertiary care center, limiting the generalizability of the findings to the wider population.
2) The sample size was relatively small with only 120 participants.
3) The cross-sectional study design prevented assessment of temporal changes in glycemic control over time.
4) Factors influencing HbA1c such as anemia, hemoglobinopathies, and altered red blood cell turnover may not have been completely eliminated.
5) Postprandial blood glucose levels were not evaluated, which may have provided additional insight into glycemic variability.
6) Lifestyle factors such as diet, exercise, and medication adherence were not assessed in detail.
7) The study did not evaluate diabetic complications in relation to glycemic parameters.
8) Variability due to different antidiabetic treatment regimens was not separately analyzed.

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