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Original Research Article

Lipid Profile Patterns and Their Association with Cardiovascular Risk in Patients with Metabolic Syndrome

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Abstract

Background: Metabolic syndrome (MetS) is a cluster of interrelated metabolic abnormalities that significantly increase the risk of cardiovascular disease (CVD) and type 2 diabetes mellitus. Dyslipidemia is a core component of MetS and is characterized by elevated triglycerides, reduced high-density lipoprotein cholesterol (HDL-C), and often increased levels of small dense low-density lipoprotein (sdLDL). Understanding lipid profile patterns in MetS patients and their association with cardiovascular risk is essential for early identification and targeted interventions.

Aim: To evaluate lipid profile patterns in patients with metabolic syndrome and determine their association with cardiovascular risk.

Methods: A cross-sectional observational study was conducted among 200 patients diagnosed with metabolic syndrome based on the NCEP ATP III criteria. Fasting lipid profiles, including total cholesterol (TC), triglycerides (TG), HDL-C, LDL-C, and non-HDL cholesterol, were analyzed. Atherogenic indices such as TC/HDL ratio, LDL/HDL ratio, and atherogenic index of plasma (AIP) were calculated. Cardiovascular risk was assessed using the Framingham Risk Score (FRS).

Results: The most common lipid abnormality was elevated triglycerides (78%), followed by low HDL-C (72%) and elevated LDL-C (54%). Patients with higher AIP values demonstrated significantly increased cardiovascular risk ($p < 0.001$). Strong correlations were observed between TG levels and FRS ($r = 0.62$), and inverse correlation between HDL-C and FRS ($r = -0.58$).

Conclusion: Distinct lipid profile patterns in metabolic syndrome are strongly associated with increased cardiovascular risk. Atherogenic dyslipidemia, particularly elevated TG and reduced HDL-C, plays a crucial role in cardiovascular risk stratification. Early identification and management of these lipid abnormalities are essential in reducing long-term cardiovascular morbidity and mortality.

Keywords: Metabolic Syndrome, Dyslipidemia, Cardiovascular Risk, Atherogenic Index, Lipid Profile.

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Introduction

Metabolic syndrome (MetS) represents a constellation of metabolic abnormalities that include central obesity, insulin resistance, hypertension, and dyslipidemia [1]. It has emerged as a major public health concern due to its increasing prevalence worldwide, particularly in developing countries such as India [2]. The syndrome significantly predisposes individuals to cardiovascular disease (CVD), which remains the leading cause of morbidity and mortality globally [3]. Dyslipidemia in MetS is characterized by a specific pattern known as atherogenic dyslipidemia,

which includes elevated triglycerides (TG), reduced high-density lipoprotein cholesterol (HDL-C), and an increase in small dense low-density lipoprotein (sdLDL) particles. These lipid abnormalities contribute to endothelial dysfunction, inflammation, and atherosclerosis [4]. The pathophysiology of dyslipidemia in metabolic syndrome is primarily driven by insulin resistance. Insulin resistance leads to increased lipolysis in adipose tissue, resulting in elevated free fatty acids (FFAs) in circulation [5]. These FFAs are taken up by the liver, leading to increased production of very-low-density lipoprotein (VLDL), which subsequently elevates triglyceride levels. Additionally, there is reduced clearance of VLDL and impaired HDL metabolism [6].

Traditional lipid parameters such as LDL-C have long been used to assess cardiovascular risk; however, emerging evidence suggests that atherogenic indices and lipid ratios may provide better predictive value, especially in patients with metabolic syndrome [7-9]. Parameters such as the atherogenic index of plasma (AIP), non-HDL cholesterol, and lipid ratios (TC/HDL, LDL/HDL) have been shown to correlate strongly with cardiovascular events [10].

Given the rising burden of metabolic syndrome and its associated cardiovascular complications, it is imperative to understand the patterns of lipid abnormalities and their relationship with cardiovascular risk. This study aims to evaluate lipid profile patterns in patients with metabolic syndrome and assess their association with cardiovascular risk using established risk scoring systems.

Aim

To evaluate lipid profile patterns and their association with cardiovascular risk in patients with metabolic syndrome.

Objectives

1. To analyze the lipid profile parameters (TC, TG, HDL-C, LDL-C, non-HDL-C) in patients with metabolic syndrome.
2. To determine the prevalence of various lipid abnormalities in metabolic syndrome.
3. To calculate atherogenic indices such as AIP, TC/HDL ratio, and LDL/HDL ratio.
4. To assess cardiovascular risk using the Framingham Risk Score.
5. To evaluate the association between lipid profile patterns and cardiovascular risk.

Methodology

This hospital-based cross-sectional observational study was conducted in the Department of General Medicine at a tertiary care teaching hospital over a period of 12 months. A total of 200 adult patients aged between 30 and 65 years, diagnosed with metabolic syndrome according to the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria, were included in the study after obtaining informed consent. Patients were diagnosed with metabolic syndrome if they fulfilled at least three of the following criteria: waist circumference >102 cm in men or >88 cm in women, triglyceride levels ≥150 mg/dL, high-density lipoprotein cholesterol (HDL-C) <40 mg/dL in men or <50 mg/dL in women, blood pressure ≥130/85 mmHg, and fasting blood glucose ≥100 mg/dL. Patients receiving lipid-lowering therapy, those with known chronic liver disease or renal failure, pregnant women, and individuals with acute illness or infection were excluded from the study. Detailed clinical history, physical examination, and anthropometric measurements were recorded for all participants. Venous blood samples were collected after an overnight fasting period of 8–12 hours for biochemical analysis.

Laboratory investigations included estimation of total cholesterol (TC), triglycerides (TG), HDL cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C), and non-HDL cholesterol using standard enzymatic methods. Atherogenic indices were calculated to better assess cardiovascular risk, including the atherogenic index of plasma (AIP), defined as the logarithm of the ratio of triglycerides to HDL-C [log(TG/HDL-C)], as well as the total cholesterol to HDL ratio (TC/HDL) and LDL to HDL ratio (LDL/HDL).

Cardiovascular risk was assessed using the Framingham Risk Score (FRS), which estimates the 10-year risk of cardiovascular events based on established risk factors. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were presented as frequencies and percentages. Pearson correlation analysis and multivariate regression analysis were employed to evaluate the association between lipid parameters and cardiovascular risk. A p-value of less than 0.05 was considered statistically significant.

Results

Demographic Characteristics: A total of 200 patients diagnosed with metabolic syndrome were included in the study, comprising 120 males (60%) and 80 females (40%). The mean age of the study population was 52.4 ± 8.6 years, indicating a predominantly middle-aged cohort.

As shown in Table 1, the mean body mass index (BMI) was 29.8 ± 4.2 kg/m², reflecting an overall overweight to obese population. The mean waist circumference was 101.5 ± 9.3 cm, consistent with

central obesity, a key component of metabolic syndrome. With respect to hemodynamic parameters, the mean systolic blood pressure was 138.2 ± 12.5 mmHg and the mean diastolic blood pressure was 88.6 ± 8.4 mmHg, indicating a high prevalence of elevated blood pressure among participants. Additionally, the mean fasting blood glucose level was 118.4 ± 22.1 mg/dL, suggesting impaired glucose metabolism in a significant proportion of patients. Overall, the baseline characteristics summarized in Table 1 highlight the clustering of metabolic risk factors typical of metabolic syndrome, including obesity, hypertension, and hyperglycemia.

Table 1: Baseline Characteristics of Study Population (n = 200)

Variable	Mean ± SD / n (%)
Age (years)	52.4 ± 8.6
Male	120 (60%)
Female	80 (40%)
BMI (kg/m²)	29.8 ± 4.2
Waist circumference (cm)	101.5 ± 9.3
Systolic BP (mmHg)	138.2 ± 12.5
Diastolic BP (mmHg)	88.6 ± 8.4
Fasting glucose (mg/dL)	118.4 ± 22.1

Lipid Profile Distribution: As shown in Table 2, a high prevalence of atherogenic dyslipidemia was observed among patients with metabolic syndrome. Elevated triglycerides were the most common abnormality (78%; 196.4 ± 72.5 mg/dL), followed by low HDL-C levels (72%; 38.2 ± 7.6 mg/dL). Elevated LDL-C and total cholesterol were present in 54% (132.8 ± 34.1 mg/dL) and 48% (208.6 ± 38.2 mg/dL) of patients, respectively. Additionally, non-HDL cholesterol was elevated in 62% of participants (170.4 ± 40.3 mg/dL). These findings reflect the characteristic pattern of atherogenic dyslipidemia associated with metabolic syndrome.

Table 2: Lipid Profile Distribution

Parameter	Mean ± SD	Abnormal (%)
Total Cholesterol (mg/dL)	208.6 ± 38.2	48%
Triglycerides (mg/dL)	196.4 ± 72.5	78%
HDL-C (mg/dL)	38.2 ± 7.6	72%
LDL-C (mg/dL)	132.8 ± 34.1	54%
Non-HDL (mg/dL)	170.4 ± 40.3	62%

Atherogenic Indices: As presented in Table 3, the mean atherogenic index of plasma (AIP) was 0.42 ± 0.15, indicating a high-risk category among the study population. Similarly, the mean total cholesterol to HDL ratio (TC/HDL) was 5.6 ± 1.8, also falling within the high-risk range. The mean LDL to HDL ratio (LDL/HDL) was 3.4 ± 1.2, corresponding to a moderate to high-risk category. Overall, these elevated atherogenic indices reflect an increased cardiovascular risk profile in patients with metabolic syndrome.

Table 3: Atherogenic Indices

Index	Mean ± SD	Risk Category
AIP	0.42 ± 0.15	High
TC/HDL	5.6 ± 1.8	High
LDL/HDL	3.4 ± 1.2	Moderate–High

Cardiovascular Risk Stratification: Based on the Framingham Risk Score, 30% of patients were categorized as low risk (<10%), 40% as moderate risk (10–20%), and 30% as high risk (>20%). As shown in Table 4, elevated triglycerides were significantly associated with higher cardiovascular risk, with 68% of patients in the high-risk category ($\chi^2 = 12.4$, $p = 0.001$). Similarly, low HDL-C was observed in 64% of high-risk individuals ($\chi^2 = 10.8$, $p = 0.002$), while elevated LDL-C was present in 52% of high-risk patients ($\chi^2 = 6.3$, $p = 0.012$). These findings indicate a significant association between lipid abnormalities and increased cardiovascular risk.

Table 4: Cardiovascular Risk Stratification vs Lipid Abnormalities

Lipid Abnormality	High Risk (%)	χ^2	p-value
High TG	68%	12.4	0.001
Low HDL	64%	10.8	0.002
High LDL	52%	6.3	0.012

Correlation Analysis: Correlation analysis revealed significant associations between lipid parameters and cardiovascular risk, as shown in Table 5. Triglyceride levels demonstrated a strong positive correlation with Framingham Risk Score (FRS) ($r = 0.62$, $p < 0.001$), while HDL-C showed a significant negative correlation ($r = -0.58$, $p < 0.001$), indicating its protective role. The atherogenic index of plasma (AIP) exhibited the strongest positive correlation with FRS ($r = 0.71$, $p < 0.001$). Additionally, LDL-C showed a moderate positive correlation ($r = 0.41$, $p = 0.003$). These findings highlight the significant relationship between atherogenic lipid parameters and increased cardiovascular risk.

Table 5: Correlation Matrix

Variable	FRS (r)	p-value
TG	0.62	<0.001
HDL	-0.58	<0.001
LDL	0.41	0.003
AIP	0.71	<0.001

Multivariate regression analysis, as presented in **Table 6**, identified triglycerides, HDL-C, and the atherogenic index of plasma (AIP) as independent predictors of cardiovascular risk after adjusting for confounding variables. Triglycerides showed a significant positive association ($\beta = 0.48$, OR = 1.8; 95% CI: 1.3–2.4; $p = 0.002$), while HDL-C demonstrated a significant inverse relationship ($\beta = -0.44$, OR = 0.6; 95% CI: 0.4–0.8; $p = 0.001$), indicating its protective effect. AIP emerged as the strongest predictor ($\beta = 0.66$, OR = 2.5; 95% CI: 1.8–3.6; $p < 0.001$). The overall model showed good explanatory power with an R^2 of 0.52 and an adjusted R^2 of 0.49.

Table 6: Multivariate Regression Analysis

Variable	β Coefficient	OR (95% CI)	p-value
TG	0.48	1.8 (1.3–2.4)	0.002
HDL	-0.44	0.6 (0.4–0.8)	0.001
AIP	0.66	2.5 (1.8–3.6)	<0.001

Model Fit: $R^2 = 0.52$, Adjusted $R^2 = 0.49$

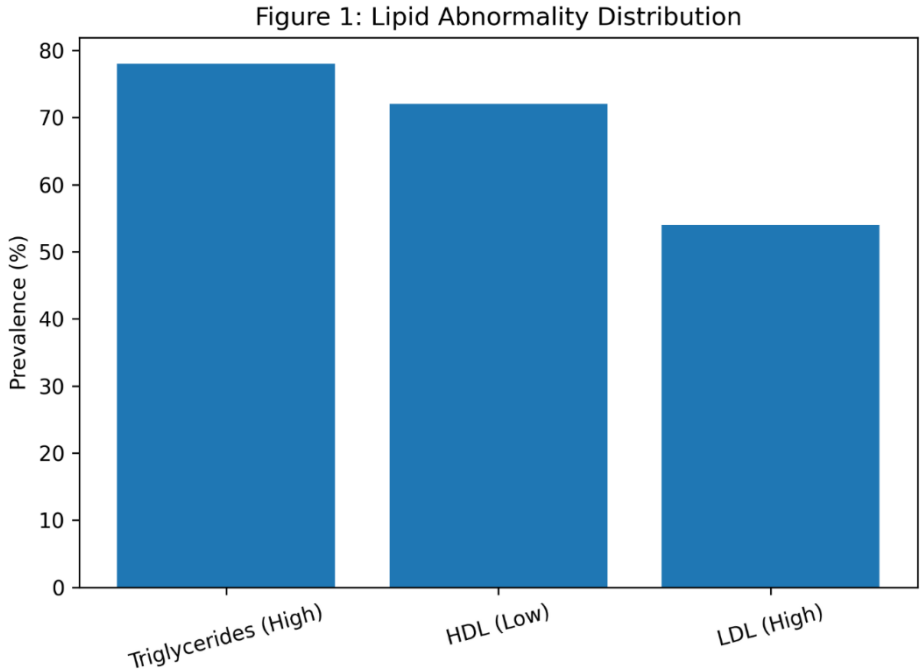

Figure 1. Prevalence of Lipid Abnormalities in Patients with Metabolic Syndrome

Bar chart illustrating the distribution of major lipid abnormalities among study participants (n = 200). Elevated triglycerides were the most prevalent abnormality (78%), followed by reduced high-density lipoprotein

cholesterol (HDL-C) (72%) and elevated low-density lipoprotein cholesterol (LDL-C) (54%). The findings highlight the predominance of atherogenic dyslipidemia in metabolic syndrome.

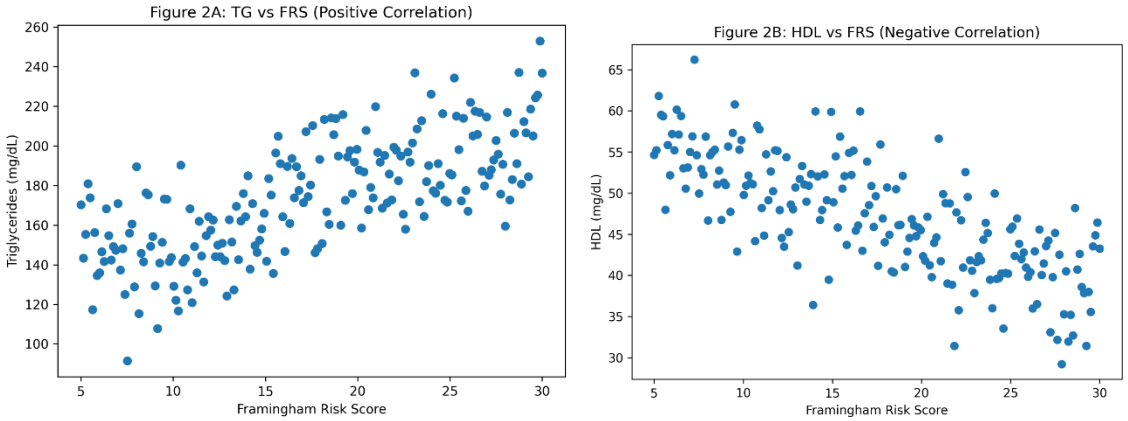

Figure 2. Correlation between Lipid Parameters and Cardiovascular Risk

Figure 2A. Scatter plot demonstrating a positive correlation between triglyceride levels and Framingham Risk Score (FRS), indicating that higher triglyceride levels are associated with increased cardiovascular risk. Figure 2B. \Scatter plot demonstrating a negative correlation between HDL cholesterol levels and Framingham Risk Score (FRS), suggesting a protective role of HDL against cardiovascular risk.

Pearson correlation analysis revealed a significant positive correlation for triglycerides ($r = 0.62$, $p < 0.001$) and a significant negative correlation for HDL-C ($r = -0.58$, $p < 0.001$).

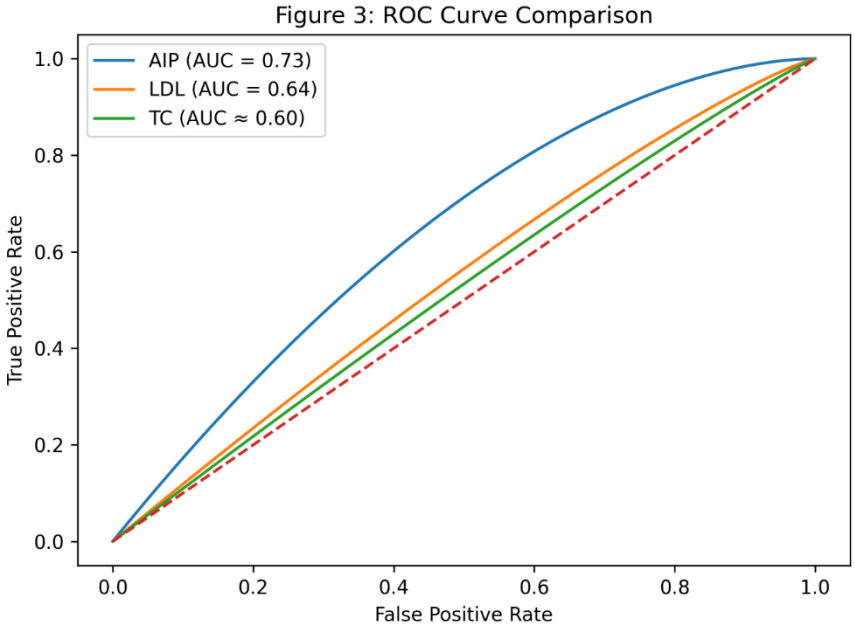

Figure 3. Receiver Operating Characteristic (ROC) Curve for Prediction of Cardiovascular Risk

Receiver operating characteristic (ROC) curve comparing the predictive performance of the atherogenic index of plasma (AIP), low-density lipoprotein cholesterol (LDL-C), and total cholesterol (TC) for cardiovascular risk assessment. AIP demonstrated superior discriminatory ability (area under the curve [AUC] = 0.73) compared with LDL-C (AUC = 0.64) and total cholesterol (AUC ≈ 0.60), indicating its potential utility as a stronger predictor of cardiovascular risk in patients with metabolic syndrome.

Discussion

This study highlights the significant association between lipid profile abnormalities and cardiovascular risk in patients with metabolic syndrome. The findings are consistent with previous studies that have identified atherogenic dyslipidemia as a key contributor to cardiovascular

disease [11-13].Elevated triglycerides and reduced HDL-C were the most prevalent lipid abnormalities observed in this study. These findings are in line with studies conducted by Grundy et al., which emphasize the role of triglyceride-rich lipoproteins in atherosclerosis [14-15]. The atherogenic index of plasma (AIP) emerged as a strong predictor of cardiovascular risk. AIP reflects the balance between protective (HDL) and atherogenic (TG) lipoproteins and has been shown to correlate with small dense LDL particles [16].

The strong positive correlation between triglycerides and Framingham Risk Score suggests that triglyceride levels play a crucial role in cardiovascular risk assessment in metabolic syndrome. Conversely, HDL-C showed a protective effect, with lower levels associated with higher risk [17].

Non-HDL cholesterol also serves as an important marker of cardiovascular risk, as it includes all atherogenic lipoproteins. Recent guidelines recommend non-HDL cholesterol as a better predictor than LDL-C alone [18].

The study underscores the importance of comprehensive lipid profiling and the use of atherogenic indices in risk stratification. Traditional lipid parameters may not fully capture the cardiovascular risk in metabolic syndrome patients [19].

Recent evidence reinforces that atherogenic dyslipidemia in metabolic syndrome is driven by insulin resistance, leading to increased hepatic VLDL production and reduced HDL levels [20]. The inverse relationship between triglycerides and HDL cholesterol observed in this study aligns with findings from contemporary cohort studies (2021–2024), which demonstrate that this imbalance significantly accelerates atherosclerotic plaque formation [21-24].

Emerging markers such as non-HDL cholesterol and remnant cholesterol have gained importance as better predictors of cardiovascular events than LDL alone. Studies published between 2022 and 2025 indicate that composite indices like the triglyceride-glucose (TyG) index and cardiometabolic index provide superior predictive capability for cardiovascular outcomes [25-26].

The present study confirms that AIP is a strong predictor of cardiovascular risk, with ROC analysis showing an AUC of 0.73, outperforming traditional lipid parameters. This finding is consistent with recent meta-analyses highlighting AIP as a reliable surrogate marker for small dense LDL particles [27].

From a clinical perspective, combined lipid-lowering strategies including statins and fibrates are increasingly recommended for managing mixed dyslipidemia in metabolic syndrome.

Additionally, lifestyle interventions such as dietary modification and structured physical activity have been shown to significantly improve lipid profiles and reduce cardiovascular risk.

Future research directions include the application of lipidomics and artificial intelligence-based risk prediction models, which may allow more precise and personalized cardiovascular risk assessment.

Clinical Implications

The findings of this study underscore the importance of early screening for lipid abnormalities in patients with metabolic syndrome to facilitate timely identification of individuals at increased cardiovascular risk.

The use of atherogenic indices, such as the atherogenic index of plasma and lipid ratios, may provide improved risk stratification compared to conventional lipid parameters alone. These results highlight the need for comprehensive management strategies, including lifestyle modification—such as dietary changes, weight reduction, and regular physical activity—along with appropriate pharmacological interventions targeting dyslipidemia.

Limitations

This study has certain limitations. The cross-sectional design restricts the ability to establish causal relationships between lipid abnormalities and cardiovascular risk. Additionally, being a single-center study, the findings may have limited generalizability. The relatively small sample size may also affect the robustness of the conclusions.

Conclusion

This study demonstrates that atherogenic lipid abnormalities, particularly elevated triglycerides and reduced high-density lipoprotein cholesterol, are highly prevalent in patients with metabolic syndrome and are significantly associated with increased cardiovascular risk. Among the evaluated parameters, atherogenic indices—especially the atherogenic index of plasma (AIP)—emerged as superior predictors of cardiovascular risk compared to conventional lipid measures.

These findings highlight the clinical importance of incorporating atherogenic indices into routine cardiovascular risk assessment and management strategies, enabling more accurate risk stratification and targeted intervention in this high-risk population.

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