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Pattern of Individual Lipid Abnormalities Across Different Glycemic States among Adult Patients Attending a Tertiary Care Centre: A Retrospective Laboratory-Based Study

Dr Sarah Ibrahim[1], Dr Ajit Umar[2]

[1]Department of Biochemistry, The Medical City Hospital, Syria
[2]Department of Biochemistry, The Medical City Hospital, Syria

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Corresponding Author:

Dr Ajit Umar
Department of Biochemistry,
The Medical City Hospital,
Syria.

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ABSTRACT

Background: Abnormalities of lipid metabolism frequently accompany disturbances in glucose regulation and contribute to an increased cardiometabolic risk. Although dyslipidemia is well recognized in diabetes mellitus, lipid abnormalities may also be present during the prediabetic stage. Evaluation of individual lipid components across different glycemic states may provide a better understanding of the pattern of biochemical abnormalities encountered in routine tertiary-care practice.
Objective: To evaluate the pattern and distribution of individual lipid abnormalities across normal, prediabetic, and diabetic-range glycemic states among adult patients attending a tertiary care centre.
Methods: A retrospective laboratory-based observational study was conducted in the Department of Biochemistry using routinely generated laboratory records from January 2024 to September 2024. Records of 300 adults with complete fasting plasma glucose and lipid profile results were included. Patients were categorized into normal glycemic, prediabetic, and diabetic-range groups according to fasting plasma glucose values. Total cholesterol, triglycerides, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) were evaluated. The prevalence of individual lipid abnormalities was compared across the three glycemic categories.
Results: Among 300 patients, 92 (30.7%) had normal glycemic status, 86 (28.7%) were in the prediabetic range, and 122 (40.7%) were in the diabetic range. Mean total cholesterol increased progressively from 167.0 ± 25.3 mg/dL in the normal group to 184.0 ± 26.6 mg/dL in the prediabetic group and 199.3 ± 33.4 mg/dL in the diabetic group ($p<0.001$). Triglycerides increased from 102.9 ± 31.2 mg/dL to 137.7 ± 43.5 mg/dL and 156.0 ± 67.2 mg/dL, respectively ($p<0.001$). LDL-C also increased progressively, while HDL-C demonstrated a declining pattern (all $p<0.001$). Elevated total cholesterol was present in 9.8%, 26.7%, and 49.2% of normal, prediabetic, and diabetic-range patients, respectively. Elevated triglycerides occurred in 6.5%, 38.4%, and 52.5%, while reduced HDL-C was observed in 15.2%, 26.7%, and 41.0%, respectively. Overall dyslipidemia was present in 70.0% of the study population.
Conclusion: Individual lipid abnormalities showed a progressive increase with worsening glycemic status, while HDL-C demonstrated an inverse pattern. Importantly, several lipid abnormalities were already evident among patients with prediabetes. Routine assessment of lipid parameters alongside glycemic evaluation may therefore assist in early recognition of unfavorable metabolic patterns.

Keywords: *Glycemic status; Dyslipidemia; Triglycerides; LDL-C; HDL-C; Prediabetes; Diabetes mellitus; Lipid abnormalities.*

INTRODUCTION

Glucose and lipid metabolism are closely interconnected physiological processes. Disturbances in glucose regulation are frequently accompanied by changes in serum lipid concentrations, particularly in individuals progressing toward or already having diabetes mellitus. These metabolic abnormalities are clinically important because they contribute to the development of atherosclerotic cardiovascular disease and may increase long-term morbidity.

Diabetes mellitus is characterized by persistent elevation of blood glucose resulting from impaired insulin secretion, impaired insulin action, or a combination of both. The metabolic consequences of abnormal glucose regulation extend beyond hyperglycemia and may involve changes in lipid synthesis, transport, and clearance. As a result, patients with abnormal glycemic status may demonstrate an altered lipid profile even when clinical symptoms are not prominent.

The conventional lipid profile includes total cholesterol, triglycerides, HDL-C, and LDL-C. Each of these parameters provides complementary information regarding metabolic and cardiovascular risk. Diabetes-associated dyslipidemia is commonly characterized by elevated triglycerides, reduced HDL-C, and an atherogenic LDL profile. Such abnormalities may develop gradually as insulin resistance and impaired glucose regulation progress.

Prediabetes represents an intermediate metabolic state between normal glucose regulation and diabetes. Although it is primarily recognized because of its increased risk of progression to diabetes, metabolic abnormalities may already be present during this stage. Evaluation of lipid parameters in individuals with prediabetes may therefore provide additional information regarding their cardiometabolic profile.

Patients attending tertiary care centres constitute a clinically diverse population. Such populations may include individuals with normal glucose regulation, impaired fasting glucose, established diabetes, or other metabolic risk factors. Laboratory investigations performed during routine clinical care provide an opportunity to characterize the distribution of biochemical abnormalities within these groups.

Previous observations have demonstrated associations between abnormal glucose levels and unfavorable lipid patterns. Increasing glucose concentrations have been associated with higher triglycerides and LDL-related measures, while HDL-C may show an inverse relationship. The simultaneous assessment of glucose and lipid parameters can therefore provide a broader view of metabolic health.

However, considering the lipid profile only as a single composite outcome may obscure the specific lipid components responsible for the observed abnormality. Examining total cholesterol, triglycerides, LDL-C, and HDL-C individually across glycemic categories may provide a more detailed description of the biochemical pattern.

The present study was therefore undertaken to evaluate the distribution of individual lipid parameters and lipid abnormalities among adult patients classified according to glycemic status. Particular emphasis was placed on identifying the progressive pattern of lipid alterations from normal glycemia through prediabetes to the diabetic range.

MATERIALS AND METHODS

Study Design and Setting

This was a retrospective observational, laboratory-based study conducted in the Department of Biochemistry at a tertiary care centre. The study utilized routinely generated laboratory records of adult patients undergoing biochemical investigations during the study period.

The original laboratory records were generated during the period from January 2024 to September 2024. No additional biological samples were collected specifically for the present analysis.

Study Population

The study population consisted of adult patients whose laboratory records contained the required glycemic and lipid parameters. A total of 300 eligible records were included in the final analysis.

Each patient was included only once. Where multiple eligible laboratory reports were available for the same individual, the earliest complete set of investigations was considered to avoid duplication.

Inclusion Criteria

Records were eligible when they fulfilled the following criteria:

1. Adult patients aged 18 years or older.
2. Patients of either sex.
3. Attendance at the tertiary care centre during the defined study period.
4. Availability of fasting plasma glucose results.
5. Availability of a complete lipid profile.
6. Laboratory investigations performed during the study period.

Exclusion Criteria

Records were excluded when they contained:

1. Incomplete laboratory information.
2. Missing major glycemic or lipid parameters.
3. Duplicate patient entries.
4. Obvious analytical or data-entry errors.
5. Age below 18 years.
6. Documented sample-quality problems that could affect biochemical analysis.

These criteria were consistent with the eligibility framework used for the laboratory dataset.

Data Collection
Relevant demographic and biochemical information was retrospectively extracted from laboratory records. The variables considered included age, sex, fasting plasma glucose, total cholesterol, triglycerides, HDL-C, and LDL-C.

The dataset did not contain personally identifying information in the analytical file. Each eligible record was represented using a study identification number.

Laboratory Parameters
Fasting plasma glucose was assessed using the routine enzymatic laboratory method. The lipid profile consisted of total cholesterol, triglycerides, HDL-C, and LDL-C.

Total cholesterol was estimated using an enzymatic cholesterol-based method, while triglycerides were measured using an enzymatic colorimetric procedure. HDL-C was measured using the laboratory's routine method, and LDL-C was obtained either through direct measurement or the validated calculation procedure used by the laboratory.

Classification of Glycemic Status
Patients were categorized according to fasting plasma glucose:

- **Normal:** <100 mg/dL
- **Prediabetes:** 100–125 mg/dL
- **Diabetic range:** ≥126 mg/dL

These categories were used for laboratory-based analytical comparison.

Assessment of Lipid Abnormalities
The lipid profile was evaluated both as continuous biochemical measurements and as categorized abnormalities.

The individual abnormalities assessed included:

- Elevated total cholesterol
- Elevated triglycerides
- Elevated LDL-C
- Reduced HDL-C

Dyslipidemia was considered present when at least one major lipid component was outside the accepted laboratory reference range. Patients with more than one abnormal component were considered to have combined lipid abnormalities.

Statistical Analysis
Continuous variables were expressed as mean ± standard deviation where appropriate, while categorical variables were presented as frequencies and percentages. Comparisons of lipid parameters were performed across the three glycemic categories. Associations between glycemic category and individual lipid abnormalities were assessed statistically.

A two-sided p value <0.05 was considered statistically significant.

RESULTS

Demographic Characteristics
A total of 300 adult patient records were included. The mean age of the study population was 47.2 ± 12.5 years. Males accounted for 168 (56.0%) patients and females for 132 (44.0%).

Based on fasting plasma glucose, 92 (30.7%) patients had normal glycemic status, 86 (28.7%) were in the prediabetic range, and 122 (40.7%) were in the diabetic range.

The mean age increased from 38.6 ± 10.6 years among patients with normal glycemic status to 47.0 ± 10.4 years among those with prediabetes and 53.8 ± 11.3 years among patients in the diabetic range (p<0.001). Sex distribution did not differ significantly between the three groups (p=0.906).

Table 1. Demographic profile according to glycemic status

Characteristic	Normal (n=92)	Prediabetes (n=86)	Diabetes range (n=122)	Total (n=300)	p value
Age, years, mean ± SD	38.6 ± 10.6	47.0 ± 10.4	53.8 ± 11.3	47.2 ± 12.5	<0.001
Male, n (%)	50 (54.3)	48 (55.8)	70 (57.4)	168 (56.0)	0.906
Female, n (%)	42 (45.7)	38 (44.2)	52 (42.6)	132 (44.0)	—

Glycemic Distribution
The mean fasting plasma glucose concentration for the complete study population was 128.3 ± 38.5 mg/dL.

Patients with normal glycemic status had a mean fasting plasma glucose of 92.3 ± 4.5 mg/dL. The corresponding value among patients with prediabetes was 113.2 ± 6.4 mg/dL, whereas the diabetic-range group had a mean value of 166.1 ± 32.1 mg/dL.

Table 2. Distribution of study participants according to glycemic category

Glycemic category	FPG criterion	Number	Percentage	Mean FPG ± SD (mg/dL)
Normal	<100 mg/dL	92	30.7%	92.3 ± 4.5
Prediabetes	100–125 mg/dL	86	28.7%	113.2 ± 6.4
Diabetes range	≥126 mg/dL	122	40.7%	166.1 ± 32.1
Total	—	**300**	**100.0%**	**128.3 ± 38.5**

Pattern of Lipid Parameters

A progressive deterioration of the lipid profile was observed with increasing glycemic abnormality.

Mean total cholesterol increased from 167.0 ± 25.3 mg/dL among patients with normal glycemic status to 184.0 ± 26.6 mg/dL among prediabetic patients and 199.3 ± 33.4 mg/dL among patients in the diabetic range ($p<0.001$).

Triglyceride concentrations demonstrated a similar increase, from 102.9 ± 31.2 mg/dL in the normal group to 137.7 ± 43.5 mg/dL in the prediabetic group and 156.0 ± 67.2 mg/dL in the diabetic-range group ($p<0.001$).

LDL-C increased progressively across the three categories. In contrast, HDL-C demonstrated a decreasing pattern, with the lowest mean value observed among patients in the diabetic range.

Table 3. Mean lipid profile values across glycemic categories

Lipid parameter	Normal	Prediabetes	Diabetes range	Overall p value
Total cholesterol, mg/dL	167.0 ± 25.3	184.0 ± 26.6	199.3 ± 33.4	<0.001
Triglycerides, mg/dL	102.9 ± 31.2	137.7 ± 43.5	156.0 ± 67.2	<0.001
HDL-C, mg/dL	48.2 ± 8.1	45.5 ± 6.5	41.6 ± 7.4	<0.001
LDL-C, mg/dL	102.3 ± 24.9	118.3 ± 25.1	127.7 ± 28.8	<0.001

Distribution of Individual Lipid Abnormalities

Overall, 210 (70.0%) patients had at least one lipid abnormality.

The frequency of elevated total cholesterol increased from 9.8% in the normal glycemic group to 26.7% among prediabetic patients and 49.2% among patients in the diabetic range.

Elevated triglycerides demonstrated a particularly marked increase, from 6.5% in the normal group to 38.4% in the prediabetic group and 52.5% in the diabetic-range group.

Similarly, elevated LDL-C increased from 13.0% to 31.4% and 46.7%, respectively. Reduced HDL-C increased from 15.2% among patients with normal glycemic status to 26.7% among prediabetic patients and 41.0% among those in the diabetic range.

The overall association between glycemic category and the presence of individual lipid abnormalities was statistically significant ($p<0.001$).

Table 4. Distribution of individual lipid abnormalities according to glycemic status

Lipid abnormality	Normal n (%)	Prediabetes n (%)	Diabetes range n (%)	Total n (%)	p value
Elevated total cholesterol	9 (9.8)	23 (26.7)	60 (49.2)	92 (30.7)	<0.001
Elevated triglycerides	6 (6.5)	33 (38.4)	64 (52.5)	103 (34.3)	<0.001
Elevated LDL-C	12 (13.0)	27 (31.4)	57 (46.7)	96 (32.0)	<0.001
Reduced HDL-C	14 (15.2)	23 (26.7)	50 (41.0)	87 (29.0)	<0.001
Any dyslipidemia	34 (37.0)	63 (73.3)	113 (92.6)	210 (70.0)	<0.001

Correlation Between Fasting Glucose and Lipid Parameters

Fasting plasma glucose showed statistically significant relationships with all four major lipid parameters.

Positive correlations were observed between fasting plasma glucose and total cholesterol ($r=0.324$), triglycerides ($r=0.325$), and LDL-C ($r=0.241$). Conversely, HDL-C demonstrated a negative correlation with fasting plasma glucose ($r=-0.281$). All correlations were statistically significant at $p<0.001$.

Table 5. Relationship between fasting plasma glucose and lipid parameters

Lipid parameter	Correlation coefficient (r)	p value	Direction
Total cholesterol	0.324	<0.001	Positive
Triglycerides	0.325	<0.001	Positive
LDL-C	0.241	<0.001	Positive
HDL-C	−0.281	<0.001	Negative

DISCUSSION

The present study provides a laboratory-based description of lipid abnormalities across different states of glycemic regulation. The most important observation was that unfavorable changes in individual lipid parameters were not restricted to patients in the diabetic range. Several abnormalities were already apparent among individuals classified as prediabetic.

The progressive increase in total cholesterol across the glycemic groups demonstrates a gradual deterioration in lipid metabolism accompanying increasing fasting glucose concentrations. Mean total cholesterol increased from 167.0 mg/dL in the normal group to 184.0 mg/dL among prediabetic patients and 199.3 mg/dL among patients in the diabetic range. This stepwise pattern suggests that lipid alterations may accompany the progression of glucose dysregulation rather than developing only after diabetes has been established.

Triglycerides showed a particularly prominent change. Mean triglyceride concentrations increased from 102.9 mg/dL in normoglycemic patients to 137.7 mg/dL in the prediabetic group and 156.0 mg/dL in the diabetic-range group. At the categorical level, elevated triglycerides were identified in only 6.5% of normoglycemic individuals compared with 38.4% of prediabetic patients and 52.5% of patients in the diabetic range.

The substantial increase in triglyceride abnormality during prediabetes is clinically relevant. Prediabetes is commonly considered a stage of increased future diabetes risk, but the current findings indicate that biochemical metabolic abnormalities may already be substantial during this period. This observation is consistent with previous work reporting higher triglycerides and other atherogenic lipid measures among prediabetic individuals.

LDL-C also demonstrated a progressive increase with worsening glycemic status. Mean LDL-C increased from 102.3 mg/dL among patients with normal glycemic status to 118.3 mg/dL in the prediabetic group and 127.7 mg/dL in the diabetic-range group. The proportion of patients with elevated LDL-C similarly increased across the three groups.

In contrast to the other lipid components, HDL-C showed an inverse pattern. Mean HDL-C declined from 48.2 mg/dL in normoglycemic individuals to 45.5 mg/dL among prediabetic patients and 41.6 mg/dL among patients in the diabetic range. Reduced HDL-C was also increasingly frequent with worsening glycemic status.

The simultaneous increase in triglycerides and LDL-C with reduction in HDL-C represents an increasingly unfavorable lipid pattern. Such changes are biologically plausible in the setting of insulin resistance, where increased free fatty acid delivery to the liver can promote triglyceride synthesis and secretion of triglyceride-rich lipoproteins, while alterations in lipoprotein metabolism may contribute to lower HDL-C concentrations.

The present findings are broadly consistent with previously reported observations. A retrospective biochemical study by Rathi et al. involving control, prediabetic, and diabetic groups demonstrated higher total cholesterol, triglycerides, LDL-C and atherogenic indices in prediabetic and diabetic individuals, together with lower HDL-C.

Similarly, Kansal and Kamble reported that prediabetic individuals had higher total cholesterol, LDL-C, triglycerides, and other lipid-related measures compared with normoglycemic controls, while HDL-C was lower. These findings support the concept that metabolic risk-associated lipid alterations can become detectable before the onset of overt diabetes.

The correlation analysis in the present study further demonstrated that fasting plasma glucose was positively associated with total cholesterol, triglycerides, and LDL-C and negatively associated with HDL-C. The strongest positive correlation among the examined parameters was observed between fasting plasma glucose and triglycerides (r=0.325), whereas HDL-C showed a significant inverse relationship (r=−0.281).

Comparable relationships have been described in larger populations. Analysis of NHANES data demonstrated positive associations between blood glucose and triglycerides and inverse associations between glucose and HDL-C. The DECODA study involving Asian populations also reported relationships between increasing glucose concentrations and several lipid parameters, supporting the presence of metabolic interactions across different levels of glucose regulation.

An important feature of the current study was the high overall frequency of dyslipidemia. Seven out of every ten patients had at least one abnormal lipid component. The prevalence was substantially higher among patients in the diabetic range and was also considerable among individuals with prediabetes. This finding is relevant in the Indian setting, where dyslipidemia is common and frequently coexists with glucose abnormalities.

The pattern of individual abnormalities provides additional information beyond the overall prevalence of dyslipidemia. Triglyceride elevation was the most frequent individual abnormality in the overall study population, followed by elevated

LDL-C, elevated total cholesterol, and reduced HDL-C. More importantly, each of these abnormalities became progressively more frequent as glycemic status worsened.

The presence of lipid abnormalities among prediabetic patients deserves particular attention. In the present dataset, nearly three-quarters of patients with prediabetes had at least one lipid abnormality. This suggests that the prediabetic state may already be accompanied by substantial metabolic disturbance. Identification of these abnormalities at an earlier stage may provide an opportunity for lifestyle-based risk reduction and closer metabolic monitoring.

From a laboratory medicine perspective, the findings highlight the importance of evaluating the conventional lipid profile alongside fasting glucose. Both investigations are routinely available and relatively accessible in tertiary-care laboratories. Their combined interpretation may help identify patients demonstrating an unfavorable cardiometabolic pattern during routine clinical evaluation.

The results should nevertheless be interpreted in light of the study design. Because this was a retrospective analysis, temporal and causal relationships between glycemic abnormalities and lipid changes cannot be established. The study was performed at a single tertiary care centre and included patients who underwent laboratory testing, which may limit generalizability to the broader population.

In addition, information on several potential confounding factors—including body mass index, dietary patterns, physical activity, smoking, hypertension, duration of diabetes, antihyperglycemic treatment, and lipid-lowering medication—was not consistently available. These variables could influence lipid concentrations independently of glycemic status.

Despite these limitations, the study has the advantage of examining multiple lipid components simultaneously across clearly defined glycemic categories. The inclusion of normal, prediabetic, and diabetic-range groups allows the progressive pattern of individual lipid abnormalities to be appreciated rather than simply comparing diabetic and non-diabetic individuals.

CONCLUSION

The study demonstrates a clear progressive pattern of lipid abnormalities with worsening glycemic status among adult patients attending a tertiary care centre. Total cholesterol, triglycerides, and LDL-C increased progressively from normal glycemia through prediabetes to the diabetic range, whereas HDL-C showed a consistent decline.

Triglyceride elevation was particularly prominent, while substantial increases in elevated LDL-C, total cholesterol, and reduced HDL-C were also observed among patients with abnormal glycemic status. Importantly, these abnormalities were already evident among individuals with prediabetes.

The findings support the value of evaluating individual lipid components alongside glycemic status during routine laboratory assessment. Early recognition of an unfavorable lipid pattern, particularly during the prediabetic stage, may assist in identifying patients who could benefit from closer metabolic and cardiovascular risk assessment.

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