

Bronchodilator Responsiveness in Different Ventilatory Patterns

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ABSTRACT

Background: Bronchodilator response varies across ventilatory impairments, influencing diagnosis and treatment decisions. While obstructive lung diseases like asthma and COPD often show reversibility, the response in restrictive and mixed impairments remains unclear. In resource-limited settings, spirometry with bronchodilator testing is a valuable tool for distinguishing these conditions. The objective of the study was to evaluate bronchodilator response in obstructive, restrictive, and mixed ventilatory impairments and its clinical implications.

Methods: This study analyzed spirometric parameters ($FEV_1\%$ and $PEF\%$) before and after bronchodilator administration in individuals with different ventilatory patterns. Reversibility was assessed by comparing pre- and post-bronchodilator values, identifying significant changes within each impairment group.

Results: The obstructive group exhibited significant improvements in $FEV_1\%$ and $PEF\%$, confirming bronchodilator reversibility in asthma and mild COPD. In contrast, restrictive and mixed impairments showed minimal or negative responses, suggesting limited therapeutic benefit. The restrictive group's decline in $PEF\%$ and $FEV_1\%$ likely reflects parenchymal or chest wall limitations rather than reversible airway obstruction. The mixed pattern demonstrated the least response, highlighting its complex interplay between obstruction and restriction. Normal and obstructive groups had the highest reversibility, while restrictive cases showed the lowest.

Conclusion: Spirometry with bronchodilator testing is an effective, low-cost diagnostic tool for distinguishing ventilatory impairments, particularly in resource-limited settings. The findings reinforce the limited role of bronchodilators in restrictive lung diseases and emphasize the need for alternative treatment strategies. Future research should explore long-term bronchodilator responsiveness in restrictive and mixed impairments, incorporating biomarkers such as eosinophil counts or FeNO to improve personalized treatment approaches.

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INTRODUCTION

Bronchodilator responsiveness is a fundamental parameter in evaluating lung function, particularly in patients with airflow limitation. Spirometry

serves as the gold standard for categorizing pulmonary diseases into obstructive, restrictive, mixed, and normal ventilatory patterns, with FEV_1/FVC and FVC being the primary diagnostic

criteria (Liu et al., 2023; Poncet et al., 2023). Obstructive lung diseases, including chronic obstructive pulmonary disease (COPD) and asthma, are characterized by airflow limitation, whereas restrictive lung diseases result in reduced lung volumes due to parenchymal or extrapulmonary causes without significant airway narrowing (Cukic et al., 2012; Barnes et al., 2024), while mixed patterns exhibit features of both obstruction and restriction (Odler et al., 2016). Understanding the variability in bronchodilator response among these categories has important clinical and therapeutic implications.

Bronchodilator responsiveness is commonly used to distinguish asthma, which typically demonstrates significant reversibility, from COPD, where airflow obstruction is more persistent (Obi & Baughman, 2020). However, studies indicate that a subset of COPD patients exhibit partial reversibility, challenging the notion of fixed obstruction and suggesting potential benefits from bronchodilator therapy (Kim et al., 2017; Barjaktarevic et al., 2018). The role of bronchodilator responsiveness in restrictive and mixed ventilatory patterns remains less well defined, though emerging evidence suggests that some restrictive and mixed cases may show modest reversibility (Keddissi et al., 2013), warranting further investigation into its clinical relevance.

Asthma and COPD constitute major public health concerns globally, with significant burdens in Sub-Saharan Africa, including Nigeria. According to the Global Initiative for Asthma (GINA), asthma affects over 300 million people worldwide (Boulet et al., 2019), with prevalence rates in Africa ranging between 10% and 30% depending on the population studied (Adeloye et al., 2013; Faniyi et al., 2024). In Nigeria, studies estimate asthma prevalence at about 6%-10%, with higher rates observed in urban areas due to increasing exposure to air pollution and allergens (Ozoh et al., 2019; Desalu et al., 2021). COPD, on the other hand, is a leading cause of morbidity and mortality worldwide, affecting an estimated 384 million people and causing over 3.5 million deaths yearly (WHO, 2025). In Sub-Saharan Africa, the burden of COPD is rising due to risk factors such as biomass fuel exposure, occupational dust, and tobacco smoking (Soriano et al., 2020; Awokola et al., 2022), emphasizing the need for improved diagnosis and management strategies. Limited access to advanced pulmonary function testing, underdiagnosis, and inadequate healthcare infrastructure further complicate the management

of these chronic respiratory conditions (Erhabor, 2021; Al-Moamary et al., 2021).

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In Nigeria, a nationwide study placed the prevalence of asthma in adults as between 9.1% - 12.0%, depending on the age group, while COPD ranges between 7.6% and 24.2%, being commoner among older adults (Ozoh et al., 2019; Ojuawo et al., 2022; Ale et al., 2022).

This study aims to categorize patients into obstructive, restrictive, mixed, and normal groups based on pre-bronchodilator spirometry and assess bronchodilator responsiveness within each category. By comparing changes in FEV₁, FVC, and PEF following bronchodilator administration, the study seeks to determine whether restrictive and mixed patterns exhibit clinically significant reversibility, which could refine disease classification and influence treatment decisions.

The findings could provide valuable insights into airway physiology across different lung function patterns and contribute to evidence-based, regionally applicable therapeutic strategies.

Improving our understanding of bronchodilator responsiveness beyond conventional obstructive lung diseases may lead to more precise phenotyping of respiratory disorders, ultimately optimizing patient management. In resource-limited settings such as Nigeria and broader Sub-Saharan Africa, a more individualized approach to bronchodilator therapy could improve symptom control, reduce hospitalizations, and enhance the overall quality of life for patients with chronic respiratory diseases.

MATERIALS AND METHODS

This study was conducted at the University of Benin Teaching Hospital (UBTH), a tertiary healthcare center that serves as a referral hospital for patients from both urban and rural communities. UBTH is a major center for respiratory medicine, providing specialized diagnostic and therapeutic services, including spirometry, which remains an essential tool for evaluating pulmonary function in patients with suspected or established respiratory diseases. The hospital caters to a diverse population, including patients referred from peripheral hospitals, primary healthcare centers, and other units within the tertiary facility.

A cross-sectional study design was employed, involving 90 patients who underwent spirometry at

UBTH over the study period. A structured approach was used to collect data on sociodemographic characteristics (age, sex), clinical indications for spirometry, referral sources, and ventilatory function outcomes. Spirometry assessment was performed in accordance with standard guidelines, with pre- and post-bronchodilator tests conducted where necessary.

Patients were categorized into obstructive, restrictive, mixed, and normal groups based on pre-bronchodilator spirometry results. Ventilatory function was classified using forced expiratory volume in one second (FEV₁) and forced vital capacity (FVC) ratios based on the joint

classification of the European Respiratory Society and the American Thoracic Society: Normal function was defined as FEV₁/FVC equal to or above 70%, with FEV₁ and FVC each equal to or above 80% of the predicted value. Obstructive impairment was defined as FEV₁/FVC below 70%, while restrictive impairment was classified as FEV₁/FVC equal to or above 70% with FEV₁ and FVC below 80% of predicted values. Mixed ventilatory impairment was defined as FEV₁/FVC below 70% and FVC below 80% of predicted values (Stanojevic et al., 2022). Figure 1 shows the flowchart for the selection of patients for the study, and the diagnostic criteria used.

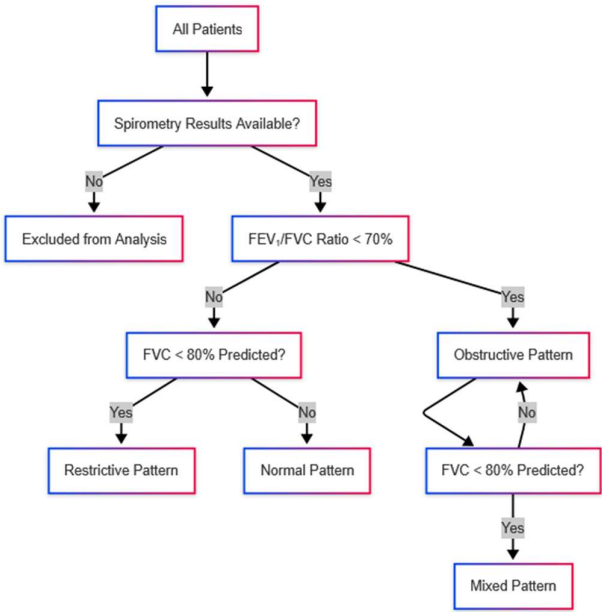


Figure 1: Flowchart for selection of patients

Data collection involved pre- and post-bronchodilator spirometry using standardized protocols. Baseline measurements of FEV₁, FVC, and peak expiratory flow (PEF) were recorded, followed by administration of a short-acting bronchodilator. Repeat spirometry was performed after 15 minutes, and changes in lung function parameters were analyzed.

Data analysis was conducted using SPSS version 26. Descriptive statistics, including means, standard deviations, and frequency distributions, were used to summarize demographic and clinical characteristics. Paired t-tests were used to assess significant changes in FEV₁, FVC, and PEF post-bronchodilator within each ventilatory pattern. ANOVA was applied to compare responsiveness across groups, with statistical significance set at p

< 0.05. The findings were presented using tables and graphical illustrations to highlight patterns of bronchodilator responsiveness across different ventilatory groups. Ethical clearance was sought and obtained from the Ethical Department of the University of Benin Teaching Hospital.

RESULTS

Baseline characteristic of study population (Table 1)

The mean age of participants varied significantly across ventilatory patterns, with the normal group having the youngest mean age of 20.7 ± 1.9 years, while the mixed pattern group had the highest mean age of 55.9 ± 23.9 years. The overall mean age across all groups was 43.84 ± 23.4 years, with a

statistically significant difference observed ($p = 0.041$)

Weight did not differ significantly between groups, with values ranging from 54.50 ± 17.3 kg in the normal group to 71.52 ± 16.9 kg in the mixed group ($p = 0.209$). Similarly, height was comparable across groups, with the lowest mean height recorded in the normal group at 147.00 ± 11.2 cm and the highest in the mixed pattern group at 157.13 ± 8.3 cm ($p = 0.157$).

BMI followed a similar trend, with the restrictive group having the highest mean BMI of 31.08 ± 9.9

kg/m², while the normal group had the lowest at 24.68 ± 5.3 kg/m², though this difference was not statistically significant ($p = 0.144$).

The distribution of sex across the groups showed that 44 participants were male, with the highest proportion found in the obstructive group (18), while 46 participants were female, with the highest number also in the obstructive group (19). There was no statistically significant difference in sex distribution across ventilatory patterns ($p = 0.798$).

Table 1: Baseline characteristic of study population

Variable	Normal(n=8) Mean \pm S.D	Obstructive(n=37) Mean \pm S.D	Restrictive(n=22) Mean \pm S.D	Mixed(n=23) Mean \pm S.D	Total(N=90) Mean \pm S.D	p-value
Age (years) (\pm S.D)	20.7 \pm 1.9	44.24 \pm 22.8	38.95 \pm 20.5	55.9 \pm 23.9	43.84 \pm 23.4	0.041*
Weight (kg) (\pm S.D)	54.50 \pm 17.3	67.54 \pm 11.7	71.36 \pm 15.1	71.52 \pm 16.9	68.33 \pm 15.0	0.209
Height (cm) (\pm S.D)	147.00 \pm 11.2	155.11 \pm 7.6	153.86 \pm 14.8	157.13 \pm 8.3	154.60 \pm 10.4	0.157
BMI(kg/m ²) (\pm S.D)	24.68 \pm 5.3	28.17 \pm 5.1	31.08 \pm 9.9	29.05 \pm 7.0	29.79 \pm 7.1	0.144
Male (%)	3 (6.8)	18 (40.9)	10 (22.7)	13 (29.5)	44 (100.0)	0.798
Female (%)	5 (10.9)	19 (41.3)	12 (26.1)	10 (21.7)	46 (100.0)	

* $p < 0.05$ is statistically significant

Reversibility of $>12\%$ or 200mls was used in combination with clinical findings to confirm asthma diagnosis

Mean Differences in Spirometric Parameters Across Ventilatory Patterns (Table 2 and Figure 3)

The change in spirometric indices following bronchodilator administration varied across ventilatory patterns. In the normal group, the mean change in PEF% predicted was -6.43 ± 13.9 , with no statistically significant difference observed ($p = 0.266$).

However, both FVC% predicted and FEV% predicted showed significant increases, with mean changes of 8.79 ± 7.4 ($p = 0.020$) and 5.29 ± 2.2 ($p < 0.001$), respectively.

Among participants with an obstructive ventilatory pattern, there was a significant increase in PEF% predicted (5.31 ± 14.6 , $p = 0.020$) and FEV% predicted (7.06 ± 9.8 , $p < 0.001$), whereas the change in FVC% predicted (3.09 ± 12.1) was not statistically significant ($p = 0.097$).

The restrictive group showed a significant decrease in PEF% predicted (-8.14 ± 10.2 , $p = 0.006$) and FEV% predicted (-8.74 ± 9.3 , $p = 0.002$), while the reduction in FVC% predicted (-4.25 ± 12.4) was not statistically significant ($p = 0.192$).

In the mixed ventilatory pattern group, there were no statistically significant changes observed, with PEF% predicted decreasing by -2.59 ± 14.7 ($p = 0.430$), FVC% predicted by -2.76 ± 16.9 ($p = 0.464$), and FEV% predicted by -2.39 ± 16.8 ($p = 0.523$).

The mean plots illustrated changes in **FEV₁% Predicted**, **FVC% Predicted**, and **PEF% Predicted** after bronchodilator therapy across spirometric patterns.

- **FEV₁% Predicted** showed the greatest improvement in the obstructive group, reflecting bronchodilator responsiveness typical of asthma, while the restrictive group exhibits a marked decline (Figure 4).
- **FVC% Predicted** followed a similar trend, with the normal group showing the highest positive change, while restrictive and mixed patterns remain negative (Figure 5).
- **PEF% Predicted** improved in the normal and obstructive groups, while the restrictive and mixed patterns showed limited or negative change, suggesting reduced peak flow response (Figure 6).

Changes in Spirometric Parameters Following Bronchodilator Administration Across Ventilatory Patterns (Table 3)

In the normal group, FEV₁% predicted increased by 5.29 ± 2.2 , FVC% predicted by 8.79 ± 7.4 , while PEF% predicted decreased by -6.43 ± 13.87 . The obstructive group showed increases in FEV₁% (7.06 ± 9.8), FVC% (3.09 ± 12.1), and PEF% (5.3 ± 14.6). In contrast, the restrictive and mixed groups exhibited declines across all indices. Differences were statistically significant for FEV₁% ($p < 0.001$), FVC% ($p = 0.049$), and PEF% ($p = 0.004$).

Post hoc analysis revealed:

- **FEV₁% predicted:** The restrictive group showed significantly lower changes than the normal ($p = 0.009$) and obstructive groups ($p < 0.001$).
- **FVC% predicted:** The restrictive and mixed groups had significantly lower changes than the normal group ($p = 0.032$, $p = 0.048$).
- **PEF% predicted:** The obstructive group had greater improvement than the normal ($p = 0.041$), restrictive ($p = 0.001$), and mixed groups ($p = 0.035$).

Table 2: Mean Differences in Spirometric Parameters Across Ventilatory Patterns

Ventilatory Function	Spirometry test	Mean difference (\pm S.D)	t-test	p-value
Normal	PEF% Predicted	-6.43 ± 13.9	-1.226	0.266
	FVC% Predicted	8.79 ± 7.4	3.124	0.020
	FEV% Predicted	5.29 ± 2.2	6.404	<0.001
Obstructive	PEF% Predicted	5.31 ± 14.6	2.413	0.020
	FVC% Predicted	3.09 ± 12.1	1.695	0.097
	FEV% Predicted	7.06 ± 9.8	4.771	<0.001
Restrictive	PEF% Predicted	-8.14 ± 10.2	-3.184	0.006
	FVC% Predicted	-4.25 ± 12.4	-1.366	0.192
	FEV% Predicted	-8.74 ± 9.3	-3.777	0.002
Mixed	PEF% Predicted	-2.59 ± 14.7	-0.806	0.430
	FVC% Predicted	-2.76 ± 16.9	-0.747	0.464
	FEV% Predicted	-2.39 ± 16.8	-0.650	0.523

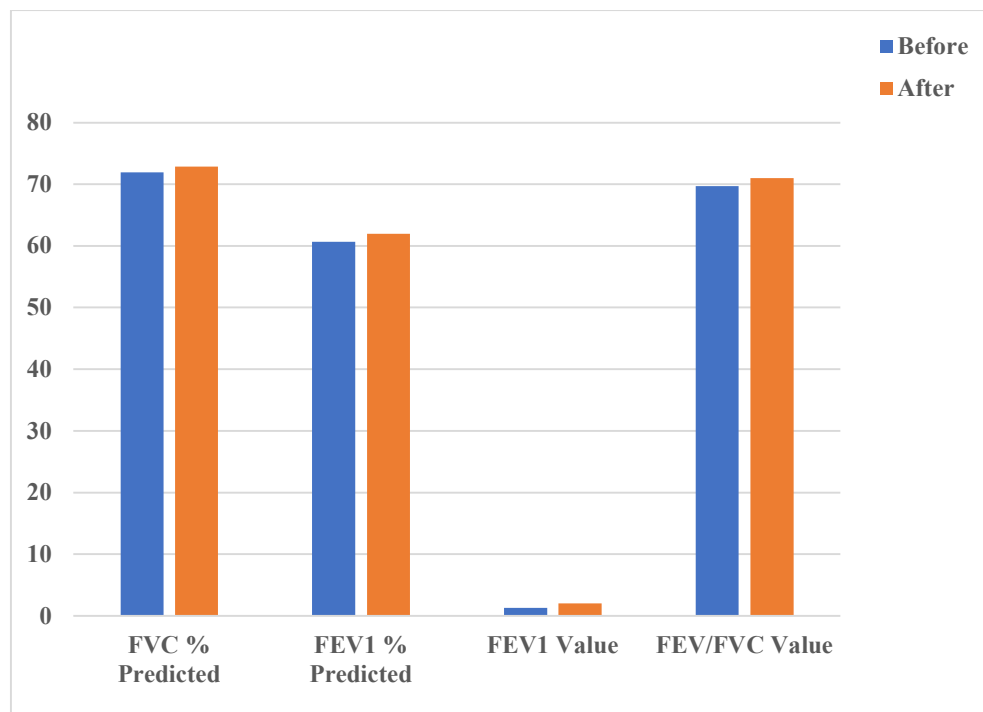


Figure 2: Overall changes in spirometry parameters

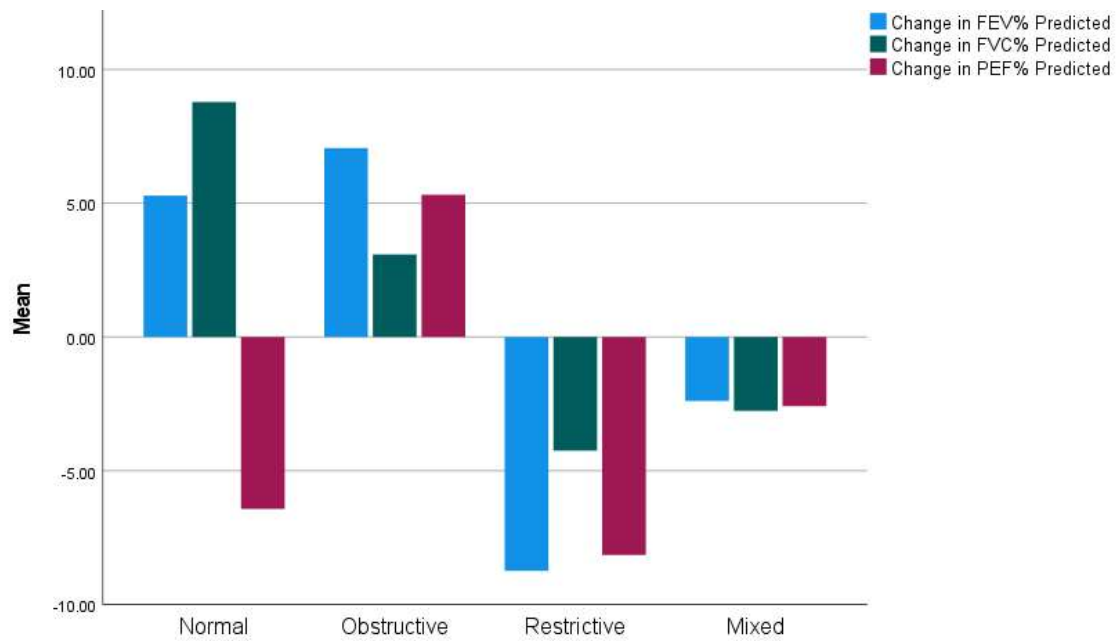


Figure 3: Mean changes of spirometric values in relation to ventilatory function after bronchodilator therapy

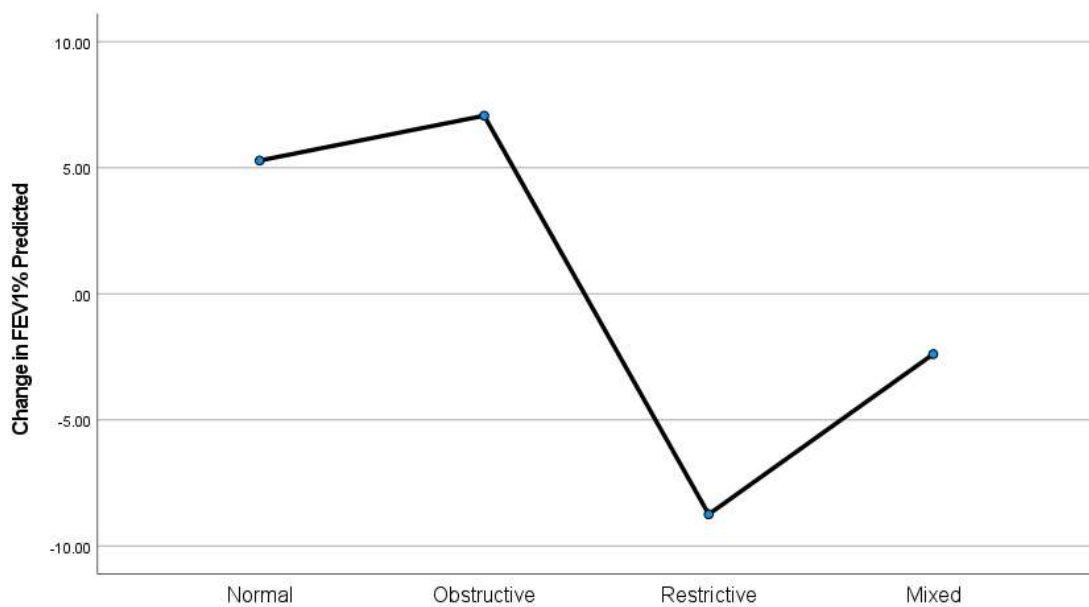


Figure 4: Means plot of change in FEV1% Predicted across ventilatory patterns

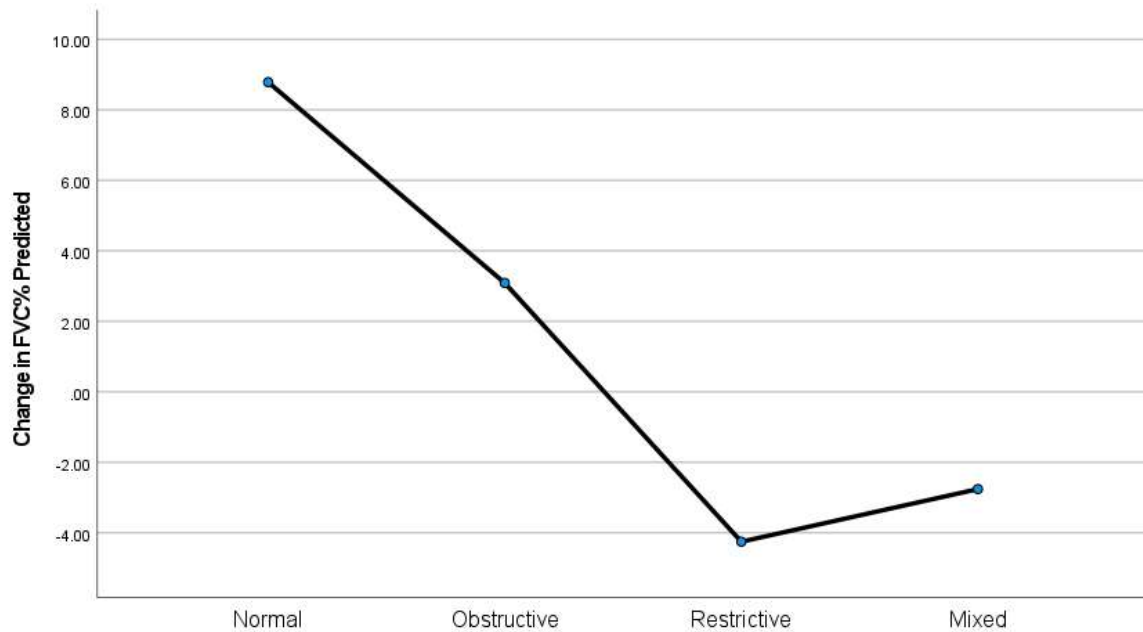


Figure 5: Means plot of FVC% Predicted across ventilatory patterns

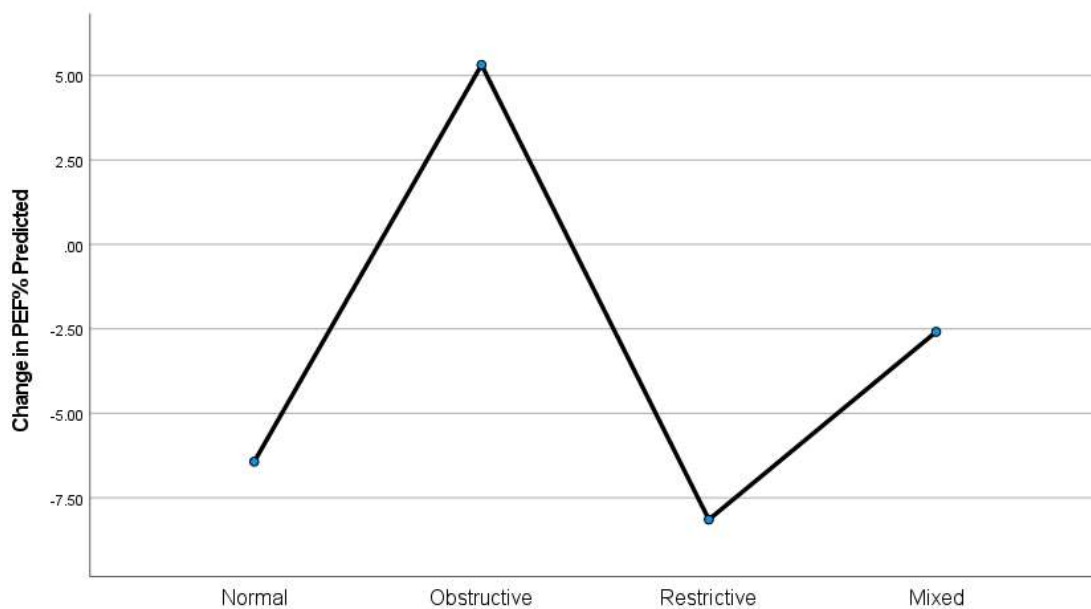


Figure 6: Means plot of Change in PEF% Predicted across ventilatory patterns

Comparability of reversibility criteria among ventilatory groups (Table 4)

A significant association was observed between ventilatory function and bronchodilator reversibility ($\chi^2 = 8.899$, $p = 0.026$). Reversibility was most common in individuals with a normal

ventilatory pattern (71.4%), while the restrictive group had the lowest reversibility rate (12.5%). In the obstructive pattern, 43.5% were reversible, whereas in the mixed pattern, 28.6% showed reversibility.

Table 3: Changes in Spirometric Parameters Following Bronchodilator Administration Across Ventilatory Patterns

Ventilatory Pattern	$\Delta FEV_1\%$ Predicted (Mean \pm SD)	$\Delta FVC\%$ Predicted (Mean \pm SD)	$\Delta PEF\%$ Predicted (Mean \pm SD)
Normal	5.29 \pm 2.2	8.79 \pm 7.4	-6.43 \pm 13.87
Obstructive	7.06 \pm 9.8	3.09 \pm 12.1	5.3 \pm 14.6
Restrictive	-8.74 \pm 9.3	-4.25 \pm 12.4	-8.14 \pm 10.2
Mixed	-2.39 \pm 16.4	-2.75 \pm 16.9	-2.59 \pm 14.7
p-value	<0.001	0.049	0.004

Table 4: Comparability of reversibility criteria among ventilatory groups

Variables	Reversibility		χ^2	p-value
	Reversible (n = 33) n (%)	Non reversible (n = 57) n (%)		
Ventilatory Function				
Normal	5 (71.4)	2 (28.6)	8.899	0.026
Obstructive	20 (43.5)	26 (56.5)		
Restrictive	2 (12.5)	14 (87.5)		
Mixed	6 (28.6)	15 (71.4)		

DISCUSSION

The findings of this study reveal significant variability in bronchodilator responsiveness across different ventilatory patterns, offering important insights into the pathophysiology and management of respiratory diseases. In the obstructive group, a significant increase in $FEV_1\%$ predicted and $PEF\%$ predicted was observed following bronchodilator administration, consistent with the characteristic reversibility of airway obstruction seen in conditions such as asthma and chronic obstructive pulmonary disease (COPD). Similar findings were seen in Müller et al. (2016), which showed that asthma typically demonstrates greater reversibility than COPD, though a subset of COPD patients also exhibits partial reversibility. Lee et al. (2024) further supported this, noting that COPD patients with eosinophilic inflammation may show some degree of bronchodilator response. This study however, contrasted with findings done by Ojo (2022), which showed poor reversibility of FEV_1 among asthmatics. This finding was attributed to poor levels of asthma control among respondents, which may negatively affect reversibility due to chronic lung damage. The improvement in FEV_1 and PEF in our study likely reflects the relaxation of bronchial smooth muscles and reduction in airway inflammation induced by bronchodilators, as suggested by Wedzicha et al. (2012). However, the lack of significant change in $FVC\%$ predicted may indicate persistent air trapping or hyperinflation, which are common in obstructive diseases (Thomas et al., 2013; Kim et al., 2022). These findings emphasize the critical role of

bronchodilator therapy in managing obstructive lung diseases, as improvements in FEV_1 and PEF can lead to better symptom control, reduced exacerbations, and enhanced quality of life. Regular spirometry assessments are recommended to monitor treatment efficacy and guide therapeutic adjustments.

In contrast, the restrictive group exhibited a significant decline in $PEF\%$ predicted and $FEV_1\%$ predicted post-bronchodilator, with no significant change in $FVC\%$ predicted. This unexpected finding suggests that bronchodilators may not be beneficial in restrictive lung diseases, which are primarily characterized by reduced lung volumes due to parenchymal or extrapulmonary causes rather than airway obstruction. Assayag et al. (2015) similarly found that bronchodilator response in restrictive lung diseases is often absent or even paradoxical. A study conducted by Ike-Samuel et al. (2025) showed similar abnormalities in spirometric indices among workers with restrictive lung diseases, with majority of them having abnormal FEV_1 , $FVC\%$ predicted as well as reduction in FVC in comparison to reference ranges. The decline in spirometric parameters could be attributed to the lack of reversible airway narrowing in restrictive conditions, as bronchodilators primarily target smooth muscle relaxation in the airways. Another possible explanation is exhaustion from repeated forced expiratory maneuvers, particularly in individuals with neuromuscular weakness or poor effort, as observed by Patel et al. (2017) and Graham et al. (2019). These findings challenge the assumption that bronchodilators may have a role in restrictive

lung diseases and highlight the need for alternative therapeutic strategies focused on addressing the underlying causes of restriction, such as pulmonary fibrosis or chest wall abnormalities. Clinicians should exercise caution when prescribing bronchodilators to patients with restrictive patterns and consider further diagnostic evaluations to identify the specific aetiology of restriction.

The mixed ventilatory pattern group showed no statistically significant changes in spirometric parameters post-bronchodilator, which may reflect the complex interplay of both obstructive and restrictive mechanisms in these patients. Lee et al. (2010) reported similar findings, suggesting that in cases where the restrictive component is dominant, bronchodilators may have limited efficacy. This highlights the need for a more detailed approach to managing mixed ventilatory disorders, potentially combining bronchodilators with other therapies targeting the restrictive component.

The normal ventilatory pattern group demonstrated a significant increase in FEV₁% predicted and FVC% predicted post-bronchodilator. Hegewald et al. (2012) reported a similar phenomenon, suggesting that bronchodilator responsiveness in normal spirometry may indicate subclinical airway hyperresponsiveness. Chen et al. (2021) also found that some individuals with normal spirometry can still experience airflow limitation that responds to bronchodilators, particularly in cases of subclinical asthma. This suggests that bronchodilator responsiveness may serve as an early marker of respiratory dysfunction, even in individuals with normal baseline spirometry. Clinicians should consider bronchodilator testing in patients with respiratory symptoms but normal spirometry to identify subtle abnormalities that may warrant closer monitoring or intervention.

This variability stresses the importance of tailoring bronchodilator therapy based on the ventilatory pattern. In resource-limited settings, such as Nigeria and broader Sub-Saharan Africa, where access to advanced diagnostic tools is often limited, these findings can inform more individualized and cost-effective approaches to managing chronic respiratory diseases.

CONCLUSION

This study highlights distinct bronchodilator response patterns across ventilatory impairments, reinforcing spirometry's diagnostic value. Obstructive cases showed significant FEV₁% and PEF% improvement, confirming reversibility in

asthma and mild COPD. Restrictive and mixed patterns showed minimal response, suggesting limited therapeutic benefit.

A strong association between ventilatory function and bronchodilator reversibility reaffirms bronchodilators' role in lung diseases. In resource-limited settings, spirometry remains a cost-effective tool for distinguishing impairments. Future research should explore long-term bronchodilator effects and biomarkers for personalized treatment.

LIMITATIONS

This study has several limitations that should be considered when interpreting the findings. First, the sample size may not be large enough to fully capture variability in bronchodilator responsiveness across different ventilatory patterns. A larger, more diverse cohort would improve the generalizability of the results.

Second, spirometry is effort-dependent, and variability in patient effort could have influenced the findings, particularly in the restrictive group, where a decline in values post-bronchodilator may have been due to exhaustion from repeated maneuvers or neuromuscular limitations rather than an actual physiological response.

Third, the study did not assess inflammatory biomarkers or other physiological parameters that could provide deeper insight into the mechanisms underlying bronchodilator responsiveness. Including tests such as fractional exhaled nitric oxide (FeNO) or blood eosinophil counts could have helped differentiate subgroups with varying levels of airway inflammation.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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