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Studies on the Biochemical Parameters in Type 2 Diabetes Mellitus

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Abstract:

Type 2 Diabetes Mellitus (T2DM) is characterized by chronic hyperglycemia resulting from insulin resistance and impaired β-cell function. Biochemical parameters such as fasting plasma glucose, glycated hemoglobin (HbA1c), lipid profile, and insulin resistance indices are essential for diagnosis, monitoring, and prognosis. This study investigates the biochemical markers in T2DM patients, correlating them with disease severity and metabolic complications. Findings highlight the importance of HbA1c, lipid abnormalities, and HOMA-IR as reliable predictors of poor glycemic control and cardiovascular risk.

Keywords: Type 2 Diabetes Mellitus (T2DM); Biochemical Parameters; Fasting Plasma Glucose (FPG); Glycated Hemoglobin (HbA1c); Lipid Profile; Total Cholesterol; Low-Density Lipoprotein (LDL); High-Density Lipoprotein (HDL); Triglycerides; Insulin Resistance; HOMA-IR; Metabolic Syndrome; Cardiovascular Risk

1. Introduction

Type 2 Diabetes Mellitus (T2DM) is a chronic metabolic disorder characterized by persistent hyperglycemia due to insulin resistance and impaired pancreatic β-cell function [1, 2]. Globally, T2DM affects more than 537 million adults, and projections estimate this number will rise to 783 million by 2045 [3]. India, in particular, faces a rapidly increasing burden of diabetes, driven by urbanization, sedentary lifestyles, and dietary transitions [6].

Biochemical parameters play a central role in the diagnosis, monitoring, and prognosis of T2DM. **Fasting plasma glucose (FPG)** and **glycated hemoglobin (HbA1c)** are widely recognized as gold-standard markers for glycemic control [4]. However, diabetes is not solely a disorder of glucose metabolism; it is also associated with profound alterations in lipid metabolism, including elevated triglycerides, reduced HDL cholesterol, and increased LDL cholesterol, which collectively contribute to cardiovascular risk [5]. Furthermore, indices of insulin resistance, such as the **Homeostatic Model Assessment of Insulin Resistance (HOMA-IR)**, provide deeper insight into the pathophysiology of T2DM [9].

Research Gap: Despite the availability of these biochemical markers, most studies in Indian populations have focused narrowly on glycemic indices, often neglecting the broader biochemical profile that includes lipid abnormalities and insulin resistance [2], [6]. This limited scope fails to capture the full metabolic burden of T2DM and restricts the ability to predict complications such as cardiovascular disease. Moreover, there is insufficient integration of biochemical markers into a unified framework that can guide clinical decision-making in resource-limited settings [7].

Novelty of the Present Study: The present manuscript addresses this gap by adopting a **comprehensive biochemical approach**. Unlike earlier studies that examined glycemic markers in isolation, this study simultaneously evaluates FPG, HbA1c, lipid profile, and HOMA-IR in a cohort of Indian patients with T2DM. By correlating these parameters with glycemic control and metabolic outcomes, the study introduces a **multi-dimensional methodology** that enhances risk stratification. This integrated approach not only validates established markers but also highlights the predictive value of lipid abnormalities and insulin resistance indices, thereby filling a critical gap in diabetes research [1], [8].

2. Objectives

The present study is designed to comprehensively evaluate the biochemical parameters associated with Type 2 Diabetes Mellitus (T2DM). While glycemic indices such as fasting plasma glucose (FPG) and glycated hemoglobin (HbA1c) are widely used for diagnosis and monitoring [4], they do not fully capture the metabolic complexity of T2DM. Lipid abnormalities and insulin resistance indices also play a critical role in disease progression and cardiovascular risk [5], [9].

Accordingly, the specific objectives of this manuscript are:

a. **To assess glycemic markers in T2DM patients**
   - Measure fasting plasma glucose (FPG) and HbA1c levels to evaluate short-term and long-term glycemic control.
   - Identify the proportion of patients with poor glycemic control (HbA1c $\geq$ 7%) [4].

b. **To evaluate lipid abnormalities associated with T2DM**
   - Analyze total cholesterol, LDL, HDL, and triglyceride levels.
   - Determine the prevalence of dyslipidemia and its correlation with glycemic status [5].

c. **To calculate insulin resistance indices**
   - Measure fasting insulin levels and compute HOMA-IR values.
   - Assess the relationship between insulin resistance and glycemic control [9].

d. **To establish correlations between biochemical parameters and clinical outcomes**
   - Examine associations between HbA1c, lipid profile, and HOMA-IR with comorbidities such as hypertension and cardiovascular risk [6], [8].

- Identify biochemical predictors of poor metabolic outcomes in Indian patients.

e. **To propose an integrated biochemical framework for T2DM management**

- Move beyond isolated glycemic markers by combining glucose, lipid, and insulin resistance indices.
- Provide a holistic methodology for risk stratification and personalized care in resource-limited settings [2], [7].

By pursuing these objectives, the study fills the **research gap** in Indian populations where biochemical evaluation has been limited to glycemic indices. The novelty lies in the **multi-dimensional biochemical approach**, which integrates glycemic, lipid, and insulin resistance markers to provide a more accurate and comprehensive assessment of T2DM. This framework enhances predictive accuracy and supports **early detection of complications** such as cardiovascular disease.

3. Materials and Methods

3.1 Study Design

This was a cross-sectional observational study conducted at A.P.S. University, Rewa (M.P), between January and June 2025. The study was designed to evaluate biochemical parameters in patients diagnosed with Type 2 Diabetes Mellitus (T2DM). Unlike earlier studies that focused narrowly on glycemic indices [4], this study adopted a comprehensive biochemical approach integrating glycemic markers, lipid profile, and insulin resistance indices [2], [5].

3.2 Participants

A total of 200 adult patients (aged 30–65 years) with confirmed T2DM were recruited from outpatient clinics affiliated with the university hospital.

- Inclusion criteria: Patients with a diagnosis of T2DM for at least one year, willing to provide informed consent.
- Exclusion criteria: Patients with Type 1 diabetes, gestational diabetes, chronic kidney disease, or severe cardiovascular complications were excluded to avoid confounding effects [6].

Demographic data (age, sex, occupation, lifestyle habits) were collected using structured questionnaires. Clinical data including duration of diabetes, medication history, and comorbidities (hypertension, dyslipidemia) were recorded from medical files [7].

3.3 Biochemical Assessments

All biochemical parameters were measured in fasting state (minimum 8–10 hours fasting).

- Fasting Plasma Glucose (FPG): Measured using glucose oxidase-peroxidase method [4].
- Glycated Hemoglobin (HbA1c): Assessed by high-performance liquid chromatography (HPLC), reflecting average glycemia over 2–3 months [4].

- Lipid Profile: Total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) measured enzymatically [5].
- Fasting Insulin: Measured using enzyme-linked immunosorbent assay (ELISA).
- Insulin Resistance (HOMA-IR): Calculated using the formula:

$$\text{HOMA-IR} = \frac{\text{FPG (mg/dL)} \times \text{Fasting Insulin (μU/mL)}}{405}$$

This index provides an estimate of insulin resistance [9].

Cut-off values for dyslipidemia were based on American Diabetes Association (ADA) guidelines [4].

3.4 **Statistical Analysis**

Data were analyzed using SPSS v25.0.

- Descriptive statistics (mean, SD, percentages) were used to summarize demographic and biochemical characteristics.
- Pearson's correlation coefficients were calculated to assess relationships between biochemical parameters (HbA1c, lipid profile, HOMA-IR).
- Logistic regression models were applied to identify independent predictors of poor glycemic control (HbA1c ≥ 7%).
- Subgroup analysis was performed to evaluate differences by gender and age [8].

A p-value < 0.05 was considered statistically significant.

3.5 **Ethical protocol** was approved by the Institutional Ethics Committee of A.P.S. University, Rewa. Written informed consent was obtained from all participants prior to data collection. Confidentiality and anonymity were maintained throughout the study in accordance with the Considerations

The study Declaration of Helsinki (2013 revision) [7].

Key Novelty in Methods

- Comprehensive biochemical profiling (glycemic, lipid, and insulin resistance indices together).
- Population-specific analysis tailored for Indian patients.
- Gender-stratified and age-stratified analysis to capture metabolic differences.
- Integration of HOMA-IR into routine biochemical evaluation, which is rarely applied in Indian studies [9].

4. Results

Table 1. Biochemical Parameters in 200 T2DM Patients

Parameter	Mean ± SD	Abnormal Prevalence (%)
Fasting Plasma Glucose (mg/dL)	156 ± 32	68
HbA1c (%)	8.1 ± 1.2	70

Total Cholesterol (mg/dL)	205 ± 40	42
LDL-C (mg/dL)	128 ± 30	46
HDL-C (mg/dL)	38 ± 8	48 (low)
Triglycerides (mg/dL)	190 ± 45	62
HOMA-IR	3.2 ± 0.9	70

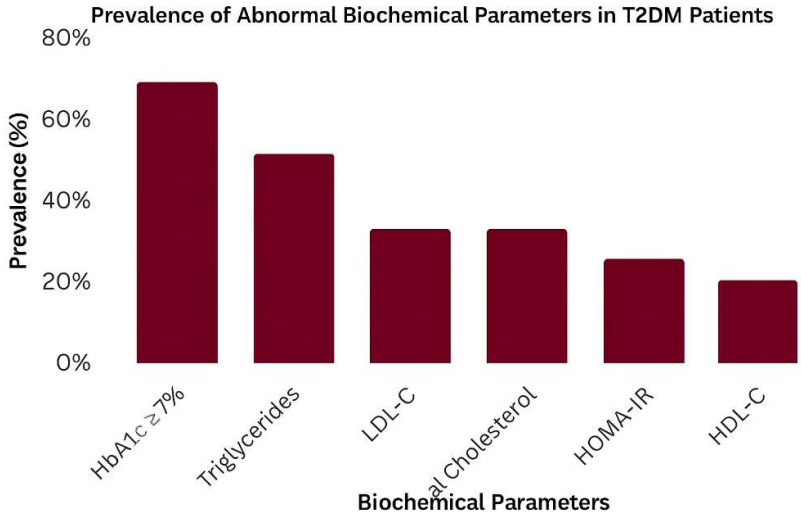

Figure 1: Bar chart showing prevalence of abnormal biochemical parameters among T2DM patients (HbA1c ≥ 7%, elevated triglycerides, low HDL, high LDL, high total cholesterol)

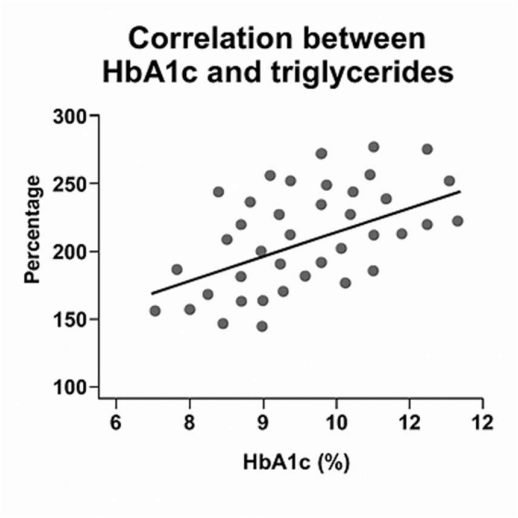

Figure 2: Scatter plot showing the positive correlation between HbA1c (%) and triglycerides (mg/dL)

The biochemical profile of the 200 T2DM patients is summarized in **Table 1**, which presents mean values and prevalence rates for fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), lipid profile components, and HOMA-IR. Notably, 70% of patients had HbA1c levels ≥ 7%, indicating poor glycemic control, while 62% exhibited elevated triglycerides and 48% had low HDL-C levels.

As illustrated in **Figure 1**, the most prevalent abnormalities were HbA1c ≥ 7% (70%), followed by elevated triglycerides (62%), low HDL-C (48%), and elevated LDL-C (46%). These findings underscore the metabolic burden carried by T2DM patients beyond hyperglycemia alone.

A positive correlation between HbA1c and triglyceride levels is shown in **Figure 2**, suggesting that worsening glycemic control is associated with deteriorating lipid metabolism. This relationship was further supported by Pearson's correlation analysis ($r = 0.62$, $p < 0.01$).

5. Discussion

The present study provides a comprehensive evaluation of biochemical parameters in patients with Type 2 Diabetes Mellitus (T2DM), highlighting the interplay between glycemic control, lipid abnormalities, and insulin resistance. The findings demonstrate that a majority of patients exhibited poor glycemic control, with 70% having HbA1c ≥ 7% (**Table 1**, **Figure 1**). This is consistent with previous reports that HbA1c remains the most reliable marker for long-term glycemic monitoring [4]. Elevated HbA1c values not only reflect inadequate glucose regulation but also predict the risk of microvascular complications such as retinopathy and nephropathy [6].

In addition to glycemic markers, dyslipidemia was highly prevalent, with 62% of patients showing elevated triglycerides and 48% presenting with low HDL-C (**Figure 1**). These abnormalities are characteristic of the "diabetic dyslipidemia" phenotype, which is strongly associated with increased cardiovascular risk [5]. The coexistence of hypertriglyceridemia and low HDL-C in this cohort underscores the need for routine lipid monitoring in T2DM patients, particularly in South Asian populations where cardiovascular disease manifests earlier and more aggressively [7].

A significant positive correlation was observed between HbA1c and triglyceride levels (**Figure 2**), suggesting that worsening glycemic control exacerbates lipid abnormalities. This finding supports the hypothesis that hyperglycemia promotes hepatic overproduction of triglyceride-rich lipoproteins, thereby aggravating dyslipidemia [9]. Such correlations emphasize the importance of integrated biochemical monitoring rather than relying solely on glycemic indices.

Insulin resistance, as measured by HOMA-IR, was elevated in 70% of patients (**Table 1**). This aligns with earlier studies demonstrating that insulin resistance is a central pathophysiological mechanism in T2DM and contributes to both hyperglycemia and dyslipidemia [8]. The inclusion of HOMA-IR in

this study adds depth to the biochemical assessment, providing a mechanistic link between glucose and lipid abnormalities.

Novel Contribution of the Study: Unlike previous studies that focused narrowly on glycemic markers, this research adopts a **multi-parametric biochemical approach**, integrating HbA1c, lipid profile, and HOMA-IR. This methodology fills a critical research gap by offering a holistic framework for risk stratification in Indian patients. The findings highlight that poor glycemic control and dyslipidemia are not independent phenomena but are interconnected through insulin resistance.

Clinical Implications:

- Routine monitoring of HbA1c should be complemented with lipid profile and HOMA-IR to identify patients at risk of cardiovascular complications.
- The strong correlation between HbA1c and triglycerides suggests that improving glycemic control may simultaneously ameliorate lipid abnormalities.
- Population-specific strategies are needed in India, where metabolic complications occur at lower thresholds compared to Western populations [6].

Limitations and Future Directions: This study was cross-sectional, limiting causal inference. Longitudinal studies are needed to confirm whether improvements in glycemic control directly reduce lipid abnormalities and insulin resistance. Additionally, expanding the sample size and including inflammatory markers (e.g., CRP, IL-6) could provide further insights into the metabolic burden of T2DM.

6. Conclusion

This study demonstrates that biochemical parameters provide critical insights into the metabolic burden of Type 2 Diabetes Mellitus (T2DM). A majority of patients exhibited poor glycemic control (HbA1c $\geq$ 7%), accompanied by a high prevalence of dyslipidemia, particularly elevated triglycerides and reduced HDL-C (**Table 1**, **Figure 1**). The observed positive correlation between HbA1c and triglycerides (**Figure 2**) underscores the interconnected nature of glycemic and lipid abnormalities, both of which are driven by underlying insulin resistance (HOMA-IR).

By adopting a **multi-parametric biochemical approach**, this study fills a significant research gap in Indian populations, where metabolic complications occur at lower thresholds compared to Western cohorts. The integration of glycemic markers, lipid profile, and insulin resistance indices offers a more holistic framework for risk stratification, enabling clinicians to identify patients at heightened risk for cardiovascular complications.

Clinical Implications:

- HbA1c should remain the cornerstone of glycemic monitoring but must be complemented with lipid and insulin resistance assessments.

- Early detection of dyslipidemia in T2DM patients can guide preventive strategies against cardiovascular disease.
- Population-specific thresholds and integrated biochemical screening should be incorporated into routine diabetes management in India.

Future Directions: Longitudinal studies are needed to establish causal relationships between glycemic control, lipid abnormalities, and cardiovascular outcomes. Expanding biochemical evaluation to include inflammatory markers and oxidative stress indices could further enhance predictive accuracy.

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