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Association of serum triglyceride and high-density lipoprotein cholesterol levels with forced vital capacity and forced expiratory volume in the first second-to-forced vital capacity ratio in metabolic syndrome: a prospective observational study

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Abstract

Background:

This study evaluated the association of serum triglyceride and high-density lipoprotein cholesterol (HDL-C) levels with pulmonary function in patients with metabolic syndrome.

Methods

This prospective observational study included 100 patients with metabolic syndrome at Gouri Devi Institute of Medical Sciences and Hospital, Durgapur, from July 2014 to February 2016. Demographic, anthropometric, biochemical, and spirometric parameters were assessed, including forced vital capacity (FVC) and forced expiratory volume in the first second-to-forced vital capacity ratio (FEV1/FVC).

Results

Among 100 participants, 51 (51.0%) were male, and 49 (49.0%) were female. The largest age group was 41–60 years (48.0%). Mean serum triglyceride and HDL-C levels were 128.78 ± 49.63 mg/dL and 39.39 ± 8.21 mg/dL, respectively. Mean FVC was 65.78 ± 19.64% predicted, and mean FEV1/FVC was 84.29 ± 7.18%. Restrictive and mixed ventilatory patterns occurred in 58 (58.0%) and 8 (8.0%) participants, respectively. Triglycerides were not significantly correlated with FVC ($r = -0.16$, $p = 0.108$) or FEV1/FVC ($r = -0.09$, $p = 0.365$). Similarly, HDL-C showed no significant correlation with FVC ($r = 0.14$, $p = 0.162$) or FEV1/FVC ($r = 0.08$, $p = 0.421$). FVC was significantly lower in participants with restrictive patterns than in those with normal pulmonary function (53.57 ± 11.64% vs. 90.06 ± 8.72%; $p < 0.001$).

Conclusion

Restrictive ventilatory patterns were common, but triglyceride and HDL-C levels were not significantly associated with pulmonary function.

Recommendation

Larger studies incorporating complete pulmonary function testing, including total lung capacity, are recommended.

Keywords: *Metabolic syndrome; triglycerides; high-density lipoprotein cholesterol; forced vital capacity; forced expiratory volume in the first second-to-forced vital capacity ratio; spirometry.*
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Introduction

Metabolic syndrome (MetS) is a cluster of interrelated cardiometabolic abnormalities characterized by central obesity, elevated blood pressure, impaired glucose regulation, elevated triglycerides, and reduced high-density lipoprotein cholesterol (HDL-C). The coexistence of these abnormalities is associated with an increased risk of cardiovascular disease and type 2 diabetes mellitus. The harmonized definition of metabolic syndrome recommends the presence of any three of five metabolic abnormalities, with ethnicity-specific waist circumference thresholds used where appropriate [1,2].

Although the major clinical consequences of metabolic syndrome are cardiovascular and metabolic, increasing evidence suggests that metabolic abnormalities may also affect the respiratory system. Impaired pulmonary function has been associated with obesity, insulin resistance, hypertension, systemic inflammation, and other components of metabolic syndrome [3]. Potential mechanisms include the mechanical effects of central adiposity, reduced chest-wall compliance, impaired diaphragmatic excursion, insulin resistance, endothelial dysfunction, oxidative stress, and chronic low-grade systemic inflammation [3,4].

Pulmonary function is commonly assessed by spirometry, particularly forced vital capacity (FVC), forced expiratory volume in the first second (FEV1), and the FEV1/FVC ratio. A reduced FVC with a relatively preserved FEV1/FVC ratio may indicate a restrictive ventilatory pattern; however, true restrictive lung disease requires confirmation by measurement of total lung capacity. Appropriate

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standardization and interpretation of spirometry are therefore essential when evaluating pulmonary function [5]. Several population-based studies have demonstrated an association between metabolic syndrome and impaired pulmonary function. Chen et al., in a cross-sectional analysis of 8,602 participants from the Third National Health and Nutrition Examination Survey, reported that individuals with a greater number of metabolic syndrome components had significantly lower predicted FVC and FEV1 after adjustment for potential confounders. Abdominal obesity, elevated blood pressure, high triglycerides, and low HDL-C were also associated with impaired pulmonary function [6]. Similarly, Yoon et al. evaluated 6,684 non-smoking Korean adults and found that metabolic syndrome and increasing metabolic syndrome scores were inversely associated with predicted FVC and FEV1. Metabolic syndrome was also associated with a significantly greater likelihood of restrictive pulmonary impairment [7]. These findings suggest that the relationship between metabolic syndrome and pulmonary function may be present even in the absence of smoking exposure.

The relationship has also been reported in other populations. Bae et al. demonstrated an association between metabolic syndrome and pulmonary function in Korean adults, supporting the possibility that the cumulative metabolic burden may contribute to respiratory impairment [8]. Studies of older adults have similarly suggested associations between metabolic syndrome, type 2 diabetes, obesity, and reduced lung function [9].

More recently, Fang et al. performed a meta-analysis of 15 studies involving 10,285 participants with metabolic syndrome and 25,416 controls. The analysis demonstrated significantly lower FVC and FEV1 among individuals with metabolic syndrome, whereas the FEV1/FVC ratio did not differ significantly between groups. These findings support a predominantly restrictive pattern of pulmonary impairment in metabolic syndrome [10].

Despite these observations, the contribution of individual lipid components to pulmonary dysfunction remains incompletely understood. Triglycerides and HDL-C are important components of metabolic syndrome, but their individual associations with pulmonary function may differ according to age, sex, adiposity, smoking exposure, and the presence of other metabolic abnormalities. Therefore, evaluating these parameters in relation to objective spirometric measurements may provide additional information regarding the relationship between metabolic abnormalities and respiratory function.

The present study was undertaken to evaluate pulmonary function among patients with metabolic syndrome and to determine the association of **serum triglyceride and HDL-C levels with FVC, FEV1/FVC, and overall pulmonary function pattern**. The study also aimed to characterize the distribution of normal, restrictive, obstructive, and mixed spirometric patterns in this population.

Aim

To evaluate the association of serum triglyceride and HDL-C levels with FVC and FEV1/FVC in patients with metabolic syndrome.

Objectives

1. To assess pulmonary function using spirometry in patients with metabolic syndrome.
2. To determine the distribution of normal, restrictive, obstructive, and mixed ventilatory patterns.
3. To evaluate the association of serum triglyceride levels with FVC and FEV1/FVC.
4. To evaluate the association of serum HDL-C levels with FVC and FEV1/FVC.
5. To assess the relationship of pulmonary function with selected clinical and anthropometric characteristics of patients with metabolic syndrome.

Materials and Methods

Study Design and Setting

This was a hospital-based prospective observational study conducted at Gouri Devi Institute of Medical Sciences and Hospital, Durgapur, West Bengal, India, from July 2014 to February 2016. The study was undertaken among patients attending the institution for various clinical indications, including preoperative assessment for procedures requiring general anaesthesia. The institution provides hospital-based medical services, with the Department of Pulmonary Medicine and Critical Care involved in the conduct of the study. A total of 100 patients diagnosed with metabolic syndrome were included and evaluated for their demographic, anthropometric, biochemical, and pulmonary function parameters.

Study Population

The study population comprised adult patients with metabolic syndrome who attended the study centre during the study period. Participants were recruited consecutively until the predetermined sample size of 100 was achieved. All participants were assessed for eligibility according to the predefined inclusion and exclusion criteria before enrolment.

Diagnostic Criteria for Metabolic Syndrome

Metabolic syndrome was diagnosed using the revised National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria, with Asian-specific waist circumference thresholds. A participant was considered to have metabolic syndrome when three or more of the following five components were present [1,2]:

1. **Abdominal obesity:** Waist circumference greater than 90 cm in men or 80 cm in women.

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2. **Hypertriglyceridemia:** Serum triglyceride concentration ≥150 mg/dL.
3. **Reduced high-density lipoprotein cholesterol (HDL-C):** HDL-C concentration less than 40 mg/dL in men or less than 50 mg/dL in women.
4. **Elevated blood pressure:** Systolic blood pressure ≥130 mmHg and/or diastolic blood pressure ≥85 mmHg.
5. **Elevated fasting blood glucose:** Fasting blood glucose concentration ≥100 mg/dL.

Participants receiving antihypertensive or antidiabetic medication were considered positive for the corresponding metabolic syndrome component.

Inclusion Criteria

Participants were eligible for inclusion if they:

- Fulfilled the modified NCEP ATP III criteria for metabolic syndrome.
- Were Asian men or women.
- Provided written informed consent before enrolment.
- Were able to perform acceptable spirometric manoeuvres.

Exclusion Criteria

Participants were excluded if they:

- Had a known history of asthma, chronic obstructive pulmonary disease (COPD), or other chronic pulmonary diseases.
- Had any other condition that prevented reliable pulmonary function testing.

Bias

Several measures were adopted to minimize potential sources of bias. Selection bias was addressed through consecutive enrolment of eligible participants using predefined inclusion and exclusion criteria. A structured study proforma was used to ensure consistency in demographic, clinical, and anthropometric data collection. Standardized procedures were followed for measuring blood pressure, height, weight, and waist circumference to minimize measurement variability. Pulmonary function testing was performed by an experienced technician using an automated spirometer. At least three acceptable spirometric manoeuvres were performed, and the highest acceptable forced vital capacity (FVC) and forced expiratory volume in the first second (FEV1) values were used for analysis. These procedures were intended to improve the consistency and reliability of data collection.

Study Size

A total of 100 patients with metabolic syndrome were included in the study. Participants were consecutively recruited from the study centre during the study period until the predetermined sample size was achieved. The sample size and recruitment strategy were based on the feasibility of participant recruitment and the availability of eligible patients at the study centre.

Clinical and Anthropometric Assessment

Demographic and clinical information was recorded using a structured study proforma. The collected information included age, sex, smoking status, alcohol consumption, physical activity, hypertension status, antihypertensive medication use, and relevant clinical history.

Blood pressure was measured after the participant had rested in a seated position for at least five minutes. Height was measured with the participant barefoot using a calibrated measuring device, while weight was measured with light clothing. Body mass index (BMI) was calculated as weight in kilograms divided by height in metres squared.

Waist circumference was measured with the participant standing, using a non-stretchable measuring tape, according to the study protocol.

Smoking status was categorized as never smoker, former smoker, or current smoker. Alcohol consumption was recorded according to the participant's reported drinking history. Physical activity was categorized as mild, moderate, or vigorous according to the reported level of activity.

Biochemical Assessment

Venous blood samples were obtained for biochemical assessment. Serum triglyceride and HDL-C concentrations were recorded and expressed in mg/dL.

The mean serum triglyceride and HDL-C concentrations were subsequently evaluated in relation to the principal spirometric parameters, namely FVC and the forced expiratory volume in the first second-to-forced vital capacity ratio (FEV1/FVC).

Pulmonary Function Testing

Pulmonary function testing was performed in all participants using an automated flow-sensing spirometer by an experienced technician. Spirometry was performed according to accepted American Thoracic Society recommendations.

The following parameters were recorded:

- Forced vital capacity (FVC).
- Forced expiratory volume in the first second (FEV1).
- Forced expiratory volume in the first second-to-forced vital capacity ratio (FEV1/FVC).

At least three acceptable spirometric manoeuvres were performed, and the highest acceptable FVC and FEV1 values were used for analysis. FVC was expressed as a percentage of the predicted value, while FEV1/FVC was expressed as a percentage.

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Classification of Spirometric Patterns

For this study, spirometric findings were categorized as follows:

- **Obstructive pattern:** FEV1/FVC less than 0.70 with FVC ≥80% of predicted.
- **Restrictive ventilatory pattern:** FVC less than 80% of predicted with FEV1/FVC ≥0.70.
- **Mixed pattern:** FEV1/FVC less than 0.70 with FVC less than 80% of predicted.
- **Normal pattern:** Findings not fulfilling the above criteria.

Because reduced FVC with a preserved FEV1/FVC ratio on spirometry does not by itself establish reduced total lung capacity, the term "restrictive ventilatory pattern" was used rather than confirmed physiological restriction. Confirmation of true restriction would require measurement of total lung capacity.

Study Variables and Outcomes

The primary outcomes were the associations of serum triglyceride and HDL-C levels with the following pulmonary function parameters:

- FVC (% predicted).
- FEV1/FVC ratio.

Secondary outcomes included the distribution of normal, restrictive, obstructive, and mixed spirometric patterns and the relationship of pulmonary function with selected demographic, anthropometric, clinical, and lifestyle characteristics, including age, sex, BMI, waist circumference, smoking, alcohol consumption, physical activity, and antihypertensive medication use.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows, version 17.0.

Continuous variables were summarized as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages.

Continuous variables were assessed for distribution before analysis. Normally distributed variables were compared using the unpaired Student's t-test, whereas the Mann–Whitney U test was used for non-normally distributed variables. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate.

For comparisons involving three pulmonary function groups, one-way analysis of variance (ANOVA) was used for normally distributed continuous variables. When the overall ANOVA was statistically significant, appropriate post-hoc testing was performed. The Kruskal–Wallis test was used for non-normally distributed continuous variables across three groups.

Associations between serum triglyceride and HDL-C status and pulmonary function abnormalities were evaluated using appropriate categorical and continuous-variable analyses. A two-sided p-value less than 0.05 was considered statistically significant.

Results

Participant Flow

During the study period, eligible patients attending Gouri Devi Institute of Medical Sciences and Hospital, Durgapur, were assessed for inclusion according to the predefined eligibility criteria. A total of 100 participants with metabolic syndrome were consecutively enrolled in the study. All enrolled participants underwent demographic, anthropometric, biochemical, and pulmonary function assessments. Complete spirometric data were available for all 100 participants, and all were included in the final analysis.

Study Population and Baseline Characteristics

A total of **100 patients with metabolic syndrome** were included in the study. Of these, **51 (51.0%) were males, and 49 (49.0%) were females**. The largest proportion of participants belonged to the **41–60-year age group (48.0%)**, followed by those aged **>60 years (41.0%)**.

The mean height of the study population was **160.28 ± 8.42 cm**, mean body weight was **74.24 ± 12.16 kg**, and mean waist circumference was **94.05 ± 9.18 cm**. The mean serum triglyceride concentration was **128.78 ± 49.63 mg/dL**, while the mean HDL-C concentration was **39.39 ± 8.21 mg/dL**.

The mean FVC was **65.78 ± 19.64% of predicted**, and the mean FEV1/FVC ratio was **84.29 ± 7.18%**. The baseline demographic, anthropometric, biochemical, and pulmonary function characteristics are summarized in **Table 1**.

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Table 1. Baseline demographic, anthropometric, biochemical, and pulmonary function characteristics of the study population (n = 100)

Parameter	Value
Sex, n (%)	
Male	51 (51.0)
Female	49 (49.0)
Age group, n (%)	
41–60 years	48 (48.0)
>60 years	41 (41.0)
Anthropometric parameters	
Height (cm), mean ± SD	160.28 ± 8.42
Weight (kg), mean ± SD	74.24 ± 12.16
Waist circumference (cm), mean ± SD	94.05 ± 9.18
Biochemical parameters	
Serum triglycerides (mg/dL), mean ± SD	128.78 ± 49.63
HDL-C (mg/dL), mean ± SD	39.39 ± 8.21
Pulmonary function parameters	
FVC (% predicted), mean ± SD	65.78 ± 19.64
FEV1/FVC (%), mean ± SD	84.29 ± 7.18

Abbreviations: HDL-C, high-density lipoprotein cholesterol; FVC, forced vital capacity; FEV1, forced expiratory volume in the first second; SD, standard deviation.

Distribution of Pulmonary Function Patterns

Pulmonary function testing was performed in all 100 participants. A restrictive ventilatory pattern was observed in 58 (58.0%) participants, while 8 (8.0%) participants demonstrated a mixed ventilatory pattern. No participant had an isolated obstructive pattern.

Overall, 66 (66.0%) participants had an abnormal pulmonary function pattern, comprising restrictive and mixed patterns, whereas 34 (34.0%) had normal pulmonary function. Thus, the restrictive ventilatory pattern was the predominant spirometric abnormality observed in the study population.

The distribution of pulmonary function patterns is presented in Table 2.

Table 2. Distribution of pulmonary function patterns among patients with metabolic syndrome (n = 100)

Pulmonary function pattern	n	%
Normal	34	34.0
Restrictive ventilatory pattern	58	58.0
Obstructive pattern	0	0.0
Mixed pattern	8	8.0
Abnormal pulmonary function	**66**	**66.0**
Total	**100**	**100.0**

Association of Serum Triglycerides with Pulmonary Function

The mean serum triglyceride concentration was 128.78 ± 49.63 mg/dL. Serum triglyceride levels were evaluated in relation to FVC, FEV1/FVC, and overall pulmonary function abnormality.

Serum triglyceride concentration showed a weak inverse correlation with FVC, but this association did not reach statistical significance ($r = -0.16$, $p = 0.108$). Similarly, triglyceride concentration was not significantly correlated with FEV1/FVC ($r = -0.09$, $p = 0.365$).

When participants were categorized according to triglyceride status, no statistically significant association was observed between elevated triglyceride status and overall pulmonary function abnormality ($\chi^2 = 0.84$, $p = 0.359$). Thus, serum triglyceride levels were not significantly associated with FVC, FEV1/FVC, or overall pulmonary function abnormality in the study population.

The findings are summarized in Table 3.

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Table 3. Association of serum triglyceride concentration with pulmonary function parameters

Analysis	Statistical result	p-value	Interpretation
Triglycerides vs FVC	r = −0.16	0.108	Not significant
Triglycerides vs FEV1/FVC	r = −0.09	0.365	Not significant
Elevated triglyceride status vs abnormal pulmonary function	$\chi^2 = 0.84$	0.359	Not significant

Abbreviations: FVC, forced vital capacity; FEV1/FVC, forced expiratory volume in the first second-to-forced vital capacity ratio; r, correlation coefficient; χ^2, chi-square statistic.

Association of HDL-C with Pulmonary Function

The mean HDL-C concentration was 39.39 ± 8.21 mg/dL. HDL-C concentration was evaluated in relation to FVC, FEV1/FVC, and pulmonary function pattern.

HDL-C showed a weak positive correlation with FVC, but the association was not statistically significant (r = 0.14, p = 0.162). Similarly, HDL-C was not significantly correlated with FEV1/FVC (r = 0.08, p = 0.421).

Participants with low HDL-C did not demonstrate a statistically significant difference in the prevalence of abnormal pulmonary function compared with participants without low HDL-C ($\chi^2 = 1.21$, p = 0.271).

Therefore, serum HDL-C concentration was not significantly associated with FVC, FEV1/FVC, or overall pulmonary function abnormality in the study population.

The findings are presented in Table.

Table 4. Association of serum HDL-C concentration with pulmonary function parameters

Analysis	Statistical result	p-value	Interpretation
HDL-C vs FVC	r = 0.14	0.162	Not significant
HDL-C vs FEV1/FVC	r = 0.08	0.421	Not significant
Low HDL-C status vs abnormal pulmonary function	$\chi^2 = 1.21$	0.271	Not significant

Abbreviations: HDL-C, high-density lipoprotein cholesterol; FVC, forced vital capacity; FEV1/FVC, forced expiratory volume in the first second-to-forced vital capacity ratio; r, correlation coefficient; χ^2, chi-square statistic.

FVC According to Pulmonary Function Pattern

Because reduced FVC represented the principal spirometric abnormality, FVC was compared between participants with normal pulmonary function and those with a restrictive ventilatory pattern.

The mean FVC was **90.06 ± 8.72% of predicted** among participants with normal pulmonary function, compared with **53.57 ± 11.64% of predicted** among participants with a restrictive ventilatory pattern.

The difference was statistically significant (**t = 17.42, p < 0.001**), demonstrating substantially lower FVC among participants classified as having a restrictive ventilatory pattern.

The comparison is presented in **Table 5**.

Table 5. Comparison of FVC according to pulmonary function pattern

Pulmonary function pattern	n	Mean FVC (% predicted) ± SD	Statistical comparison
Normal	34	90.06 ± 8.72	
Restrictive ventilatory pattern	58	53.57 ± 11.64	
Between-group comparison			**t = 17.42, p < 0.001**

Abbreviations: FVC, forced vital capacity; SD, standard deviation.

Relationship of Clinical and Anthropometric Characteristics with Pulmonary Function

The mean BMI was **28.5 ± 3.9 kg/m²** among participants with normal pulmonary function and **29.3 ± 4.2 kg/m²** among those with abnormal pulmonary function. The difference was not statistically significant (**p = 0.327**).

Similarly, mean waist circumference did not differ significantly between participants with normal and abnormal pulmonary function (**p = 0.214**).

Increasing age showed a significant association with abnormal pulmonary function (**p = 0.032**), with pulmonary abnormalities occurring more frequently among older participants.

Smoking status was not significantly associated with pulmonary function abnormality (**p = 0.481**). This finding

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should be interpreted cautiously because the majority of participants were never smokers and only a small proportion were current smokers.

Physical activity also did not demonstrate a statistically significant association with pulmonary function (**p = 0.684**). Interpretation was limited by the predominance of mild physical activity in the study population.

Sex, alcohol consumption, and antihypertensive medication use were also not significantly associated with abnormal pulmonary function (**p > 0.05 for each comparison**).

Summary of Main Findings

Among the 100 patients with metabolic syndrome, **66 (66.0%) demonstrated abnormal pulmonary function**, including **58 (58.0%) with a restrictive ventilatory pattern and 8 (8.0%) with a mixed pattern**. No isolated obstructive pattern was observed.

The mean serum triglyceride and HDL-C concentrations were **128.78 ± 49.63 mg/dL** and **39.39 ± 8.21 mg/dL**, respectively. The mean FVC was **65.78 ± 19.64% of predicted**, while the mean FEV1/FVC ratio was **84.29 ± 7.18%**.

Serum triglyceride concentration showed a weak inverse relationship with FVC (**r = −0.16**), and HDL-C showed a weak positive relationship with FVC (**r = 0.14**); however, **neither association was statistically significant**.

Neither triglyceride nor HDL-C concentration was significantly associated with FEV1/FVC or overall pulmonary function abnormality.

In contrast, FVC was markedly lower among participants with a restrictive ventilatory pattern than among those with normal pulmonary function (**53.57% vs. 90.06% predicted; p < 0.001**).

Overall, the findings indicate that although abnormal pulmonary function—particularly a restrictive ventilatory pattern—was common among patients with metabolic syndrome, **serum triglyceride and HDL-C levels alone did not significantly explain the observed impairment in pulmonary function**.

Discussion

The present study evaluated pulmonary function and the relationship between serum triglyceride and HDL-C concentrations and spirometric parameters among 100 patients with metabolic syndrome. The principal findings were that **abnormal pulmonary function was common**, with a restrictive ventilatory pattern being the predominant abnormality. A restrictive ventilatory pattern was observed in 58% of participants, while 8% demonstrated a mixed pattern and no participant had an isolated obstructive pattern. Despite the high prevalence of abnormal pulmonary function, serum triglyceride and HDL-C concentrations were not significantly associated with FVC, FEV1/FVC, or overall pulmonary function abnormality.

Pulmonary Function Abnormalities in Metabolic Syndrome

The high prevalence of abnormal pulmonary function observed in the present study is consistent with previous evidence linking metabolic syndrome with impaired respiratory function. Chen et al. demonstrated that increasing numbers of metabolic syndrome components were associated with progressively lower predicted FVC and FEV1 after adjustment for age, body mass index, inflammatory factors, medical conditions, and smoking status [6]. Their study also found associations between impaired pulmonary function and individual metabolic components, including abdominal obesity, elevated blood pressure, high triglycerides, and low HDL-C [6].

Yoon et al. similarly reported an inverse association between metabolic syndrome and predicted FVC and FEV1 in 6,684 non-smoking Korean adults. Importantly, metabolic syndrome was associated with a significantly increased likelihood of restrictive pulmonary impairment, with the association becoming stronger as the metabolic syndrome score increased [7]. The findings of the present study are broadly consistent with these observations.

The predominance of a restrictive ventilatory pattern in our study is also supported by the meta-analysis conducted by Fang et al. [10]. Their analysis demonstrated significantly reduced FVC and FEV1 among individuals with metabolic syndrome, whereas the FEV1/FVC ratio was not significantly different from controls. The authors concluded that metabolic syndrome was associated with a restrictive ventilatory functional disturbance [10].

In the present study, the mean FVC was **65.78 ± 19.64% of predicted**, whereas the mean FEV1/FVC ratio was **84.29 ± 7.18%**. The relatively preserved FEV1/FVC ratio in the presence of reduced FVC is compatible with the predominance of a restrictive spirometric pattern.

Several mechanisms may explain this association. Central obesity can increase abdominal pressure, reduce chest-wall compliance, limit diaphragmatic excursion, and consequently reduce lung volumes. In addition, insulin resistance, chronic low-grade inflammation, endothelial dysfunction, oxidative stress, and altered respiratory muscle mechanics may contribute to impaired pulmonary function [3,4].

The present study also demonstrated a marked difference in FVC between participants with normal pulmonary function and those with a restrictive ventilatory pattern (**90.06 ± 8.72% vs. 53.57 ± 11.64% predicted; p < 0.001**). This finding provides internal support for the observed spirometric classification.

However, it is important to distinguish a **spirometric restrictive ventilatory pattern from confirmed restrictive lung disease**. A reduced FVC with a preserved FEV1/FVC ratio suggests a restrictive pattern but does not establish reduced total lung capacity. Confirmation of true restriction requires measurement of lung volumes, particularly total lung capacity [5]. Therefore, the term

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"restrictive ventilatory pattern" rather than "restrictive lung disease" should be used throughout the present manuscript.

Serum Triglycerides and Pulmonary Function

Serum triglycerides were evaluated because hypertriglyceridemia is one of the established components of metabolic syndrome [1,2]. In the present study, the mean serum triglyceride concentration was **128.78 ± 49.63 mg/dL**.

A weak inverse correlation was observed between triglyceride concentration and FVC (**r = −0.16**); however, this association was not statistically significant (**p = 0.108**). Similarly, triglyceride concentration was not significantly associated with FEV1/FVC (**r = −0.09, p = 0.365**) or overall pulmonary function abnormality.

These findings differ from some previous population-based observations. Chen et al. reported that high triglyceride levels were associated with impaired pulmonary function after adjustment for potential confounding factors [6]. However, their study involved a large nationally representative population, whereas the present study included only 100 participants, which may have limited the ability to detect relatively weak associations.

The lack of statistical significance in the present study may also be explained by the fact that all participants already had metabolic syndrome. Therefore, the study population may have had less variability in metabolic risk factors than a population including both metabolically healthy and metabolically unhealthy individuals.

Furthermore, the pulmonary effects of triglycerides may be mediated indirectly through obesity, insulin resistance, systemic inflammation, hypertension, and other components of metabolic syndrome rather than through triglyceride concentration alone [3,6]. Thus, the present findings suggest that serum triglyceride concentration alone may not be a sufficient predictor of pulmonary impairment among patients with metabolic syndrome**.**

HDL-C and Pulmonary Function

The mean HDL-C concentration in the present study was **39.39 ± 8.21 mg/dL**. HDL-C showed a weak positive correlation with FVC (**r = 0.14**), but the association was not statistically significant (**p = 0.162**). HDL-C was also not significantly associated with FEV1/FVC (**r = 0.08, p = 0.421**) or overall pulmonary function abnormality.

The absence of a significant association indicates that HDL-C alone may not explain the pulmonary abnormalities observed in this population. This should be interpreted cautiously because previous studies have demonstrated associations between individual metabolic components and pulmonary function [6,8].

The study by Chen et al. reported that low HDL-C was associated with impaired pulmonary function in a large population-based sample [6]. In contrast, the present study did not demonstrate a statistically significant relationship. Differences in sample size, population characteristics, age distribution, sex, adiposity, and the presence of other metabolic abnormalities may contribute to this discrepancy. It is therefore more appropriate to conclude that HDL-C was not an independent statistically significant correlate of pulmonary function in the present study**,** rather than concluding that HDL-C has no relationship with pulmonary function.

Anthropometric and Clinical Factors

BMI and waist circumference were not significantly associated with abnormal pulmonary function in the present study. Although participants with abnormal pulmonary function had a numerically higher BMI, the difference was not statistically significant.

Previous studies have emphasized the importance of obesity and abdominal adiposity in the relationship between metabolic syndrome and reduced lung volumes [6,9]. The absence of a significant association in the present study may be related to the relatively small sample size and the fact that all participants already fulfilled criteria for metabolic syndrome.

Age was significantly associated with abnormal pulmonary function. This finding is biologically plausible because advancing age is accompanied by reductions in elastic recoil, respiratory muscle strength, chest-wall compliance, and other determinants of pulmonary function. The observed association may therefore reflect the combined influence of age-related physiological changes and metabolic abnormalities.

Smoking was not significantly associated with pulmonary function abnormality in the present study. However, this finding should be interpreted cautiously because only a small proportion of participants were current smokers. The study was also not designed primarily to investigate smoking-related pulmonary disease.

Absence of an Isolated Obstructive Pattern

No participant demonstrated an isolated obstructive pattern, whereas 8% demonstrated a mixed pattern. This distribution further supports the predominance of reduced lung volumes rather than isolated airflow obstruction in the present study. The finding is consistent with the meta-analysis by Fang et al., which demonstrated significantly reduced FVC and FEV1 but no significant difference in FEV1/FVC between participants with metabolic syndrome and controls [10]. Similarly, Yoon et al. found an increased likelihood of restrictive pulmonary impairment among non-smoking adults with metabolic syndrome [7].

Nevertheless, the absence of an isolated obstructive pattern should not be interpreted as evidence that metabolic syndrome is unrelated to obstructive lung disease. The relatively small sample size and exclusion of participants with established chronic pulmonary disease may have influenced the observed distribution.

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Clinical Implications

The high prevalence of abnormal spirometric findings observed in this study suggests that pulmonary function assessment may be useful in selected patients with metabolic syndrome, particularly when respiratory symptoms, reduced exercise tolerance, obesity, or preoperative concerns are present.

However, the findings do not support the use of serum triglyceride or HDL-C concentrations alone as screening markers for pulmonary dysfunction. The absence of statistically significant associations indicates that pulmonary impairment in metabolic syndrome is likely multifactorial.

When spirometry demonstrates a restrictive pattern, further evaluation may be appropriate because spirometry alone cannot confirm reduced total lung capacity [5].

Generalizability

The findings of this study should be interpreted with caution when applying them to the wider population. The study was conducted at a single tertiary-care hospital and included 100 patients with metabolic syndrome. Therefore, the findings may not be fully representative of community-based populations or patients attending other healthcare settings. Differences in demographic characteristics, clinical profiles, lifestyle factors, and the prevalence of metabolic abnormalities may influence pulmonary function outcomes. Nevertheless, the findings provide useful insights into the pattern of pulmonary function abnormalities among hospital-based patients with metabolic syndrome. Further multicenter studies involving larger and more diverse populations are required to establish the generalizability of these findings.

Limitations

The present study has several limitations. First, the relatively small sample size of 100 participants may have limited the statistical power to detect modest associations between serum triglyceride and HDL-C levels and pulmonary function parameters. Second, the hospital-based, single-centre observational design may limit the generalizability of the findings to the wider population of individuals with metabolic syndrome. Third, the absence of a healthy control group prevented direct comparison of pulmonary function between individuals with and without metabolic syndrome.

Furthermore, the observational design does not allow causal relationships to be established between metabolic abnormalities and pulmonary function impairment. Although relevant clinical and anthropometric parameters were assessed, residual confounding by other metabolic, lifestyle, and clinical factors cannot be excluded. Smoking and physical activity categories were also unevenly distributed, which may have limited the interpretation of subgroup comparisons.

Most importantly, total lung capacity was not measured. Therefore, the restrictive patterns identified through spirometry could not be confirmed as true restrictive ventilatory impairment. Measurement of total lung capacity and other lung-volume parameters would have provided a more comprehensive assessment of pulmonary function. Future studies should address these limitations through larger, multicentre populations, inclusion of appropriate control groups, and comprehensive pulmonary function testing.

Conclusion

Abnormal pulmonary function was common among patients with metabolic syndrome, with a restrictive ventilatory pattern being the predominant finding. Serum triglyceride and HDL-C levels were not significantly associated with FVC, FEV1/FVC, or overall pulmonary function abnormality. These findings suggest that pulmonary dysfunction in metabolic syndrome may be multifactorial. However, the absence of total lung capacity measurements limits confirmation of true restrictive impairment. Larger multicentre studies with comprehensive pulmonary function testing are recommended to validate these findings.

Recommendation

Based on the findings of this study, pulmonary function assessment may be considered in selected patients with metabolic syndrome, particularly those presenting with respiratory symptoms, reduced exercise tolerance, obesity, or undergoing preoperative evaluation. However, serum triglyceride and HDL-C levels should not be used independently to predict pulmonary function abnormalities. Patients demonstrating a restrictive spirometric pattern may require further evaluation, including measurement of total lung capacity, to confirm the presence of true restrictive ventilatory impairment. Future studies should include larger, multicenter populations, appropriate healthy control groups, comprehensive pulmonary function testing, and multivariable analysis to further investigate the relationship between individual metabolic components and pulmonary function.

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List of Abbreviations

- BMI: Body Mass Index
- FEV1: Forced Expiratory Volume in the First Second
- FEV1/FVC: Forced Expiratory Volume in the First Second-to-Forced Vital Capacity Ratio
- FVC: Forced Vital Capacity

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- HDL-C: High-Density Lipoprotein Cholesterol
- MetS: Metabolic Syndrome
- NCEP ATP III: National Cholesterol Education Program Adult Treatment Panel III
- SPSS: Statistical Package for the Social Sciences
- TG: Triglycerides
- TLC: Total Lung Capacity

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The authors declare that they have no conflicts of interest related to the conduct of this study or the publication of this manuscript.

Data Availability
The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions
Dr. Krittibus Samui contributed to the conceptualization, study design, supervision, and critical revision of the manuscript. Dr. Amrita Ranjan Kundu contributed to the study methodology, clinical coordination, data collection, and manuscript review. Both authors reviewed and approved the final version of the manuscript.

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