Section: Miscellaneous

Original Research Article

PULMONARY FUNCTION ABNORMALITIES IN ADULTS WITH METABOLIC SYNDROME AND THEIR ASSOCIATION WITH METABOLIC SYNDROME SEVERITY

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ABSTRACT

Background: Metabolic syndrome (MetS) is associated with systemic metabolic and vascular abnormalities that may adversely affect respiratory function. However, evidence regarding pulmonary function abnormalities across different levels of MetS severity remains limited, particularly among Indian adults. This study evaluated pulmonary function abnormalities in adults with MetS and examined their association with metabolic syndrome severity.

Materials and Methods: This cross-sectional study included 380 adults aged 30–65 years with MetS diagnosed according to the modified National Cholesterol Education Program Adult Treatment Panel III criteria. Clinical, anthropometric, and biochemical parameters were assessed. Pulmonary function was evaluated by computerized spirometry, including forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1 /FVC ratio, peak expiratory flow rate (PEFR), and forced expiratory flow between 25% and 75% of FVC (FEF25–75%). Participants were categorized according to the presence of three, four, or five MetS components. Appropriate correlation and group comparison tests were applied.

Results: The mean predicted FVC and FEV_1 were 79.33 ± 13.16% and 81.74 ± 15.36%, respectively, with a preserved FEV_1 /FVC ratio. A spirometric restrictive pattern was observed in 39.2% of participants and was the most frequent pulmonary abnormality. Waist circumference showed significant inverse correlations with FVC and FEV_1 , while systolic and diastolic blood pressure were inversely correlated with FVC and PEFR. HDL-C showed significant positive correlations with FVC, FEV_1 , PEFR, and FEF25–75%. With an increasing number of MetS components, all assessed pulmonary function parameters showed a downward trend; however, statistically significant differences were observed only for PEFR (p=0.036) and FEF25–75% (p=0.031).

Conclusion: Pulmonary function impairment in adults with MetS was predominantly characterized by a spirometric restrictive pattern. Central obesity showed the strongest association with reduced lung function, while greater clustering of MetS components was associated with significant deterioration in selected expiratory flow parameters.

Keywords: Metabolic syndrome, pulmonary function, spirometry, restrictive pattern, central obesity, metabolic syndrome severity.

INTRODUCTION

Metabolic syndrome (MetS) is a cluster of interrelated metabolic abnormalities characterized by central obesity, hypertension, dyslipidemia, and impaired glucose metabolism. It is associated with an increased risk of type 2 diabetes mellitus, cardiovascular disease, and premature mortality. The increasing prevalence of obesity, physical inactivity, and unhealthy dietary habits has contributed to a substantial rise in the burden of MetS worldwide, making it a major public health challenge. In India, the prevalence of MetS among adults has been estimated to be approximately 30%, with higher prevalence reported among women, urban populations, and older individuals.[1,2]

Although MetS has traditionally been recognized for its cardiovascular and metabolic consequences, growing evidence suggests that it also adversely affects respiratory health. Pulmonary function impairment is increasingly being reported among individuals with MetS, even in the absence of clinically apparent respiratory disease. Several population-based studies have demonstrated significantly lower forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) among individuals with MetS compared with those without the syndrome, suggesting a predominantly restrictive pattern of ventilatory dysfunction.[3,4]

Spirometry is a simple, non-invasive, and widely used method for assessing pulmonary function. Parameters such as FVC, FEV_1, and the FEV_1/FVC ratio provide valuable information regarding ventilatory capacity and respiratory mechanics. These spirometric indices have been widely employed in epidemiological and clinical studies evaluating the impact of metabolic disorders on lung function and are useful for detecting early pulmonary impairment associated with MetS.[3,5]

The mechanisms responsible for pulmonary dysfunction in MetS are complex and multifactorial. Central obesity may mechanically restrict diaphragmatic movement and chest wall expansion, resulting in reduced lung volumes and impaired respiratory mechanics. In addition, chronic low-grade systemic inflammation, insulin resistance, oxidative stress, endothelial dysfunction, and adipokine imbalance contribute to structural and functional alterations within the respiratory system. Hyperglycemia has been associated with non-enzymatic glycation of connective tissue proteins and pulmonary microvascular injury, while dyslipidemia and hypertension may further promote airway and vascular dysfunction.[5,6]

Previous studies have examined the relationship between individual components of MetS and pulmonary function. Abdominal obesity has consistently emerged as the strongest predictor of reduced lung function, whereas elevated fasting glucose, hypertension, hypertriglyceridemia, and low HDL cholesterol have also been associated with impaired spirometric parameters.[3,7] However, the coexistence of multiple metabolic abnormalities may exert additive or synergistic effects, leading to greater deterioration in pulmonary function than any single component alone.

Recent evidence suggests that the severity of metabolic syndrome, reflected by the number of diagnostic components present, may be an important determinant of pulmonary dysfunction. Studies have demonstrated progressive reductions in spirometric parameters, particularly FEV_1 and FVC, with increasing metabolic burden. A higher prevalence of restrictive ventilatory abnormalities has also been reported among individuals with greater clustering of metabolic syndrome components, indicating that the cumulative effects of obesity, hypertension, dyslipidemia, and hyperglycemia may adversely influence respiratory function. These observations support the concept that pulmonary impairment may worsen as the severity of metabolic syndrome increases. However, available evidence remains limited and inconsistent, particularly among Indian adults, and data examining pulmonary function across different levels of metabolic syndrome severity are scarce.[8,9]

Therefore, the present study was undertaken to evaluate pulmonary function in adults with metabolic syndrome and to examine its association with metabolic syndrome severity as reflected by the number of metabolic syndrome components.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional study was conducted at a tertiary care teaching hospital in Bareilly, Uttar Pradesh, India, after obtaining approval from the Institutional Ethics Committee. Written informed consent was obtained from all participants prior to enrolment.

Study Population: Adults aged 30–65 years diagnosed with metabolic syndrome were recruited from the Medicine outpatient department. Metabolic syndrome was diagnosed according to the modified National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) criteria.[10] A total of 380 participants were included in the study, comprising 179 (47.1%) males and 201 (52.9%) females.

Eligibility Criteria: Participants fulfilling at least three criteria for metabolic syndrome were eligible for inclusion. Individuals with a history of chronic respiratory disease, pulmonary tuberculosis, bronchial asthma, chronic obstructive pulmonary disease, interstitial lung disease, significant cardiovascular illness, neuromuscular disorders affecting respiration, acute respiratory infection within the preceding four weeks, pregnancy, smoking, or inability to perform acceptable spirometric maneuvers were excluded.

Clinical and Laboratory Assessment: A detailed clinical history was obtained and a physical

examination was performed for all participants. Anthropometric measurements including height, weight, body mass index (BMI), and waist circumference were recorded using standardized techniques. Blood pressure was measured in the sitting position after an adequate period of rest.

Following an overnight fast of 8–12 hours, venous blood samples were collected for estimation of fasting blood glucose, serum triglycerides, and high-density lipoprotein cholesterol (HDL-C) levels using standard laboratory procedures.

Pulmonary Function Assessment: Pulmonary function was evaluated using computerized spirometry in accordance with the recommendations of the American Thoracic Society and European Respiratory Society.[11] Participants were familiarized with the testing procedure and instructed to perform maximal inspiratory and expiratory efforts. Spirometry was conducted in the sitting position with the use of a nose clip, and at least three technically acceptable maneuvers were obtained. The highest values meeting acceptability and reproducibility criteria were considered for analysis.

The spirometric parameters assessed included forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, peak expiratory flow rate (PEFR), and forced expiratory flow between 25% and 75% of FVC (FEF25–75%). FVC reflects the maximum volume of air exhaled forcefully following full inspiration, while FEV_1 represents the volume expired during the first second of the maneuver. The FEV_1/FVC ratio was used to identify ventilatory abnormalities and characterize pulmonary function patterns.[12]

Pulmonary function patterns were classified according to standard spirometric criteria. A normal ventilatory pattern was defined as FEV_1/FVC ≥70% with FVC ≥80% of the predicted value. An obstructive pattern was defined by FEV_1/FVC <70%, whereas a restrictive pattern was defined as FVC <80% of the predicted value with a preserved FEV_1/FVC ratio. A mixed ventilatory defect was considered when both FEV_1/FVC <70% and FVC <80% of the predicted value were present.[13]

Assessment of Metabolic Syndrome Severity: To evaluate the effect of metabolic burden on pulmonary function, participants were categorized according to the number of metabolic syndrome components present. Subjects were grouped into those having three, four, or five metabolic syndrome components, and spirometric parameters were compared across these categories.

Statistical Analysis

Statistical analysis was performed using SPSS version 26. Continuous variables were expressed as mean ± standard deviation and categorical variables as frequencies and percentages. Spearman's correlation coefficient and the Kruskal–Wallis test were used for statistical analysis, as appropriate. A p-value <0.05 was considered statistically significant.

RESULTS

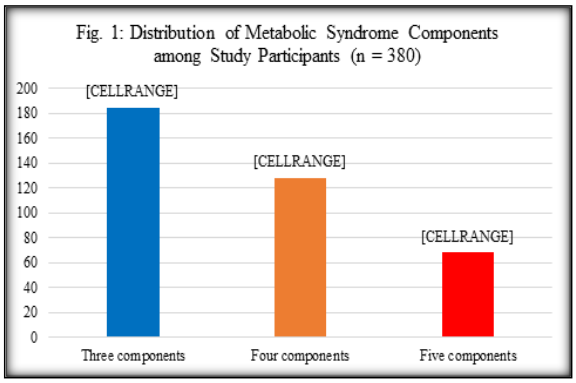

Figure 1: Distribution of Metabolic Syndrome Components among Study Participants (n = 380)

[Figure 1] presents the distribution of metabolic syndrome components in the study population. Nearly half of the participants (48.4%) had three components, while the remaining had four or five components.

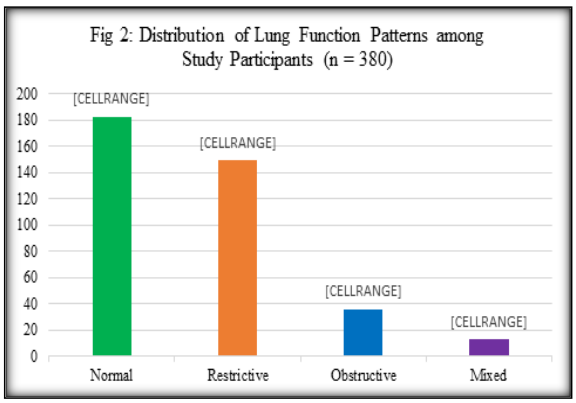

Figure 2: Distribution of Lung Function Patterns among Study Participants (n = 380)

[Figure 2] illustrates the distribution of pulmonary function patterns among the study participants. The frequencies and percentages of normal, restrictive, obstructive, and mixed ventilatory patterns are presented.

Table 1: Demographic and anthropometric characteristics of study participants

Parameters/components	Mean ± SD
Age (year)	51.60 ± 9.02
Height (m)	1.61 ± 0.087
Weight (kg)	75.51 ± 10.85
Body Mass Index (kg/m²)	29.22 ± 4.11
Waist Circumference (cm)	97.92 ± 9.60

Hip Circumference (cm)	97.56 ± 8.49
Waist Hip Ratio	1.01 ± 0.09

[Table 1] summarizes the demographic and anthropometric profile of the study participants. The participants were predominantly middle-aged adults with increased body mass index and waist circumference.

Table 2: Metabolic syndrome components data of study participants

Parameters/components	Mean ± SD
Waist Circumference (cm)	97.92 ± 9.60
Systolic Blood Pressure (mmHg)	140.34 ± 15.36
Diastolic Blood Pressure (mmHg)	89.82 ± 9.51
Fasting Blood Glucose (mg/dL)	131.17 ± 31.47
Triglycerides (mg/dL)	176.60 ± 50.52
HDL-C (mg/dL)	45.76 ± 6.58

[Table 2] presents the metabolic syndrome components of the study participants, demonstrating the overall metabolic profile of the study population.

Table 3: Pulmonary Function Parameters of Study Participants

Pulmonary Function Parameters	Mean ± SD
% Predicted FVC	79.33 ± 13.16
% Predicted FEV□	81.74 ± 15.36
% Predicted FEV□/FVC Ratio	100.39 ± 17.85
% Predicted PEFR	61.57 ± 17.80
% Predicted FEF 25–75%	75.09 ± 22.14

[Table 3] summarizes the pulmonary function parameters expressed as percentages of predicted values. Mean % predicted FVC and FEV_1 were reduced, while the FEV_1 /FVC ratio remained largely preserved.

Table 4: Correlation between Metabolic Syndrome Components and Pulmonary Function Parameters

	FVC		FEV□		FEV□/FVC		PEFR		FEF 25–75%	
	(r)	p value	(r)	p value	(r)	p value	(r)	p value	(r)	p value
WC (cm)	-0.218	<0.001	-0.11	0.039	0.091	0.075	-0.071	0.168	-0.098	0.056
FBG (mg/dL)	-0.047	0.364	-0.02	0.717	0.022	0.667	-0.003	0.95	0.014	0.788
TGs (mg/dL)	-0.093	0.071	-0.05	0.295	0.041	0.425	-0.047	0.36	-0.054	0.295
HDL-C (mg/dL)	0.115	0.024	0.14	0.006	0.006	0.909	0.129	0.01	0.114	0.026
SBP (mmHg)	-0.159	0.002	-0.09	0.091	0.008	0.879	-0.138	0.007	-0.088	0.086
DBP (mmHg)	-0.129	0.012	-0.08	0.101	-0.012	0.822	-0.11	0.032	-0.08	0.119

WC: Waist circumference; FBG: Fasting blood glucose; TG: Triglycerides; HDL-C: High-density lipoprotein cholesterol; SBP: Systolic blood pressure; DBP: Diastolic blood pressure; FVC: Forced vital capacity; FEV_1 : Forced expiratory volume in one second; PEFR: Peak expiratory flow rate; FEF25–75%: Forced expiratory flow between 25% and 75% of FVC. *Spearman's correlation; $p<0.05$ was considered statistically significant.

[Table 4] shows the correlations between individual metabolic syndrome components and pulmonary function parameters. Waist circumference was significantly and inversely correlated with FVC and FEV_1 , while systolic and diastolic blood pressure showed significant inverse correlations with FVC and PEFR. HDL-C demonstrated significant positive correlations with FVC, FEV_1 , PEFR, and FEF25–75%.

Table 5: Comparison of Pulmonary function parameters according to number of Metabolic Syndrome components

Parameters	Three Components (Mean ± SD)	Four Components (Mean ± SD)	Five Components (Mean ± SD)	P Value
% Predicted FVC	80.07 ± 12.64	79.59 ± 12.88	76.85 ± 14.86	0.133
% Predicted FEV□	83.21 ± 14.88	80.77 ± 16.56	79.60 ± 14.03	0.101
% Predicted FEV□/FVC Ratio	100.95 ± 17.64	100.25 ± 18.19	99.13 ± 17.99	0.696
% Predicted PEFR	63.68 ± 17.32	60.59 ± 18.92	57.72 ± 16.29	0.036
% Predicted FEF 25–75%	77.99 ± 20.33	73.23 ± 25.25	70.74 ± 19.67	0.031

***Kruskal–Wallis test, p < 0.05 (statistically significant)**

[Table 5] compares pulmonary function parameters according to the number of metabolic syndrome components. A progressive decline in all pulmonary function parameters was observed with increasing metabolic syndrome severity. However, statistically significant differences were observed only for PEFR and FEF25–75%, while FVC, FEV_1 , and

FEV_1 /FVC ratio did not differ significantly across the groups.

DISCUSSION

The present study evaluated pulmonary function abnormalities in adults with metabolic syndrome (MetS) and their association with metabolic syndrome severity. The findings demonstrated reduced pulmonary function, characterized by lower mean predicted FVC and FEV_1 values with a relatively preserved FEV_1 /FVC ratio. Nearly two-fifths (39.2%) of the participants exhibited a spirometric restrictive pattern, making it the most frequent pulmonary abnormality observed in the study. In addition, waist circumference showed the strongest inverse correlation with pulmonary function, and pulmonary flow parameters (PEFR and FEF25–75%) progressively declined with increasing metabolic syndrome severity.

The reduction in FVC and FEV_1 observed in the present study is consistent with previous evidence linking metabolic syndrome with impaired respiratory function. Bae et al. (2012) reported lower pulmonary function among Korean adults with MetS,[8] while Chen et al. (2014) demonstrated progressive reductions in FVC and FEV_1 with increasing number of metabolic syndrome components.[7] Molina-Luque et al. (2023) similarly reported an association between greater clustering of metabolic risk factors and poorer lung function. Although the reductions in spirometric indices in the present study were modest, these findings support an adverse relationship between increasing metabolic burden and pulmonary function.[9]

An important observation in the present study was the predominance of a spirometric restrictive pattern, characterized by reduced FVC with preservation of the FEV_1 /FVC ratio. This agrees with Nakajima et al. (2008), who reported an association between a suspected restrictive pattern and MetS, with the association becoming stronger with increasing metabolic abnormalities.[4] Baffi et al. (2016) also reviewed accumulating evidence linking MetS with impaired pulmonary function and restrictive respiratory abnormalities. The underlying mechanisms are likely multifactorial.[5] Central obesity alters respiratory mechanics and reduces lung volumes, while systemic inflammation and metabolic disturbances may further contribute to pulmonary dysfunction.[5,14] Together, these mechanisms provide a plausible explanation for the spirometric restrictive pattern observed in the present study.

Among the individual MetS components, waist circumference showed the strongest inverse correlation with FVC and FEV_1 . This is consistent with Leone et al. (2009), who identified abdominal obesity as the strongest predictor of lung-function impairment, with odds ratios of 1.94 for impaired FEV_1 and 2.11 for impaired FVC.[3] Chen et al. (2014) similarly demonstrated a prominent association between central obesity and reduced pulmonary function.[7] A meta-analysis by Forno et al. (2018) also found obesity in adults to be associated with lower lung volumes and a predominantly restrictive functional deficit.[15] Collectively, these findings support central adiposity as a major contributor to pulmonary impairment in MetS.

The present study also demonstrated modest inverse correlations of systolic and diastolic blood pressure with FVC and PEFR. Previous population-based studies conducted by Chen et al. (2014) and Molina-Luque et al. (2023) have reported the associations between metabolic risk factors, including elevated blood pressure, and reduced pulmonary function. Vascular dysfunction and systemic inflammation accompanying MetS may contribute to this relationship.[7,9]

HDL-C showed significant positive correlations with FVC, FEV_1 , PEFR, and FEF25–75% in the present study. This finding is consistent with recent cross-sectional evidence from US and Korean populations demonstrating positive associations between HDL-C and lung function (Lee et al. 2023). The anti-inflammatory, antioxidant, and endothelial effects of HDL may partly explain this association, although the biological relationship between HDL-C and pulmonary function remains incompletely understood.[16]

Unlike waist circumference and blood pressure, fasting glucose and triglyceride levels were not significantly correlated with pulmonary function in the present study. This finding suggests that central adiposity may have a stronger relationship with pulmonary function than isolated biochemical components, consistent with the prominent role of abdominal obesity reported by Leone et al. (2009) and Bae et al. (2012).[3,8] Other studies, however, have reported associations between metabolic biochemical abnormalities and reduced lung function.[7,9] Differences in population characteristics, metabolic control, and study design may account for these discrepancies.

Pulmonary function also showed a graded decline with increasing MetS severity. FVC and FEV_1 decreased progressively from participants with three to five components, although these differences were not statistically significant. In contrast, PEFR and FEF25–75% declined significantly, suggesting that expiratory flow parameters may be more sensitive to differences in metabolic burden in the present population. Chen et al. (2014) similarly reported progressive reductions in FVC and FEV_1 with increasing number of MetS components,[7] while Nakajima et al. (2008) observed a severity-dependent association between MetS and a suspected restrictive pattern.[4] The lack of statistical significance for FVC and FEV_1 may reflect the modest between-group differences, unequal group sizes, and heterogeneity within each severity category, as component count does not account for

differences in the combination, duration, severity, or control of individual metabolic abnormalities.

Overall, the findings of the present study indicate that pulmonary dysfunction represents an important but often under-recognized systemic manifestation of metabolic syndrome. The predominance of a spirometric restrictive pattern, together with the significant associations of abdominal obesity, blood pressure, and HDL-C with pulmonary function and the decline in expiratory flow parameters with increasing metabolic syndrome severity, supports the concept that respiratory involvement accompanies increasing metabolic burden.

CONCLUSION

Metabolic syndrome was associated with impaired pulmonary function, predominantly characterized by a spirometric restrictive pattern. Central obesity emerged as the metabolic component most strongly associated with reduced lung function, while blood pressure and HDL-C also showed significant associations with selected pulmonary function parameters. Although FVC and FEV_1 showed a progressive decline with increasing number of metabolic syndrome components, the differences were not statistically significant; however, PEFR and FEF25–75% decreased significantly with increasing metabolic burden. These findings suggest that pulmonary function may be adversely affected in metabolic syndrome and that greater clustering of metabolic abnormalities is associated with deterioration in selected expiratory flow parameters.

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