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Correlation Between Fasting Blood Glucose and Glycosylated Hemoglobin (HbA1c) in Type 2 Diabetic Patients: A Cross-Sectional Study

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Abstract

Diabetes Mellitus (DM) is a chronic metabolic disorder characterized by hyperglycemia, with Type 2 DM (T2DM) being the most prevalent form. Effective glycemic monitoring is crucial to prevent complications. Glycosylated hemoglobin (HbA1c) reflects long-term glucose control (2-3 months), while fasting blood glucose (FBG) provides short-term insights.

Objective: *To evaluate the correlation between FBG and HbA1c in T2DM patients.*

Methods: *This cross-sectional study included 50 T2DM patients (aged 35-50 years) at Metro Hospital, Jabalpur. FBG was measured using the Glucose Oxidase-Peroxidase method, and HbA1c via nephelometry. Descriptive statistics and Pearson correlation were performed.*

Results: *Mean FBG was 140.2 ± 30.1 mg/dL, and mean HbA1c was 7.2 ± 1.5%. A strong positive correlation existed between FBG and HbA1c ($r = 0.85$, $p < 0.001$).*

Conclusion: *HbA1c strongly correlates with FBG and is a reliable biomarker for long-term glycemic control. Combined monitoring of both parameters is essential for diabetes management.*

Keywords; Type 2 Diabetes Mellitus, Fasting Blood Glucose, HbA1c, Glycemic Control, Correlation.

INTRODUCTION

Diabetes Mellitus (DM) represents one of the most significant public health challenges of the 21st century, affecting millions worldwide and imposing substantial burdens on healthcare systems. As a chronic metabolic disorder, DM is primarily defined by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Among its various forms, Type 2 Diabetes Mellitus (T2DM) stands out as the most common, accounting for approximately 90-95% of all diagnosed cases of diabetes globally. This prevalence underscores the urgent need for effective management strategies to mitigate the disease's long-term complications, which include cardiovascular diseases, neuropathy, retinopathy, nephropathy, and even premature mortality.

The global epidemiology of T2DM paints a concerning picture. According to the World Health Organization (WHO), the number of adults living with diabetes has risen from 108 million in 1980 to 422 million in 2014, with projections indicating a further increase to 642 million by 2040 if current trends persist. In India, the situation is particularly alarming, where an estimated 77 million people are affected by diabetes, making it the second-largest diabetic population after China. Factors such as urbanization, sedentary lifestyles, obesity, and dietary shifts toward high-calorie, processed foods have fueled this epidemic. Genetic predispositions, coupled with environmental influences, further exacerbate the risk, particularly in populations with a history of insulin resistance.

Effective glycemic control is paramount in managing T2DM and preventing its microvascular and macrovascular complications.

Glycemic monitoring serves as the cornerstone of diabetes care, enabling healthcare providers to assess the efficacy of interventions such as lifestyle modifications, oral hypoglycemics, or insulin therapy. Two key biomarkers frequently employed in this context are fasting blood glucose (FBG) and glycosylated hemoglobin (HbA1c). FBG, measured after an overnight fast, offers a snapshot of short-term glucose levels, typically reflecting the metabolic state over the preceding 8-12 hours. It is influenced by recent dietary intake, physical activity, and stress, making it a dynamic indicator of acute glycemic fluctuations. In contrast, HbA1c provides a measure of average blood glucose concentrations over the past 2-3 months by quantifying the percentage of hemoglobin molecules that have undergone glycation—a non-enzymatic attachment of glucose to hemoglobin. This biomarker is less susceptible to day-to-day variations and is widely regarded as a reliable proxy for long-term glycemic control.

The relationship between FBG and HbA1c has been a subject of extensive research, with numerous studies demonstrating a positive correlation between the two parameters. For instance, the American Diabetes Association (ADA) guidelines emphasize the utility of HbA1c in diagnosing diabetes and monitoring treatment outcomes, often in conjunction with FBG measurements. Research by Nathan et al. (2008) highlighted how HbA1c levels can translate into estimated average glucose (eAG) values, facilitating a more integrated approach to patient care. However, while this correlation is generally strong, it is not absolute, as factors such as hemoglobinopathies, anemia, or variations in red blood cell turnover can introduce discrepancies. Understanding this interplay is crucial for clinicians, as it informs decision-making regarding therapeutic adjustments. For example, a patient with elevated FBG but controlled HbA1c might require short-term interventions, whereas persistently high HbA1c levels could necessitate escalation to more intensive regimens.

In the Indian context, where resource constraints often limit access to advanced diagnostic tools, studies on the correlation between FBG and HbA1c are particularly relevant. Local investigations have shown that while FBG is readily available and cost-effective, HbA1c offers a more comprehensive view of glycemic trends, especially in rural or underserved populations. This study aims to contribute to this body of knowledge by examining the correlation in a cohort of T2DM patients from Jabalpur, Madhya Pradesh. By doing so, it seeks to validate the utility of these biomarkers in a regional setting and underscore the importance of integrated monitoring for optimizing diabetes management.

The objectives of this research are twofold: first, to assess the strength of the association between FBG and HbA1c in T2DM patients; and second, to explore how this correlation can inform clinical practice. Through a cross-sectional design, the study provides insights into the reliability of HbA1c as a long-term indicator and highlights the complementary roles of FBG and HbA1c in achieving glycemic targets. Ultimately, the findings could guide healthcare providers in tailoring interventions, reducing the incidence of complications, and improving quality of life for diabetic patients.

LITERATURE REVIEW

A thorough review of existing literature reveals a robust foundation for investigating the correlation between FBG and HbA1c in T2DM. Early studies, such as those by the Diabetes Control and Complications Trial (DCCT) in the 1990s, established HbA1c as a gold standard for assessing glycemic control, demonstrating its predictive value for diabetic complications. Subsequent research has consistently shown a positive linear relationship between FBG and HbA1c, with correlation coefficients ranging from 0.6 to 0.9 across various populations. For instance, a meta-analysis by Rohlfing et al. (2002) analyzed data from over 500 studies and derived formulas to convert HbA1c to eAG, reinforcing the biomarker's role in clinical decision-making.

In Asian populations, including India, studies have echoed these findings. A study by Mohan et al. (2007) in Chennai reported a strong correlation ($r = 0.82$) in T2DM patients, attributing variations to factors like diet and medication adherence. Similarly, research in Pakistan by Shera et al. (2004) found comparable associations, though with slight differences due to ethnic and environmental influences. However, limitations in these studies, such as small sample sizes or reliance on less precise assays, highlight the need for region-specific investigations.

Methodological considerations also play a critical role. While high-performance liquid chromatography (HPLC) is considered the reference method for HbA1c, resource-limited settings often employ alternatives like nephelometry or immunoassays. Studies comparing these methods, such as those by Little et al. (2010), indicate acceptable concordance but potential biases in certain subgroups. Furthermore, confounders like age, sex, and comorbidities can modulate the FBG-HbA1c relationship, as evidenced by longitudinal data from the UK Prospective Diabetes Study (UKPDS).

Despite the wealth of evidence, gaps remain in understanding this correlation in middle-aged Indian adults, where lifestyle factors and access to care differ from Western cohorts. This study addresses these gaps by focusing on a localized sample and employing rigorous statistical methods to quantify the association.

MATERIALS AND METHODS

Study Design and Setting

This investigation was conducted as a cross-sectional observational study, a design well-suited for examining associations between variables at a single point in time without manipulating interventions. The study was carried out at Metro Hospital, Jabalpur, Madhya Pradesh, India, a tertiary care facility serving a diverse urban and semi-urban population. Jabalpur, located in central India, has a tropical climate and a demographic profile characterized by a mix of agricultural and industrial communities, which may influence diabetes prevalence through lifestyle and occupational factors. The hospital's endocrinology and pathology departments collaborated to ensure seamless data collection and analysis.

Participant Selection and Inclusion/Exclusion Criteria

A total of 50 patients diagnosed with T2DM were recruited through purposive sampling from the hospital's outpatient diabetes clinic. This sample size was determined based on prior studies indicating that 50 participants provide adequate statistical power (80%) to detect a correlation coefficient of 0.7 with an alpha of 0.05, assuming a moderate effect size. Participants were selected if they met the following inclusion criteria: (1) confirmed diagnosis of T2DM based on ADA guidelines (e.g., FBG $\geq$ 126 mg/dL or HbA1c $\geq$ 6.5% on two occasions); (2) age between 35 and 50 years to focus on a middle-aged cohort prone to T2DM complications; and (3) availability of complete medical records.

Exclusion criteria were applied to minimize confounding variables: (1) presence of serious comorbidities such as chronic kidney disease, liver dysfunction, or uncontrolled hypertension that could alter glucose metabolism; (2) pregnancy or lactation, as hormonal changes affect glycemic parameters; (3) use of medications known to interfere with glucose levels, such as corticosteroids or beta-blockers; and (4) history of blood transfusions or hemoglobinopathies that might skew HbA1c readings. Informed consent was obtained from all participants, and the study protocol was approved by the Institutional Ethics Committee of Rani Durgavati Vishwavidyalaya, ensuring compliance with the Declaration of Helsinki.

Data Collection Procedures

Data collection spanned three months, from January to March 2023, to account for seasonal variations in physical activity and diet. Demographic information, including age, sex, duration of diabetes, body mass index (BMI), and medication history, was gathered via structured questionnaires administered by trained research assistants. Anthropometric measurements, such as height and weight, were recorded using standardized equipment to calculate BMI as weight (kg) divided by height squared (m^2).

Venous blood samples were drawn in the morning after an overnight fast of at least 8 hours, adhering to standard phlebotomy protocols to avoid hemolysis or contamination. Samples were collected in ethylenediaminetetraacetic acid (EDTA) tubes for HbA1c and fluoride tubes for FBG, ensuring stability during transport to the laboratory. All procedures were performed under aseptic conditions, and samples were processed within 2 hours to maintain analyte integrity.

Laboratory Assays

FBG levels were quantified using the Glucose Oxidase-Peroxidase (GOD-POD) method on a Mindray BA-88A semi-automatic analyzer, a reliable enzymatic assay that measures glucose concentration through colorimetric detection. This method offers high precision (coefficient of variation <5%) and is widely used in clinical settings for its cost-effectiveness and speed. Calibration was performed daily using standard glucose solutions, and quality control checks were conducted thrice daily to ensure accuracy.

HbA1c was measured via nephelometry, an immunoturbidimetric technique that quantifies glycated hemoglobin by forming antigen-antibody complexes and measuring light scatter. Although less precise than HPLC (reference method), nephelometry was chosen due to resource constraints in the study setting, where advanced equipment is not always available. The assay's intra-assay and inter-assay coefficients of variation were maintained below 3% and 5%, respectively, through regular calibration and proficiency testing. Results were reported as percentages, aligned with International Federation of Clinical Chemistry (IFCC) standards.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA).

Descriptive statistics, including means, standard deviations (SD), medians, ranges, and frequencies, were computed for continuous and categorical variables. Normality was assessed using the Shapiro-Wilk test, confirming that FBG and HbA1c followed a normal distribution.

The primary analysis involved Pearson's correlation coefficient (r) to evaluate the linear relationship between FBG and HbA1c. The strength of correlation was interpreted as weak (r = 0.1-0.3), moderate (r = 0.4-0.6), or strong (r ≥ 0.7). Scatter plots were generated to visualize the association, and a linear regression model was fitted to estimate the predictive equation. Subgroup analyses were performed by sex and BMI categories (normal: <25 kg/m²; overweight: 25-29.9 kg/m²; obese: ≥30 kg/m²) to explore potential modifiers.

Statistical significance was set at $p < 0.05$, with 95% confidence intervals (CI) reported for correlation estimates. Power analysis confirmed that the sample size was sufficient to detect the observed effect size. No missing data imputation was needed, as all variables were complete.

RESULTS

Descriptive Statistics

The study cohort comprised 50 T2DM patients, with a balanced sex distribution (52% male, 48% female). The mean age was 42.5 years (SD = 5.5), ranging from 35 to 50 years, reflecting the targeted middle-aged group. The average duration of diabetes was 5.8 years (SD = 3.2), with most patients (68%) having been diagnosed within the past decade. BMI averaged 27.4 kg/m² (SD = 4.1), indicating a predominantly overweight population, consistent with T2DM risk factors.

Table 1 summarizes the key study variables. FBG levels ranged from 90 to 200 mg/dL, with a mean of 140.2 mg/dL (SD = 30.1), suggesting moderate hyperglycemia in the cohort. HbA1c values spanned 6.5% to 10.5%, averaging 7.2% (SD = 1.5), which aligns with suboptimal glycemic control according to ADA targets (<7% for most adults). Approximately 40% of patients had HbA1c ≥ 8%, indicating a need for intensified management. No significant differences were observed in FBG or HbA1c by sex ($p > 0.05$), though males exhibited slightly higher BMI (mean = 28.1 kg/m² vs. 26.6 kg/m² in females).

Table 1: Descriptive Statistics of Study Variables

Variable	Mean ± SD	Range
Age (years)	42.5 ± 5.5	35 - 50
Fasting Blood Glucose (mg/dL)	140.2 ± 30.1	90 - 200
HbA1c (%)	7.2 ± 1.5	6.5 - 10.5
BMI (kg/m²)	27.4 ± 4.1	20.5 - 35.8
Duration of Diabetes (years)	5.8 ± 3.2	1 - 15

Correlation Analysis

Pearson's correlation analysis revealed a strong positive association between FBG and HbA1c (r = 0.85, 95% CI: 0.74-0.91, $p < 0.001$). This indicates that higher FBG levels are closely linked to elevated HbA1c, explaining approximately 72% of the variance ($r^2 = 0.72$). The scatter plot (Figure 1) illustrated a linear trend, with the regression equation: HbA1c (%) = 0.025 × FBG (mg/dL) + 3.68. For every 10 mg/dL increase in FBG, HbA1c rose by about 0.25%.

Subgroup analyses showed consistent correlations across sexes (males: r = 0.83, $p < 0.001$; females: r = 0.87, $p < 0.001$) and BMI categories (normal: r = 0.81; overweight: r = 0.86; obese: r = 0.84), suggesting robustness. No outliers significantly influenced the results, as confirmed by Cook's distance (<1).

Figure 1: Scatter Plot of FBG vs. HbA1c [Description: A scatter plot showing FBG on the x-axis (mg/dL) and HbA1c on the y-axis (%). Data points form a positive linear cluster with a fitted regression line.]

DISCUSSION

The findings of this cross-sectional study affirm a robust positive correlation between FBG and HbA1c in T2DM patients, with an r-value of 0.85 underscoring the reliability of HbA1c as a long-term glycemic marker. This aligns with global literature, where similar correlations have been reported in diverse populations. For example, a study by Nathan et al. (2008) in the United States found r = 0.82, attributing the association to the cumulative effect of glucose exposure on hemoglobin glycation. In the Indian subcontinent, research by Mohan et al. (2007) echoed these results, though with slight variations due to dietary and genetic factors. Our study's higher r-value may reflect the homogeneity of the cohort, minimizing confounders like age extremes or comorbidities.

The clinical implications are profound. HbA1c's ability to mirror average glucose over months complements FBG's short-term sensitivity, enabling a holistic assessment of glycemic control. In practice, this dual monitoring can guide interventions: patients with discordant values (e.g., high FBG but normal HbA1c) might benefit from dietary

counseling, while those with elevated HbA1c warrant pharmacological escalation. The ADA's 2022 guidelines advocate this integrated approach, emphasizing HbA1c for risk stratification of complications like retinopathy.

CONCLUSION

This study confirms a strong, reliable partnership between Fasting Blood Glucose (FBG) and Glycosylated Hemoglobin(HbA1c) among middle-aged Type 2 diabetes patients in Jabalpur. With a robust correlation (r = 0.85), the data clearly demonstrates that day-to-day fasting levels mirror long-term glycemic trends quite accurately in this demographic. For clinicians and healthcare providers, this relationship offers a practical roadmap. While HbA1c remains the gold standard for tracking overall blood sugar control over a two-to-three-month window, checking FBG provides the immediate, day-to-day feedback needed to tweak daily habits or medication doses.

Relying on just one of these metrics leaves a blind spot. A patient might show a stable HbA1c but experience sharp, unmanaged spikes in fasting glucose, or vice versa. Therefore, the most effective approach to managing Type 2 diabetes isn't choosing between the short-term snapshot and the long-term history—it is combining both. By integrating regular FBG checks with periodic HbA1c screening, clinicians can build more responsive, personalized treatment plans that ultimately help keep serious diabetic complications at bay and improve patient quality of life.

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