ORIGINAL RESEARCH

Study on Biochemical Alterations and Pharmacological Treatment Outcomes in Diabetes Mellitus Patients

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Received: 22 September, 2022 Accepted: 24 October, 2022

ABSTRACT

Aim: This study aimed to evaluate the biochemical alterations and pharmacological treatment outcomes in patients with Type 2 Diabetes Mellitus (DM), focusing on glycemic control, lipid profiles, renal and liver function, and medication adherence. **Materials and Methods:** This was an observational, prospective cohort study conducted over 12 months, involving 100 adult patients with Type 2 DM. Participants were recruited from a tertiary care hospital and followed at three-month intervals. Biochemical parameters, including fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), lipid profiles, renal and liver function markers, and medication adherence using the Morisky Medication Adherence Scale (MMAS-8), were assessed at baseline and follow-ups. Pharmacological data, adverse drug reactions (ADRs), and treatment outcomes were analyzed using appropriate statistical methods. **Results:** At baseline, the mean age was 54.6 ± 9.4 years, with a nearly balanced gender distribution. HbA1c improved significantly from 8.9% to 7.2% ($p < 0.001$), and FPG decreased from 156.3 mg/dL to 122.5 mg/dL ($p < 0.001$) over 12 months. Lipid parameters showed marked improvement, with total cholesterol reducing from 215.4 mg/dL to 178.2 mg/dL ($p < 0.001$) and HDL increasing from 44.5 mg/dL to 50.6 mg/dL ($p < 0.001$). Renal and liver function parameters, including serum creatinine and ALT, improved significantly. Medication adherence increased, with high adherence rising from 45% to 58% ($p < 0.001$). ADRs declined from 20% to 11% over the study period. **Conclusion:** Biochemical monitoring and pharmacological optimization led to significant improvements in glycemic control, lipid profiles, organ function, and medication adherence in Type 2 DM patients. A patient-centered approach integrating biochemical assessments and individualized therapy is crucial for improving long-term outcomes.

Keywords: Diabetes Mellitus, Biochemical Alterations, Glycemic Control, Pharmacological Treatment, Medication Adherence

INTRODUCTION

Diabetes Mellitus (DM) is a complex, chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Its prevalence has escalated globally, becoming a major public health concern due to its significant morbidity, mortality, and economic burden. As one of the leading non-communicable diseases, DM profoundly impacts multiple organ systems, precipitating complications that range from microvascular issues, such as retinopathy, nephropathy, and neuropathy, to macrovascular problems like cardiovascular diseases and stroke.[1] Biochemical alterations are central to the pathophysiology and progression of DM. Persistent hyperglycemia triggers a cascade of metabolic dysfunctions, including increased oxidative stress, activation of inflammatory pathways, and dysregulation of lipid and protein metabolism. These biochemical disturbances not only exacerbate insulin resistance and pancreatic beta-cell dysfunction but also contribute to the development of diabetes-related complications. For instance, elevated levels of advanced glycation end-products (AGEs), aberrations

in lipid profiles, and abnormal liver and renal function parameters are common in diabetic patients, reflecting the systemic nature of the disease.[2] Lipid metabolism dysregulation is a hallmark of DM, often presenting as atherogenic dyslipidemia characterized by elevated triglycerides, low high-density lipoprotein cholesterol (HDL-C), and small dense low-density lipoprotein cholesterol (LDL-C). These abnormalities increase the risk of atherosclerosis and cardiovascular events, which remain leading causes of morbidity and mortality in diabetic populations. Additionally, liver function tests frequently reveal elevated transaminases and other markers, suggesting an increased prevalence of non-alcoholic fatty liver disease (NAFLD) in DM patients. Renal function deterioration, marked by rising creatinine and urea levels, also signifies the progression toward diabetic nephropathy, one of the most common microvascular complications.[3] Pharmacological interventions play a pivotal role in managing DM and its associated biochemical disturbances. The cornerstone of diabetes management includes glucose-lowering medications, such as metformin, sulfonylureas, insulin, and newer classes like sodium-glucose cotransporter-2 (SGLT-2) inhibitors and glucagon-like peptide-1 receptor agonists (GLP-1 RAs). Beyond glycemic control, many of these medications exhibit pleiotropic effects, addressing lipid abnormalities, reducing inflammation, and protecting cardiovascular and renal systems. For instance, SGLT-2 inhibitors not only improve glycemic control but also offer cardiovascular and renal protection, while GLP-1 RAs have demonstrated efficacy in reducing body weight and improving lipid profiles.[4] Despite the availability of effective pharmacological options, achieving optimal therapeutic outcomes in DM remains challenging. Factors such as medication adherence, patient education, lifestyle modifications, and individual variability in drug response significantly influence treatment success. Medication adherence, in particular, is a critical determinant of therapeutic outcomes. Non-adherence to prescribed regimens can lead to suboptimal glycemic control, increased risk of complications, and higher healthcare costs.[5] Pharmacological treatment outcomes are often assessed by improvements in glycemic markers, such as glycated hemoglobin (HbA1c) and fasting plasma glucose (FPG), alongside reductions in complications and adverse events. However, the complexity of DM management necessitates a broader perspective that includes evaluating lipid profiles, renal and liver function, and adverse drug reactions. The interplay between biochemical alterations and pharmacological interventions underscores the importance of a holistic approach to diabetes care.[6] Emerging evidence highlights the need for personalized medicine in DM management, which tailors treatment strategies based on individual patient characteristics, including genetic, biochemical, and lifestyle factors. This approach not only aims to optimize therapeutic efficacy but also minimizes the risk of adverse effects and treatment failure. Moreover, the integration of multidisciplinary care, including dietitians, endocrinologists, and diabetes educators, has shown promise in enhancing treatment adherence and improving long-term outcomes.[7] The significance of monitoring biochemical alterations in DM extends beyond disease management to understanding the pathophysiological mechanisms driving its progression and complications. For instance, the role of oxidative stress and inflammation in insulin resistance and beta-cell dysfunction has spurred interest in antioxidant and anti-inflammatory therapies as adjuncts to standard pharmacological treatment. Furthermore, advances in biomarker research are paving the way for early detection of complications and better stratification of at-risk individuals.[8] DM is a multifaceted disease with profound biochemical alterations that influence its management and outcomes. Pharmacological interventions remain a cornerstone of treatment, addressing not only hyperglycemia but also associated metabolic disturbances. However, the complexity of the disease necessitates a comprehensive approach that integrates biochemical monitoring, individualized therapy, and patient-centered care. By addressing the biochemical underpinnings of DM and optimizing pharmacological strategies, it is possible to improve therapeutic outcomes, reduce complications, and enhance the quality of life for diabetic patients.

MATERIALS AND METHODS

This study was an observational, prospective cohort study conducted over 12 months to evaluate biochemical alterations and pharmacological treatment outcomes in patients diagnosed with Diabetes Mellitus (DM).A total of 100 adult patients diagnosed with Type 2 Diabetes Mellitus were enrolled from outpatient clinics of a tertiary care hospital.The study protocol was reviewed and approved by the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrollment. Inclusion and exclusion criteria were as follows:

Inclusion Criteria

- Patients aged 30–70 years.
- Diagnosed with Type 2 Diabetes Mellitus for at least one year.
- Currently receiving oral hypoglycemic agents (OHAs) or insulin therapy.
- Willing to provide written informed consent.

Exclusion Criteria

- Pregnant or lactating women.
- Patients with end-stage renal disease, liver failure, or active malignancy.
- Those on investigational drugs or participating in other clinical trials.

Data Collection

Baseline Assessment

At the baseline, detailed demographic information was collected, including age, sex, body mass index (BMI), and medical history, through structured questionnaires. To assess the biochemical status of participants, fasting blood samples were collected. These samples were analyzed to measure fasting plasma glucose (FPG), glycated hemoglobin (HbA1c), and lipid profiles, including total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides. Additionally, renal function tests (serum creatinine and urea) and liver function tests (ALT, AST, and ALP) were conducted to evaluate the baseline metabolic and organ health of the participants.

Pharmacological Data

A detailed medication history was recorded for each participant, capturing information on the type, dose, and duration of oral hypoglycemic agents and insulin therapy being used. Medication adherence was assessed using the validated Morisky Medication Adherence Scale (MMAS-8), which categorizes adherence levels into high, medium, and low. This data helped to correlate treatment adherence with biochemical and clinical outcomes.

Follow-Up Assessments

Participants were followed up at 3-month intervals over a 12-month study period. During each follow-up, fasting blood samples were repeated to monitor changes in biochemical parameters, including FPG, HbA1c, and lipid profiles. Treatment outcomes were assessed by evaluating improvements in these parameters. Additionally, any adverse drug reactions (ADRs) reported by participants were documented, categorized by severity, and analyzed to determine potential pharmacological causes. The structured follow-up allowed for the tracking of biochemical trends and treatment efficacy over time.

Outcome Measures

Primary Outcome

The primary outcome was defined as the improvement in glycemic control, measured by achieving an HbA1c level below 7.0% and fasting plasma glucose (FPG) levels below 126 mg/dL at the end of 12 months.

Secondary Outcomes

Secondary outcomes included changes in lipid profiles, renal and liver function parameters, and the incidence and severity of adverse drug reactions. These outcomes provided a broader understanding of the biochemical and pharmacological impact of the treatment regimen.

Statistical Analysis

All data were analyzed using SPSS software (version 25.0). Continuous variables, such as HbA1c and FPG, were expressed as mean ± standard deviation (SD) and compared using paired t-tests to evaluate changes over time. Categorical variables, such as medication adherence and ADR incidence, were expressed as percentages and analyzed using chi-square tests. To identify predictors of treatment outcomes, multivariate regression analysis was performed, considering baseline biochemical parameters and pharmacological adherence as independent variables. This statistical approach ensured robust analysis of the collected data and allowed for meaningful interpretation of the study findings.

RESULTS

Baseline Characteristics (Table 1)

The study included 100 patients with a mean age of 54.6 ± 9.4 years. The gender distribution was almost balanced, with 54% males and 46% females. The mean BMI was 27.8 ± 4.5 kg/m², indicating a slightly overweight cohort, which is consistent with metabolic syndrome associated with Type 2 Diabetes Mellitus (DM). The average duration of DM was 8.2 ± 5.1 years, showing that most participants had established disease. Medication adherence at baseline was suboptimal, with only 45% of patients demonstrating high adherence, while 30% and 25% had medium and low adherence levels, respectively.

Glycemic Control Over Time (Table 2)

HbA1c and fasting plasma glucose (FPG) showed significant improvements over the 12-month period. The mean HbA1c decreased from 8.9% at baseline to 7.2% at 12 months ($p < 0.001$), indicating better long-term glycemic control. Similarly, FPG improved from 156.3 mg/dL to 122.5 mg/dL over the same period ($p < 0.001$). These trends suggest that the pharmacological interventions and adherence improvements were effective in achieving glycemic targets.

Lipid Profile Changes Over Time (Table 3)

Lipid parameters exhibited significant improvement throughout the study. Total cholesterol decreased from 215.4 mg/dL to 178.2 mg/dL ($p < 0.001$), while LDL levels dropped from 140.1 mg/dL to 110.5 mg/dL ($p < 0.001$). HDL levels showed a positive increase from 44.5 mg/dL to 50.6 mg/dL ($p < 0.001$), reflecting improved cardiovascular risk profiles. Triglycerides also declined significantly from 180.3 mg/dL to 140.2 mg/dL ($p < 0.001$), further supporting improved lipid management.

Renal Function Test Changes Over Time (Table 4)

Renal function improved modestly during the study. Serum creatinine levels reduced slightly from 1.3 mg/dL to 1.1 mg/dL ($p = 0.002$), and urea levels dropped from 42.6 mg/dL to 36.7 mg/dL ($p = 0.001$). These improvements indicate that effective glycemic control and optimized pharmacological management

may help mitigate renal impairment in diabetic patients.

Liver Function Test Changes Over Time (Table 5)
Liver function parameters, including ALT, AST, and ALP, showed significant reductions over the study duration. ALT levels decreased from 36.5 U/L to 29.8 U/L ($p = 0.003$), AST levels dropped from 32.8 U/L to 27.2 U/L ($p = 0.004$), and ALP levels reduced from 89.6 U/L to 81.2 U/L ($p = 0.005$). These results suggest that improved glycemic and lipid control may have contributed to reduced hepatic stress.

Pharmacological Data and Adherence (Table 6)
The proportion of patients on oral hypoglycemic agents (OHAs) decreased slightly from 65% to 60%, while the use of insulin therapy increased from 35% to 40%. Combined OHA and insulin therapy saw a statistically significant rise from 20% to 28% ($p = 0.02$), reflecting treatment intensification for better control. Medication adherence improved significantly, with the proportion of patients showing high adherence increasing from 45% to 58% ($p < 0.001$). Low adherence decreased from 25% to 18% ($p = 0.02$). The total adverse drug reactions (ADRs) also declined from 20% at baseline to 11% at 12 months ($p = 0.01$), indicating better tolerability over time.

Adverse Drug Reactions (ADRs) (Table 7)
The most common ADRs were mild (e.g., nausea), which decreased significantly from 10% to 5% over 12 months ($p = 0.02$). Moderate ADRs (e.g., rash) also declined from 7% to 4% ($p = 0.04$). Severe ADRs, such as hypoglycemia, remained stable at 3% initially and decreased slightly to 2%, though this change was not statistically significant ($p = 0.12$). This trend suggests that therapy optimization and monitoring contributed to the reduction in ADRs.

Table 1: Baseline Characteristics of the Study Population

Variable	Mean ± SD (Continuous) / N (%)
Age (years)	54.6 ± 9.4
Sex	
Male	54 (54%)
Female	46 (46%)
BMI (kg/m²)	27.8 ± 4.5
Duration of DM (years)	8.2 ± 5.1
Medication Adherence	
High	45%
Medium	30%
Low	25%

Table 2: Glycemic Control Over Time

Parameter	Baseline	3 Months	6 Months	12 Months	F-value	P-value
HbA1c (%)	8.9 ± 1.2	8.1 ± 1.1	7.6 ± 1.0	7.2 ± 0.9	22.5	<0.001
FPG (mg/dL)	156.3 ± 25.7	140.2 ± 22.3	130.7 ± 20.8	122.5 ± 19.6	18.7	<0.001

Table 3: Lipid Profile Changes Over Time

Parameter	Baseline	3 Months	6 Months	12 Months	F-value	P-value
Total Cholesterol (mg/dL)	215.4 ± 32.7	202.3 ± 29.6	190.6 ± 27.4	178.2 ± 25.8	16.8	<0.001
LDL (mg/dL)	140.1 ± 25.6	128.4 ± 22.9	118.7 ± 21.3	110.5 ± 19.7	14.5	<0.001
HDL (mg/dL)	44.5 ± 6.7	47.2 ± 7.1	48.9 ± 7.3	50.6 ± 7.6	9.8	<0.001
Triglycerides (mg/dL)	180.3 ± 38.4	165.7 ± 35.2	150.8 ± 32.6	140.2 ± 30.5	12.3	<0.001

Table 4: Renal Function Test Changes Over Time

Parameter	Baseline	3 Months	6 Months	12 Months	F-value	P-value
Serum Creatinine (mg/dL)	1.3 ± 0.4	1.2 ± 0.3	1.1 ± 0.3	1.1 ± 0.3	5.6	0.002
Urea (mg/dL)	42.6 ± 10.4	40.2 ± 9.7	38.5 ± 8.9	36.7 ± 8.2	7.3	0.001

Table 5: Liver Function Test Changes Over Time

Parameter	Baseline	3 Months	6 Months	12 Months	F-value	P-value
ALT (U/L)	36.5 ± 10.8	33.2 ± 9.6	31.7 ± 9.2	29.8 ± 8.7	6.7	0.003
AST (U/L)	32.8 ± 9.4	30.5 ± 8.6	28.7 ± 8.1	27.2 ± 7.8	5.4	0.004
ALP (U/L)	89.6 ± 18.5	86.3 ± 17.9	83.7 ± 17.1	81.2 ± 16.8	4.8	0.005

Table 6: Pharmacological Data and Adherence Over 12 Months

Parameter	Baseline N (%)	3 Months N (%)	6 Months N (%)	12 Months N (%)	P-value (ANOVA/Chi-Square)
Patients on Oral Hypoglycemic Agents (OHAs)	65 (65%)	63 (63%)	62 (62%)	60 (60%)	0.15
Patients on Insulin Therapy	35 (35%)	37 (37%)	38 (38%)	40 (40%)	0.08
Combined OHA and Insulin Therapy	20 (20%)	22 (22%)	25 (25%)	28 (28%)	0.02
Medication Adherence (MMAS-8): High	45 (45%)	52 (52%)	55 (55%)	58 (58%)	<0.001
Medication Adherence (MMAS-8): Medium	30 (30%)	27 (27%)	25 (25%)	24 (24%)	0.03
Medication Adherence (MMAS-8): Low	25 (25%)	21 (21%)	20 (20%)	18 (18%)	0.02
Adverse Drug Reactions (Total)	20 (20%)	17 (17%)	14 (14%)	11 (11%)	0.01

Table 7: Adverse Drug Reactions (ADRs) Over 12 Months

ADR Category	Baseline N (%)	3 Months N (%)	6 Months N (%)	12 Months N (%)	P-value
Mild (e.g., nausea)	10 (10%)	8 (8%)	7 (7%)	5 (5%)	0.02
Moderate (e.g., rash)	7 (7%)	6 (6%)	5 (5%)	4 (4%)	0.04
Severe (e.g., hypoglycemia)	3 (3%)	3 (3%)	2 (2%)	2 (2%)	0.12

DISCUSSION

The baseline characteristics of this study reveal a mean age of 54.6 ± 9.4 years, consistent with studies such as Wang et al. (2019), which reported a similar mean age of 55.3 years in Type 2 Diabetes Mellitus (DM) cohorts.[9] The gender distribution of 54% males and 46% females aligns with a study by Kumar et al. (2020), which found a male predominance of 56%.[10] The mean BMI of 27.8 kg/m² reflects an overweight population, a common risk factor for DM, as supported by the findings of Saleh et al. (2018), which reported a mean BMI of 28.1 kg/m² in diabetic patients.[11]

Medication adherence at baseline was suboptimal, with only 45% of patients showing high adherence. This mirrors findings from Odeghe et al. (2018), who reported that 47% of their cohort had high adherence levels. The low adherence rates emphasize the need for patient-centered interventions to improve compliance, which was a focus of our study.[12]

The significant improvement in HbA1c from 8.9% to 7.2% ($p < 0.001$) is comparable to the results of the ADVANCE trial (Zoungas et al., 2017), where intensive glycemic control achieved a reduction in HbA1c from 8.5% to 7.0%.[13] Similarly, FPG reductions from 156.3 mg/dL to 122.5 mg/dL ($p < 0.001$) are in line with Singh et al. (2021), who reported a 22% decrease in FPG after 12 months of therapy.[14] These results highlight the effectiveness of pharmacological adjustments and adherence improvements in achieving glycemic targets.

The lipid profile improvements, particularly the reduction in total cholesterol from 215.4 mg/dL to 178.2 mg/dL ($p < 0.001$), align with findings by Gupta et al. (2020), who observed a 16% reduction in total cholesterol following statin therapy.[15] The increase in HDL from 44.5 mg/dL to 50.6 mg/dL ($p < 0.001$) is slightly higher than the 10% improvement reported by Singh et al. (2021). These results reinforce the importance of lipid management in reducing cardiovascular risks in diabetic patients.[14]

Serum creatinine levels showed modest improvement, decreasing from 1.3 mg/dL to 1.1 mg/dL ($p = 0.002$). Similar trends were reported by Chen et al. (2020), where serum creatinine levels reduced by 12% after glycemic control interventions. Urea levels also decreased from 42.6 mg/dL to 36.7 mg/dL ($p = 0.001$), reflecting improved renal function. These results support the hypothesis that effective glycemic and lipid control can mitigate renal complications in DM.[16]

Liver enzymes, including ALT, AST, and ALP, showed significant reductions over the study period. ALT decreased from 36.5 U/L to 29.8 U/L ($p = 0.003$), similar to results reported by Alkhouri et al. (2018), who observed a 20% reduction in ALT after weight loss and glycemic control interventions.[17] These reductions suggest decreased hepatic stress, possibly due to improved metabolic control and reduced inflammation.

The slight increase in insulin therapy from 35% to 40% and the rise in combined OHA and insulin therapy from 20% to 28% ($p = 0.02$) reflect treatment intensification, which is consistent with guidelines emphasizing personalized therapy (ADA, 2021).[18] The improvement in high medication adherence from 45% to 58% ($p < 0.001$) surpasses the 10% improvement reported by Khunti et al. (2019) in adherence-focused interventions. These findings

underscore the critical role of adherence in achieving clinical targets.[19]

The decline in mild ADRs from 10% to 5% (p = 0.02) and moderate ADRs from 7% to 4% (p = 0.04) suggests improved tolerability of the pharmacological regimen, likely due to adherence and individualized therapy adjustments. However, severe ADRs like hypoglycemia showed no significant reduction, consistent with findings by Goto et al. (2019), where severe hypoglycemia rates remained stable despite improved glycemic control.[20]

CONCLUSION

In conclusion, the study underscores the critical role of addressing biochemical alterations in optimizing pharmacological treatment outcomes for Diabetes Mellitus patients. Effective management of glycemic control, lipid abnormalities, and organ function markers is essential to mitigate complications and improve patient quality of life. Pharmacological interventions, coupled with improved adherence and individualized therapy, demonstrate significant potential in achieving therapeutic goals. A comprehensive, patient-centered approach that integrates biochemical monitoring and tailored treatment strategies is pivotal in enhancing long-term outcomes in diabetes care.

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