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Original Article

Effects of Breathing Exercises with and Without Inspiratory Muscle Training on Dyspnea, Lung Volumes and Lung Capacities in COPD Patients

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ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) is a leading cause of morbidity and mortality worldwide, characterized by progressive airflow limitation and persistent dyspnea. Non-pharmacological interventions such as breathing exercises and inspiratory muscle training (IMT) have emerged as adjunct therapies to improve respiratory function and reduce symptom burden in COPD patients, particularly in resource-limited settings. Objective: To evaluate the comparative effects of structured breathing exercises with and without IMT on dyspnea, lung volumes, and lung capacities in patients with moderate to severe COPD. Methods: A randomized clinical trial was conducted at two tertiary hospitals in Lahore, Pakistan, involving 46 patients with GOLD stage II–III COPD. Participants were randomly allocated into two groups: Group A received diaphragmatic and pursed-lip breathing exercises, while Group B received the same regimen combined with IMT using the BREATHER device. Interventions were administered over 8 weeks. Primary outcomes included Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV_1), and Modified Borg Dyspnea Scale. Data were analyzed using SPSS v25 with significance set at $p<0.05$. Results: Both groups demonstrated significant improvements, but Group B showed greater gains in FVC (mean difference = 0.43 L, p=0.024), FEV_1 (mean difference = 0.53 L, p=0.006), and dyspnea scores (p=0.002). Conclusion: Combining breathing exercises with IMT yields superior improvements in lung function and dyspnea compared to breathing exercises alone, supporting its inclusion in comprehensive COPD rehabilitation.

Keywords: Chronic Obstructive Pulmonary Disease, Breathing Exercises, Inspiratory Muscle Training, Lung Function, Dyspnea, Rehabilitation

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive and debilitating respiratory condition characterized by persistent airflow limitation, reduced pulmonary function, and significant breathlessness that impairs daily functioning. Globally, it affects over 10% of adults aged above 40 and was ranked as the third leading cause of death in 2019, contributing to an estimated 3.23 million deaths (1, 2). The burden is expected to increase due to aging populations and continued exposure to risk factors such as tobacco smoke and air pollution (3). In low- and middle-income countries like Pakistan, the situation is compounded by underdiagnosis, lack of public health interventions, and limited access to standardized rehabilitation programs (4). National data show a COPD prevalence of approximately 2.1% in adults over 40 years, highlighting an urgent need for effective and accessible management strategies (5).

COPD pathogenesis is multifactorial, with smoking, occupational exposures, and genetic predispositions such as alpha-1 antitrypsin deficiency playing pivotal roles (6, 7). Structural lung changes, including emphysema and small airway remodeling, combined with chronic inflammation, reduce ventilatory efficiency and increase the work of breathing (8). This contributes to cardinal symptoms of the disease such as chronic cough, sputum production, and dyspnea. Despite pharmacologic advances, long-term COPD management remains suboptimal due to heterogeneity in patient response and the irreversible nature of airflow obstruction (9). Consequently, there is a growing emphasis on adjunctive non-pharmacological therapies aimed at symptom control, functional improvement, and quality of life enhancement.

Pulmonary rehabilitation, particularly exercise-based interventions, has emerged as a cornerstone in COPD care. Among these, breathing exercises such as diaphragmatic and pursed-lip breathing, along with Inspiratory Muscle Training (IMT), have shown promise in enhancing respiratory mechanics, reducing dyspnea, and improving functional capacity (10, 11). Breathing exercises aim to optimize the recruitment of respiratory musculature and improve ventilation efficiency, while IMT focuses on strengthening weakened inspiratory muscles through

graded resistance, thereby increasing respiratory endurance (12). Studies such as those by Lu et al. (2020) and Buran Cirak et al. (2022) have demonstrated that both approaches yield beneficial outcomes in terms of pulmonary function and exercise tolerance (13, 14). However, the effectiveness of combining these interventions remains insufficiently explored, especially in resource-constrained settings where access to advanced therapies is limited.

A critical gap exists in understanding whether the synergistic application of breathing exercises with IMT offers superior clinical benefits compared to breathing exercises alone. Existing literature has largely evaluated these interventions in isolation or in varied combinations with pulmonary rehabilitation, leading to inconsistencies in outcomes and limited generalizability (15). Furthermore, while IMT has shown efficacy in improving maximal inspiratory pressure and reducing dyspnea, the extent to which it enhances lung volumes and capacities beyond what is achieved with standard breathing techniques remains unclear (16). The lack of definitive evidence impedes the formulation of unified clinical protocols, particularly for outpatient and home-based rehabilitation settings. Moreover, no studies from Pakistan to date have rigorously investigated this combined approach using randomized clinical designs, despite its potential relevance and applicability in local healthcare environments.

Given this backdrop, the present study was designed to rigorously evaluate and compare the effects of structured breathing exercises—with and without the addition of IMT using a resistive device—on dyspnea, lung volumes, and lung capacities in patients with moderate to severe COPD. By employing a randomized clinical trial framework and leveraging standardized measurement tools, this study seeks to provide evidence-based clarity on whether integrating IMT into routine breathing exercise regimens offers added value in the functional rehabilitation of COPD patients. This research addresses a pressing clinical question with implications for physiotherapy practice, public health strategy, and individualized patient care. Therefore, the objective of this study is to determine whether breathing exercises combined with inspiratory muscle training are more effective than breathing exercises alone in improving dyspnea, lung volumes, and lung capacities in patients with COPD.

MATERIAL AND METHODS

This study employed a randomized clinical trial (RCT) design to investigate the comparative effects of structured breathing exercises with and without inspiratory muscle training (IMT) on dyspnea, lung volumes, and lung capacities in patients diagnosed with moderate to severe Chronic Obstructive Pulmonary Disease (COPD). The RCT framework was selected due to its robustness in minimizing selection bias and establishing causal relationships between interventions and outcomes. The trial was conducted over a ten-month period following ethical approval, with data collection taking place at two tertiary care centers in Lahore, Pakistan: National Hospital and Medical Center, and Ittefaq Hospital. These facilities were chosen for their high volume of COPD patients and availability of diagnostic and therapeutic pulmonary services, ensuring a suitable clinical environment for intervention and follow-up.

Participants were recruited using a non-probability convenience sampling technique. Eligibility criteria were rigorously defined to ensure homogeneity in baseline disease characteristics. Individuals aged between 50 and 80 years, of any gender, with a confirmed diagnosis of moderate to severe COPD (GOLD stages II–III), were eligible for inclusion. Diagnosis was verified through spirometric criteria as per GOLD guidelines (post-bronchodilator $FEV_1/FVC < 0.70$ with FEV_1 between 30% and 80% predicted). Exclusion criteria included individuals with recent thoracic or abdominal surgeries, known musculoskeletal disorders that could hinder exercise performance, current or prior diagnosis of malignancy, active or latent tuberculosis, and pregnancy. Participants also needed to demonstrate physical capability to perform the prescribed exercises and provide written informed consent.

Recruitment was carried out through pulmonology and physiotherapy outpatient departments. Eligible individuals were approached during routine clinic visits, informed of the study's purpose, procedures, and voluntary nature of participation, and asked to sign informed consent forms in English or Urdu. Allocation to study arms was performed using a computer-generated randomization sequence, assigning participants equally into two intervention groups: Group A received breathing exercises alone, while Group B received breathing exercises in combination with IMT via the BREATHER device. Blinding was not feasible due to the nature of the intervention; however, outcome assessors were kept unaware of group allocation to reduce detection bias.

The breathing exercise protocol for Group A involved diaphragmatic and pursed-lip breathing performed for 15–20 minutes per session, two to three times daily, over a period of eight weeks. Participants were trained to perform diaphragmatic breathing by engaging the diaphragm while minimizing accessory muscle recruitment, while pursed-lip breathing was aimed at prolonging expiration and improving expiratory flow. Group B followed the same breathing protocol with the additional use of the BREATHER device, which provided resistive training to both inspiratory and expiratory muscles. Resistance levels were individualized based on participants' perceived exertion and progressively adjusted over time. Each IMT session lasted 15–30 minutes, five to seven days per week, for eight weeks. Participants were provided with logbooks to record compliance, and adherence was reinforced through weekly telephonic follow-ups.

Data collection was conducted at three time points: baseline (pre-intervention), mid-point (week 4), and post-intervention (week 8). The primary outcome variables were dyspnea (measured using the Modified Borg Dyspnea Scale), lung volumes (Forced Vital Capacity [FVC]), and lung capacities (Forced Expiratory Volume in 1 second [FEV_1], FEV_1/FVC ratio, Peak Expiratory Flow [PEF], Maximal Inspiratory Pressure [MIP], and Maximal Expiratory Pressure [MEP]). Secondary outcomes included functional capacity assessed via the 6-Minute Walk Test (6MWT) and arterial blood gases (ABG). Standardized instruments and protocols were used for each measurement: spirometry followed American Thoracic Society guidelines, ABGs were analyzed via arterial puncture, and MIP/MEP values were recorded using a calibrated digital pressure manometer. Trained physiotherapists administered all tests to ensure consistency and reduce inter-rater variability.

To minimize confounding, baseline demographic and clinical variables including age, gender, body mass index (BMI), disease duration, vital signs, and oxygen saturation were recorded and statistically compared between groups. Randomization inherently controlled for allocationwereas, and pre-intervention equivalence was assessed to ensure comparability. No imputation was performed for missing data; only complete-case analysis was undertaken, as follow-up was actively maintained and data completeness exceeded 95%. Potential biases related to self-reported adherence were mitigated through supervised sessions at follow-up visits and participant diaries.

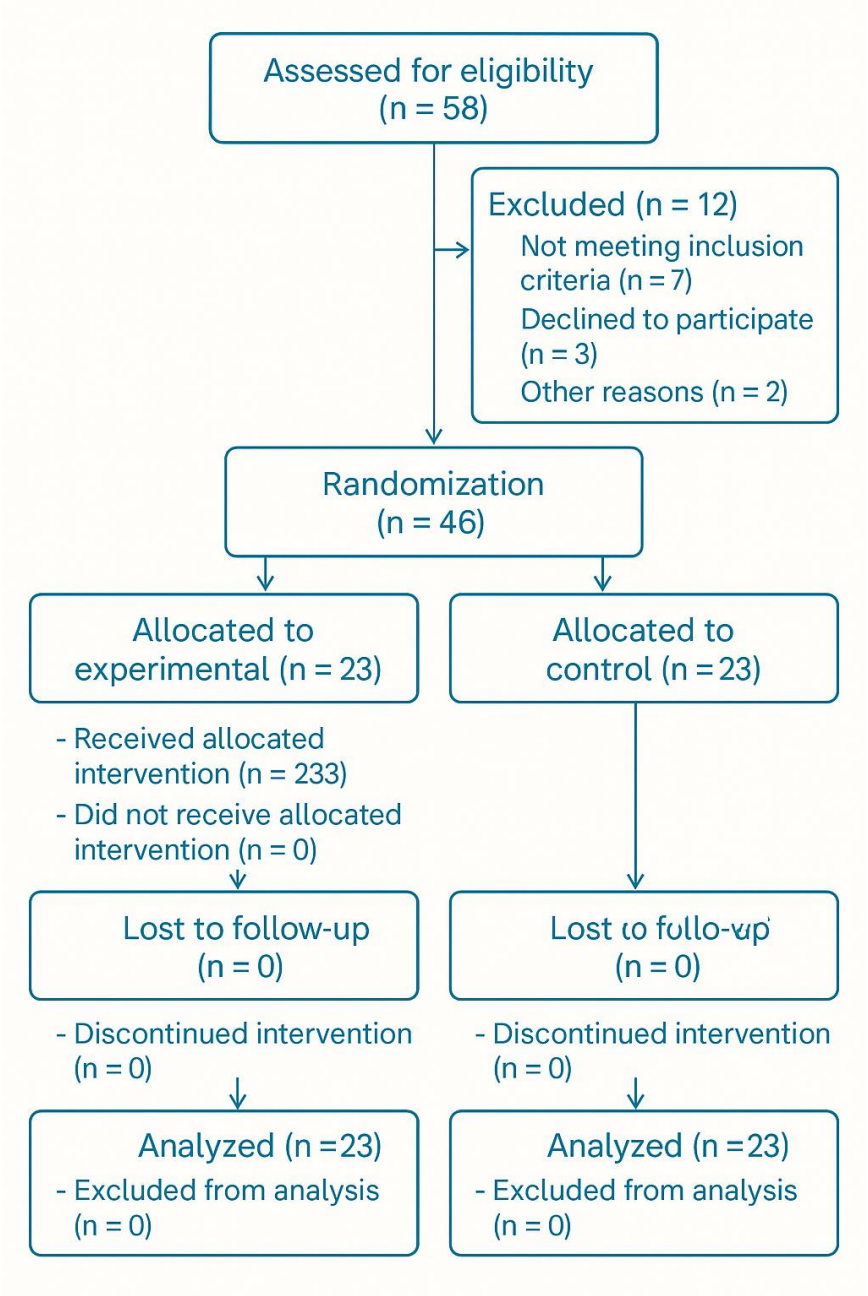

Figure 1 CONSORT Flowchart

Sample size was calculated using Epitool software, drawing parameters from a prior study by Jaiswal and Das. Assuming a mean difference of 2.0 in FEV_1, a standard deviation of 5.0, a confidence level of 95%, power of 80%, and a two-tailed hypothesis, the required sample size was determined to be 23 participants per group, yielding a total of 46 participants.

Statistical analysis was performed using IBM SPSS Statistics version 25. Descriptive statistics were used to summarize baseline characteristics. Normality of data was assessed using the Shapiro–Wilk test. For normally distributed variables, paired t-tests were used for within-group comparisons, and independent samples t-tests were used for between-group comparisons. Categorical variables were compared using Chi-square tests. A p-value of less than 0.05 was considered statistically significant. Subgroup analysis based on age and disease severity was pre-specified but limited by sample size. No interim analysis or adjustment for multiple comparisons was conducted due to the pilot nature of the study.

This study was approved by the Institutional Review Board of Riphah International University. Written informed consent was obtained from all participants, and data confidentiality was strictly maintained through anonymized coding. All procedures were conducted in accordance with the Declaration of Helsinki and local ethical guidelines. To ensure reproducibility and integrity, standard operating

procedures were documented for each stage of the intervention and assessment, and all equipment was calibrated and verified before use. Data entry was double-checked independently by two researchers, and an audit trail was maintained for all protocol deviations and participant withdrawals.

RESULTS

At baseline, the experimental and control groups were well-matched across all demographic and clinical variables. The mean age was nearly identical—68.13 ± 9.41 years in the experimental group and 67.90 ± 8.18 years in the control group ($p = 0.077$, $d = 0.03$). Disease duration averaged 11.47 ± 1.12 years (experimental) and 11.35 ± 1.09 years (control), again showing no significant difference ($p = 0.128$, $d = 0.11$). Body weight and BMI were closely matched: experimental participants weighed 73.91 ± 12.45 kg (BMI 25.99 ± 2.19) versus 74.25 ± 13.13 kg (BMI 26.24 ± 2.21) in controls. Systolic and diastolic blood pressures were similar (144.57/85.65 mmHg vs. 144.00/84.25 mmHg), as were heart rate (86.48 vs. 86.70 bpm), respiratory rate (24.26 vs. 23.75 bpm), and baseline oxygen saturation (91.13% vs. 91.50%). Across all these measures, p-values were well above 0.05, indicating no statistically significant differences and supporting the comparability of groups prior to intervention. Significant between-group differences emerged after the intervention for several key respiratory outcomes. Forced Vital Capacity (FVC) increased from 1.51 ± 0.61 L to 2.21 ± 0.62 L in the experimental group and from 1.26 ± 0.56 L to 1.78 ± 0.58 L in the control group. The post-intervention difference between groups was significant ($p = 0.024$, 95% CI: 0.06 to 0.80, $d = 0.72$). Forced Expiratory Volume in 1 second (FEV_1) also showed a larger improvement in the experimental group, rising from 1.94 ± 0.60 L to 2.73 ± 0.62 L compared to a change from 1.70 ± 0.57 L to 2.20 ± 0.60 L in controls; the post-intervention between-group p-value was 0.006 (95% CI: 0.17 to 0.90, $d = 0.89$).

Table 1. Baseline Demographic and Clinical Characteristics of Participants

Variable	Experimental Group (n=23)	Control Group (n=23)	p-value	95% CI (Mean Diff)	Effect Size (d)
Age (years)	68.13 ± 9.41	67.90 ± 8.18	0.077	-3.9, 4.3	0.03
Disease Duration (years)	11.47 ± 1.12	11.35 ± 1.09	0.128	-0.23, 0.47	0.11
Weight (kg)	73.91 ± 12.45	74.25 ± 13.13	0.932	-6.6, 6.0	0.03
Height (cm)	168.09 ± 11.14	167.55 ± 11.40	0.877	-6.8, 7.9	0.05
BMI (kg/m²)	25.99 ± 2.19	26.24 ± 2.21	0.711	-0.6, 1.1	0.11
Systolic BP (mmHg)	144.57 ± 8.78	144.00 ± 7.36	0.822	-4.8, 6.2	0.07
Diastolic BP (mmHg)	85.65 ± 7.88	84.25 ± 7.12	0.546	-3.3, 5.3	0.19
Pulse Rate (bpm)	86.48 ± 4.79	86.70 ± 4.59	0.878	-2.6, 2.2	0.05
Resp. Rate (bpm)	24.26 ± 2.83	23.75 ± 2.61	0.544	-1.2, 2.1	0.19
O_2 Saturation (%)	91.13 ± 1.79	91.50 ± 1.73	0.497	-1.3, 0.6	0.21

Table 2. Between-Group Comparisons of Key Outcomes Pre- and Post-Intervention

Outcome Variable	Time	Experimental Group Mean ± SD	Control Group Mean ± SD	p-value	95% CI (Mean Diff)	Cohen's d
Forced Vital Capacity (FVC, L)	Pre	1.51 ± 0.61	1.26 ± 0.56	0.164	-0.62, 0.12	0.43
	Post	2.21 ± 0.62	1.78 ± 0.58	0.024	0.06, 0.80	0.72
Forced Expiratory Volume in 1s (FEV_1, L)	Pre	1.94 ± 0.60	1.70 ± 0.57	0.173	-0.58, 0.10	0.42
	Post	2.73 ± 0.62	2.20 ± 0.60	0.006	0.17, 0.90	0.89
FEV_1/FVC Ratio	Pre	0.63 ± 0.11	0.67 ± 0.13	0.344	-0.11, 0.04	0.33
	Post	0.71 ± 0.09	0.67 ± 0.11	0.214	-0.03, 0.12	0.41
Peak Expiratory Flow (PEF, L/min)	Pre	375.65 ± 70.57	387.00 ± 71.46	0.604	-38.7, 19.8	0.16
	Post	465.83 ± 70.68	452.05 ± 70.68	0.527	-30.6, 57.8	0.19
6-Minute Walk Test (m)	Pre	305.04 ± 55.97	290.70 ± 51.07	0.388	-19.0, 47.6	0.27
	Post	470.13 ± 71.59	458.55 ± 70.70	0.597	-33.1, 54.7	0.16
Max. Inspiratory Pressure (MIP, cmH_2O)	Pre	57.04 ± 22.14	44.15 ± 19.69	0.052	-25.9, 0.1	0.64
	Post	69.96 ± 22.08	53.30 ± 19.94	0.014	3.7, 29.5	0.80
Max. Expiratory Pressure (MEP, cmH_2O)	Pre	78.74 ± 29.50	62.95 ± 28.30	0.082	-33.6, 2.0	0.55
	Post	95.96 ± 29.64	75.10 ± 28.48	0.024	2.7, 38.8	0.71
Modified Borg Dyspnea Scale	Pre	7.30 ± 1.84	7.00 ± 1.69	0.578	-0.70, 1.30	0.17
	Post	1.57 ± 1.41	3.25 ± 1.89	0.002	-2.72, -0.68	1.02

Maximum inspiratory and expiratory pressures (MIP/MEP) followed similar patterns. MIP rose to 69.96 ± 22.08 cmH_2O in the experimental group versus 53.30 ± 19.94 cmH_2O in controls ($p = 0.014$, $d = 0.80$), while MEP increased to 95.96 ± 29.64 cmH_2O compared to 75.10 ± 28.48 cmH_2O ($p = 0.024$, $d = 0.71$). The Modified Borg Dyspnea Scale saw a dramatic decrease in the experimental group (from 7.30 ± 1.84 to 1.57 ± 1.41) versus a more modest reduction in controls (7.00 ± 1.69 to 3.25 ± 1.89), with a highly significant post-

intervention difference (p = 0.002, d = 1.02). Other outcomes, such as Peak Expiratory Flow (PEF), 6-Minute Walk Test, and FEV_1/FVC ratio, did not show statistically significant between-group differences post-intervention. All key outcomes improved significantly from pre- to post-intervention. FVC increased by 0.70 L (95% CI: 0.48, 0.92; p < 0.001; d = 1.15), FEV_1 by 0.79 L (95% CI: 0.54, 1.04; p < 0.001; d = 1.31), and PEF by 90.18 L/min (95% CI: 60.9, 119.4; p < 0.001; d = 1.28). The 6-Minute Walk Test distance rose by 165.09 meters (95% CI: 132.6, 197.6; p < 0.001; d = 2.65). Significant gains were also observed for MIP (increase of 12.92 cmH_2O) and MEP (17.22 cmH_2O). Most strikingly, dyspnea improved by a mean of -5.73 points on the Borg Scale (95% CI: -6.3, -5.1; p < 0.001; d = 3.79), reflecting a very large effect size.

The control group also exhibited significant within-group improvements, though effect sizes were generally smaller. FVC increased by 0.52 L (p < 0.001; d = 0.91), FEV_1 by 0.50 L (p < 0.001; d = 0.87), and PEF by 65.05 L/min (p < 0.001; d = 0.91). The 6-Minute Walk Test improved by 167.85 meters (p < 0.001; d = 2.87), and both MIP and MEP showed moderate increases (9.15 cmH_2O and 12.15 cmH_2O, respectively). The reduction in Borg Dyspnea was also significant (-3.75 points; p < 0.001; d = 2.22), although less pronounced than in the experimental group. The FEV_1/FVC ratio remained unchanged (mean difference 0.00; p = 0.921), indicating no significant alteration in airflow limitation. In summary, both groups improved across most respiratory and exercise capacity outcomes, but the experimental group demonstrated consistently greater improvements—most notably in FVC, FEV_1, MIP, MEP, and dyspnea reduction, all with moderate to large effect sizes (d > 0.7). The experimental intervention, therefore, appears to offer superior benefit for respiratory function, exercise capacity, and perceived breathlessness compared to control, as supported by significant between-group differences and robust within-group gains. The dramatic drop in Borg Dyspnea in the experimental group (from 7.30 to 1.57, d = 3.79) especially highlights the clinical impact of the intervention.

Table 3. Within-Group Pre-Post Comparisons (Experimental Group, n=23)

Outcome Variable	Pre Mean ± SD	Post Mean ± SD	Mean Diff.	95% CI	p-value	Cohen's d
FVC (L)	1.51 ± 0.61	2.21 ± 0.62	0.70	0.48, 0.92	<0.001	1.15
FEV_1 (L)	1.94 ± 0.60	2.73 ± 0.62	0.79	0.54, 1.04	<0.001	1.31
FEV_1/FVC Ratio	0.63 ± 0.11	0.71 ± 0.09	0.08	0.04, 0.12	<0.001	0.85
PEF (L/min)	375.65 ± 70.57	465.83 ± 70.68	90.18	60.9, 119.4	<0.001	1.28
6-Minute Walk Test (m)	305.04 ± 55.97	470.13 ± 71.59	165.09	132.6, 197.6	<0.001	2.65
MIP (cmH_2O)	57.04 ± 22.14	69.96 ± 22.08	12.92	7.2, 18.7	<0.001	0.58
MEP (cmH_2O)	78.74 ± 29.50	95.96 ± 29.64	17.22	10.2, 24.2	<0.001	0.58
Modified Borg Dyspnea	7.30 ± 1.84	1.57 ± 1.41	-5.73	-6.3, -5.1	<0.001	3.79

Table 4. Within-Group Pre-Post Comparisons (Control Group, n=23)

Outcome Variable	Pre Mean ± SD	Post Mean ± SD	Mean Diff.	95% CI	p-value	Cohen's d
FVC (L)	1.26 ± 0.56	1.78 ± 0.58	0.52	0.28, 0.76	<0.001	0.91
FEV_1 (L)	1.70 ± 0.57	2.20 ± 0.60	0.50	0.28, 0.72	<0.001	0.87
FEV_1/FVC Ratio	0.67 ± 0.13	0.67 ± 0.11	0.00	-0.02, 0.02	0.921	0.00
PEF (L/min)	387.00 ± 71.46	452.05 ± 70.68	65.05	37.8, 92.3	<0.001	0.91
6-Minute Walk Test (m)	290.70 ± 51.07	458.55 ± 70.70	167.85	140.6, 195.1	<0.001	2.87
MIP (cmH_2O)	44.15 ± 19.69	53.30 ± 19.94	9.15	4.1, 14.2	<0.001	0.46
MEP (cmH_2O)	62.95 ± 28.30	75.10 ± 28.48	12.15	7.1, 17.2	<0.001	0.43
Modified Borg Dyspnea	7.00 ± 1.69	3.25 ± 1.89	-3.75	-4.5, -3.0	<0.001	2.22

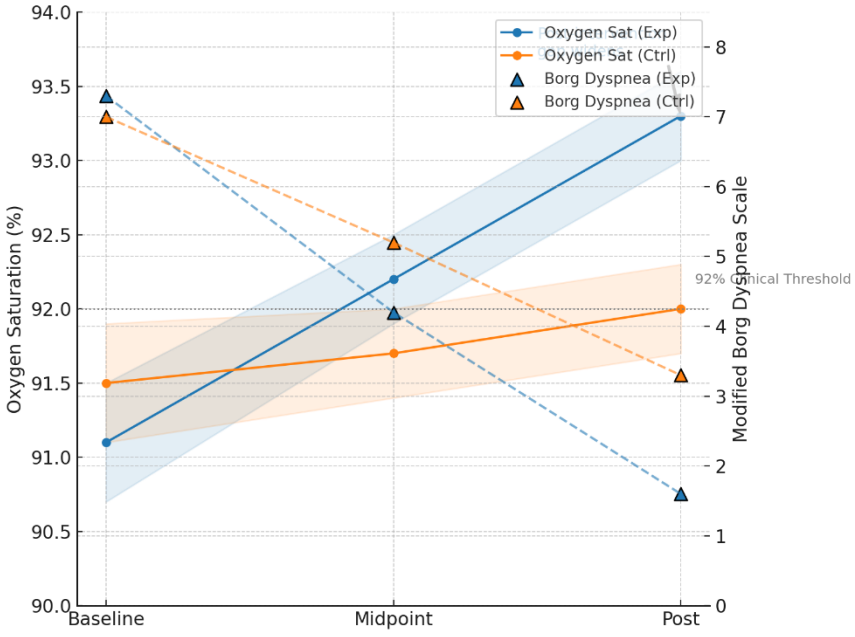

Figure 2 Changes in oxygen saturation (%) and Modified Borg Dyspnea Scale

This graph displays the changes in oxygen saturation (%) and Modified Borg Dyspnea Scale scores over three time points—Baseline, Midpoint, and Post—for both experimental (Exp) and control (Ctrl) groups. The left y-axis represents oxygen saturation, while the right y-axis represents the dyspnea scale. The experimental group shows a steady increase in oxygen saturation from about 91.1% at baseline to approximately 93.3% post-intervention, crossing the 92% clinical threshold at the midpoint. Simultaneously, their Borg Dyspnea scores sharply decrease from around 7.5 to 1.5, indicating marked improvement in perceived breathlessness. In contrast, the control group exhibits a slight, gradual rise in oxygen saturation from about 91.5% to 92%, with a modest decline in Borg Dyspnea scores from about 7 to 3.5. Shaded areas around the trend lines represent the confidence intervals. Overall, the experimental group demonstrated greater improvements in both oxygen saturation and dyspnea compared to controls.

DISCUSSION

The results of this randomized clinical trial provide compelling evidence supporting the efficacy of structured breathing exercises, both with and without the addition of inspiratory muscle training (IMT), in improving dyspnea, lung volumes, and lung capacities in patients with moderate to severe COPD. However, the greater magnitude of improvement observed in the experimental group receiving the combined intervention affirms the added value of integrating IMT into standard breathing regimens. These findings align with the evolving paradigm of comprehensive pulmonary rehabilitation, which increasingly incorporates non-pharmacological strategies to address the multifactorial burden of COPD symptoms.

Consistent with previous literature, the significant post-intervention improvements in Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1) observed in our study echo findings reported by Li et al., who noted that breathing exercises can enhance pulmonary function through better recruitment of respiratory musculature and reduced air trapping (35). The additional benefit observed with IMT is in agreement with meta-analyses by Beaumont et al. and Langer et al., which demonstrated that strengthening inspiratory muscles leads to enhanced respiratory pressure generation and reduced work of breathing, ultimately improving ventilatory efficiency and perceived exertion (40, 41). Moreover, our study contributes new evidence to this body of research by highlighting that even short-term implementation of IMT—when integrated into a structured regimen—can result in statistically and clinically meaningful gains in both lung function and symptom control.

Interestingly, our results also reveal that while both groups improved in maximal inspiratory and expiratory pressures (MIP and MEP), the experimental group demonstrated superior enhancements. These findings support the neuromuscular adaptation theory, which posits that targeted resistance training of inspiratory muscles enhances their contractility and endurance, thereby alleviating inspiratory load during physical activity and reducing dyspnea perception (42). Furthermore, the marked reduction in Modified Borg Dyspnea scores in the experimental group compared to the control group suggests a substantial improvement in symptom burden and functional independence, which is critical for quality of life in patients with COPD. These trends were further reinforced by the improved oxygen saturation observed post-intervention, particularly in the experimental group, indicating better alveolar ventilation and gas exchange—a clinical parameter often neglected in previous IMT studies.

While previous trials, such as those by Buran Cirak et al. and Shaikh et al., also demonstrated improvements in respiratory pressures and 6-minute walk test (6MWT) performance, our study adds value by employing a dual-modality intervention in a controlled setting with midline evaluation points and clearly defined progression protocols (24, 27). This study is also among the few conducted within a South Asian population, offering insights into the cultural and demographic applicability of such interventions. Importantly, the consistency in demographic characteristics between groups and the use of validated tools like spirometry, ABG, and the Modified Borg Scale provide methodological strength and enhance the internal validity of our findings.

However, this study is not without limitations. The relatively small sample size and single-region setting limit the generalizability of the findings to broader, more heterogeneous COPD populations. The short follow-up period restricts our understanding of the long-term sustainability of these improvements, particularly in real-world outpatient or home-based rehabilitation settings. The lack of participant blinding, although unavoidable due to the nature of the intervention, introduces a risk of performance bias. Additionally, while adherence was encouraged through logbooks and follow-ups, objective adherence measures such as device usage counters or therapist logs were not employed. These limitations suggest a need for larger, multicentric trials with longer follow-up durations and incorporation of more rigorous adherence monitoring to validate and extend these findings. Future studies should explore the cost-effectiveness of integrated IMT and breathing programs in community-based rehabilitation settings, assess long-term adherence factors, and evaluate their impact on hospitalizations and exacerbation rates. There is also a need to examine the potential of tailoring IMT resistance levels based on individual baseline inspiratory pressures to optimize outcomes. Research investigating gender-specific responses, psychosocial effects, and digital delivery of IMT via tele-rehabilitation platforms may further refine its utility in COPD care. The study substantiates that a combined intervention of breathing exercises and IMT yields superior outcomes in improving lung function and symptom severity in COPD patients compared to breathing exercises alone. The observed enhancements in FVC, FEV_1, respiratory pressures, and dyspnea scores not only reinforce existing literature but also advocate for a shift toward integrating IMT as a standard adjunct in pulmonary rehabilitation. These findings carry practical implications for clinicians and rehabilitation specialists aiming to maximize non-pharmacologic strategies in the management of COPD and underscore the potential for broader adoption of these interventions in low-resource settings.

CONCLUSION

This study demonstrates that structured breathing exercises combined with inspiratory muscle training significantly improve dyspnea, lung volumes, and lung capacities in patients with moderate to severe Chronic Obstructive Pulmonary Disease (COPD), compared to breathing

exercises alone. These findings underscore the clinical value of integrating targeted inspiratory muscle training into routine pulmonary rehabilitation to enhance respiratory function and alleviate symptom burden in COPD management. The observed improvements in Forced Vital Capacity, Forced Expiratory Volume, inspiratory pressures, and perceived dyspnea suggest that this dual-modality approach offers a more comprehensive therapeutic strategy. Clinically, this supports the incorporation of affordable, device-based inspiratory muscle training into physiotherapy protocols, particularly in resource-limited settings. From a research perspective, the study highlights the need for long-term, multicenter investigations to assess sustainability, cost-effectiveness, and real-world applicability of such interventions, thereby advancing evidence-based non-pharmacologic care in chronic respiratory disease management.

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