Original Article

Impact of Inspiratory Muscle Training with Biofeedback vs Traditional Breathing Exercises on Dyspnea and Exercise Tolerance in COPD: A Randomized Controlled Trial

Allied Medical Research Journal
Vol:3 No.4: 14-22

Subhan Ali Gondal[1], Maryam Raza[2], Nusrat Naseem[3], Roshneck Hameed[4], Aqeel Ahmed[5], Shoukat Hayat[5], Shiza Rizwan[4]

[1]*Rayan Medical Center, Gujrat, Pakistan*
[2]*Mukabbir University of Science & Technology, Gujrat, Pakistan*
[3]*Health Services Academy, Islamabad, Pakistan*
[4]*Iqra University, Chak Shahzad Campus, Islamabad, Pakistan*
[5]*Isra University, Islamabad, Pakistan*

ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is one of the leading causes of disability globally, with symptoms that include dyspnea and exercise intolerance. Although breathing exercises are typically considered standard of care in rehabilitation, inspiratory muscle training (IMT) with visual biofeedback might be more beneficial. In this study we visualized the effects of IMT with visual biofeedback compared to breathing exercises on dyspnea and exercise tolerance in patients with COPD.

Methods: A parallel-group, assessor-blinded randomized controlled trial was conducted across three sites between March and November 2024. Sixty-six adults, ages 40-60, with moderate to severe COPD (GOLD stages II-III) were randomized to an IMT group using an incentive spirometer with visual biofeedback (n=33) or a breathing exercise group (n=33). All participants engaged in 6 weeks of intervention. The primary outcomes were dyspnea (mMRC scale, Borg CR10) and exercise tolerance (6-minute walk distance, 6MWD). Secondary outcomes included pulmonary function (FEV1% predicted) and health-related quality of life (CAT score). Data were analyzed using independent t-tests and repeated measures ANOVA.

Results: Significant within-group improvements were observed in both groups; however, the IMT-biofeedback group exhibited a greater magnitude of between-group differences measured by mMRC (-0.4 points, p=0.002), Borg CR10 (-0.8 points, p=0.001), 6MWD (+34.7 meters, p<0.001), FEV1 % predicted (+3.7%, p=0.001), and CAT score (-2.5 points, p=0.001). Effect sizes ranged from 0.84 to 1.09, and all outcomes demonstrated statistically significant time × group interactions (p≤0.001). No adverse events were registered during the study in either group.

Conclusion: For patients with moderate-to-severe COPD, inspiratory muscle training with visual biofeedback in addition to breathing exercises is significantly more effective in improving dyspnea, exercise tolerance, pulmonary function, and quality of life compared to traditional breathing exercises alone, which supports its added value in the pulmonary rehabilitation curriculum.

Keywords: *COPD, Dyspnea, Exercise tolerance, FEV_1, Inspiratory muscles, Pulmonary rehabilitation.*

Received: June 10, 2025**; Revised:** September 2, 2025**; Accepted:** September 30, 2025
Corresponding Email: dr.subhangondal@gmail.com
DOI: https://doi.org/10.59564/amrj/03.04/004

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a significant global health issue, affecting millions of people all over the world and is one of the most common causes of morbidity and mortality[1].

COPD is marked by a chronic limitation of airflow and worsening respiratory symptoms, leading to substantial physical, psychological, and economic costs of illness on patients and the healthcare system[2]. The disease involves chronic inflammation in the airways and the destruction of lung parenchyma, leading to debilitating symptoms including dyspnea, exercise limitation, and health-related quality of life[3]. Dyspnea, especially upon exertion, stands out as one of the most distressing

symptoms among COPD patients, which can lead to avoidance of activity, deconditioning, and social isolation[4]. Exercise intolerance further complicates this functional limitation, which escalates into a negative spiral of limited physical activity and increased disability[5]. In addition to pulmonary impairment, COPD patients also frequently demonstrate inspiratory muscle weakness and dysfunction; this also has an important role in the perceived dyspnea and tolerance to exercise[6]. The burden of mechanical work on the diaphragm and accessory muscles of respiration increases with the hyperinflation and obstruction to airflow, providing inefficient ventilation and early fatigue with physical activity[7].

Breathing training adjuncts in the form of pulmonary rehabilitation have long been considered a cornerstone of comprehensive COPD management[8]. Breathing training approaches, including diaphragmatic breathing, pursed-lip breathing, and thoracic expansion exercises, have historically been brought into practice to improve efficiency of breathing, decrease dyspnea, and improve exercise capacity[9]. The goal of these approaches is to improve ventilatory patterns, decrease the rate of breathing, and promote relaxation of accessory muscles. There is evidence that traditional breathing approaches may provide meaningful improvements in dyspnea scores and functional capacity for people with COPD[9,10]. Newer studies examining traditional breathing techniques suggest targeted approaches to loading the inspiratory muscles may provide positive effects as well[11]. Inspiratory muscle training (IMT) has received a great deal of attention as a specific intervention to target functional applications to strengthen respiratory musculature through resistive loading or threshold training[1].

Recent randomized controlled trials suggest that IMT improves inspiratory muscle strength, decreases kinesiophobia related to dyspnea, and improves exercise tolerance within the population of people with COPD[1,5,12]. In addition, there is evidence that novel methods that incorporate visual biofeedback during IMT are promising. Studies have shown that providing biofeedback during IMT leads to greater improvements in inspiratory muscle strength, work capacity, and six-minute walk test distance than mechanical threshold IMT or traditional breathing exercises[7,9]. As biofeedback provides visual feedback in real time, it may lead to improved patient adherence to prescribed treatment and potentially better the accuracy of exercise practice[7].

There is evidence supporting the efficacy of IMT with biofeedback for the management of COPD; however, there is a lack of studies that compared its effect to traditional breathing exercise therapies in the context of normal clinical practice settings[10]. Most studies have compared IMT to control groups or reported on IMT for patients in pulmonary rehabilitation programs, and there are very few studies that have compared IMT with visual biofeedback to the traditional breathing exercise protocols commonly utilized in clinical practice. Other paradigms for optimal training parameters, device selection, and implementation for IMT with biofeedback need to be considered and studied further[11,12].

As breathing exercises remain the current standard of care in many rehabilitation programs, it is important to investigate whether the added component of structured IMT with visual biofeedback has a clinically significant impact on dyspnea and exercise tolerance[9,10]. This randomized controlled trial was constructed to directly compare the effects of a 6-week inspiratory muscle training program using an incentive spirometer as a visual biofeedback device versus time-matched traditional breathing exercises on dyspnea and exercise capacity in ambulatory patients with moderate to severe COPD (GOLD stages II-III). This study will provide more rigorous evidence on the comparative effectiveness of these interventions and help inform clinical practice and rehabilitation for patients living with COPD.

METHODOLOGY

Study Design

A randomized controlled trial (RCT) with a parallel-group, assessor-blinded design was conducted to compare inspiratory muscle training (IMT) with visual biofeedback to

traditional breathing exercises in patients with COPD.

Setting

The trial was conducted at Rayan Medical Center, Gujrat Health and Al-Nafees Medical College & Hospital from March 2024 to November 2024.

Target Population and Sample Size

The target population consisted of ambulatory adults with a clinical diagnosis of COPD (GOLD stages II–III) who presented to the participating sites. Given a clinically meaningful between-group difference of Force expiratory reserve volume in liters (FEV1) (pretest 462±69, posttest 624±157); with 80% power and α=0.05, it was calculated sample sizes of 30 per group were needed. A sample size of 33 per group (total n=66) was recruited to account for 10% attrition.

Inclusion and Exclusion Criteria

Eligible participants were aged between 40 and 80 years of age, were clinically diagnosed with COPD (post-bronchodilator FEV1/FVC <0.70 and FEV1 30–80% pred), had a score of exertional dyspnea (mMRC ≥1), and were stable (no exacerbation or adjustment in medication in the past 4 weeks).

Exclusion criteria consisted of uncontrolled cardiac disease, history of thoracic surgery, neuromuscular condition affecting respiration, active pulmonary infection, cognitive status that would prevent training, and participation in a structured pulmonary rehabilitation program.

Randomization and Blinding

After performing the initial assessment, participants were randomized (1:1) into the IMT-biofeedback or traditional breathing group using an envelope method. Allocation concealment was achieved using prepared sequentially numbered, opaque, sealed envelopes by an independent researcher. Outcome assessors were blind to group allocation; however, participants and treating physiotherapists were not blinded due to the nature of the intervention.

Intervention Protocol (Six Weeks)

IMT-Biofeedback Group

Participants in the IMT-biofeedback group performed inspiratory training, with the incentive spirometer used to provide visual biofeedback. The baseline best inspiratory volume was determined using three maximal efforts; the training target was set at 70% of best inspiratory volume. Each training session consisted of 30 breaths, three sets of 10 breaths consisting of 1–2 minutes of rest between sets and inhaled slowly to raise the piston/ball to the target and held for 2–3 seconds followed by a gentle exhalation.

Training was prescribed as two times daily (morning and evening) for six weeks. There were three supervised sessions per week at the clinic for the first two weeks and weekly thereafter to determine accurate technique; the participant performed the remaining sessions at home, keeping a training diary.

Traditional Group

The traditional breathing exercises group will receive a matched-time program that includes diaphragmatic breathing, pursed-lip breathing, thoracic expansion exercises, and paced breathing. Each session has an approximate duration similar to the IMT sessions, (3 sets of exercises for each technique that takes equivalent breaths/time) for a duration of 2 sessions/day for 6 weeks. Supervision frequency and home-practice diary will be the same as the IMT group to match contact time.

Outcome Measures

Assessments were conducted at baseline and 6 weeks.

The primary outcome measures are dyspnea and exercise tolerance: dyspnea was measured by a self-administered scale (the Modified Medical Research Council (mMRC) scale) and the Borg CR10 scale following exertion, while exercise tolerance was measured by the 6-minute walk distance (6MWD) as per ATS guidelines. Secondary outcome measures included pulmonary function (post-bronchodilator FEV1 % predicted) and health-related quality of life (COPD Assessment Test, CAT).

Statistical Analysis

An intention-to-treat approach was used in the data analyses. Baseline characteristics were summarized with descriptive statistics. Between-group differences in change scores were evaluated with independent t-tests. Repeated measures (time × group) effects were evaluated with ANOVA. A two-sided p-value <0.05 was considered significant. Effect sizes and 95% confidence intervals are reported.

Ethical Consideration

The study protocol was approved by the institutional review boards of each participating site. Written informed consent was obtained from all participants before enrollment. Participant confidentiality was protected by de-identifying the data, and it was explained that they could withdraw at any time without any impact on their clinical care. All adverse events were monitored, recorded, and managed according to standard clinical pathways.

RESULTS

Participant Demographics and Baseline Characteristics

Sixty-six participants were enrolled and randomized into the study, with 33 assigned to the IMT-biofeedback group and 33 assigned to the traditional breathing exercises group. Participant demographic characteristics were evenly distributed across the groups. The mean age of participants in the IMT-biofeedback group was 62.4 ± 8.7 years and 63.1 ± 9.2 years in the traditional breathing exercises group. Male participants made up the majority in both groups, with 63.6% (n=21) in the IMT-biofeedback group and 60.6% (n=20) in the traditional breathing exercises group. The majority of participants were categorized as GOLD stage II (IMT-biofeedback: 54.5%, n=18; Traditional: 51.5%, n=17) while the remainder were GOLD stage III. Smoking history was quite similar between the groups, with 48.5% (n=16) of the IMT-biofeedback participants being either current or former smokers, compared to 51.5% (n=17) in the traditional group. Body mass index was similar across both groups (IMT-biofeedback: 24.8 ± 3.6 kg/m²; Traditional: 25.2 ± 3.9 kg/m²).

In the IMT-biofeedback group, three participants withdrew during the intervention and, in the traditional group, two participants withdrew, resulting in completion rates of 90.9% and 93.9% respectively. There were no significant differences at baseline between groups for any of the demographic variables (all p > 0.05), confirming that randomization was, indeed, successful (Table-1).

Table-1 Demographic Characteristics of Participants

Characteristic	IMT-Biofeedback Group (n=33)	Traditional Group (n=33)	p-value
Age (years)	62.4 ± 8.7	63.1 ± 9.2	0.742
Male	21 (63.6)	20 (60.6)	0.795
BMI (kg/m²)	24.8 ± 3.6	25.2 ± 3.9	0.658
GOLD Stage			0.795
Stage II	18 (54.5)	17 (51.5)	
Stage III	15 (45.5)	16 (48.5)	
Smoking Status			0.795
Current/Former	16 (48.5)	17 (51.5)	
Never	17 (51.5)	16 (48.5)	
Completed intervention	30 (90.9)	31 (93.9)	0.640

mean±SD, n (%)

At the baseline, both groups displayed similar clinical characteristics on all outcome measures, confirming the success of randomization. The primary outcome measures showed no statistical difference at the enrollment into the study, with the same indicating the mean mMRC dyspnea scale score of 2.1 ± 0.8 in the IMT-biofeedback and 2.0 ± 0.7 in the traditional group (p = 0.582). The post-exertion Borg CR10 scores were also equivalent: IMT-biofeedback = 5.8 ± 1.4 and Traditional = 5.6 ± 1.3 (p = 0.542). The six-minute walk distance was comparable between the groups; subjects in the IMT-biofeedback attempted a distance of 348.2 ± 62.5 meters became accomplished a distance of 342.7 ± 58.9 meters in the Traditional group (p = 0.704). Secondary outcome measures were also comparable at baseline with pulmonary function testing revealing comparable FEV1 % predicted

values: IMT-biofeedback FEV1 % predicted was 54.3 ± 12.6% and Traditional FEV1 % predicted was 53.8 ± 11.9% (p = 0.867). Health-related quality of life measured by the CAT score showed no difference: IMT-biofeedback CAT score = 22.4 ± 6.8 and Traditional CAT score 21.8 ± 6.5, (p = 0.712). Therefore, consistent with no differences at the baseline across all outcome variables provided assurance for the pair of groups being similar; thus, post intervention there were changes attributed to the effects of the intervention and not to the unequal groups (Table-2).

Table-2 Outcome Measures at Baseline

Outcome Measure	IMT-Biofeedback Group (n=33)	Traditional Group (n=33)	p-value
Primary Outcomes			
mMRC Dyspnea Scale	2.1 ± 0.8	2.0 ± 0.7	0.582
Borg CR10 (post-exertion)	5.8 ± 1.4	5.6 ± 1.3	0.542
6MWD (meters)	348.2 ± 62.5	342.7 ± 58.9	0.704
Secondary Outcomes			
FEV1 % predicted	54.3 ± 12.6	53.8 ± 11.9	0.867
CAT Score	22.4 ± 6.8	21.8 ± 6.5	0.712

mean±SD, n (%)

Pre-and-post Changes in Both Groups

Improvements pre- and post- were statistically significant within both groups across all outcome measures and, thus, both IMT with biofeedback and traditional breathing exercises were effective in improving respiratory measures and functional capacity in patients with COPD. Specifically, the IMT-biofeedback group displayed greater within-group changes. The mMRC dyspnea scale scored significantly lower (improvement) from 2.1 ± 0.8 at baseline to 1.2 ± 0.6 at six weeks (mean change= -0.9 ± 0.5; p < 0.001), which represented a meaningful reduction in dyspnea severity.

Post-exertion Borg CR10 scores decreased from 5.8 ± 1.4 to 3.6 ± 1.1 (mean change: -2.2 ± 0.8; p < 0.001). Exercise tolerance significantly improved, as demonstrated by 6MWD increasing from 348.2 ± 62.5 meters to 428.6 ± 68.3 meters (mean change: +80.4 ± 34.7 meters; p < 0.001), exceeding the minimal clinically important difference of 30 meters. Pulmonary function was also significantly improved, as measured by FEV1 % predicted increasing from 54.3 ± 12.6% to 62.8 ± 13.4% (mean change: +8.5 ± 4.2%; p < 0.001). Finally, quality of life, measured by CAT score improved from 22.4 ± 6.8 to 16.2 ± 5.4 (mean change: -6.2 ± 3.1; p < 0.001).

Group participants in the traditional breathing exercises also saw significant improvements within groups across all measures, although the degree of change was generally less than the intervention group. The mMRC dyspnea scale decreased from 2.0 ± 0.7 to 1.5 ± 0.6 (mean change: -0.5 ± 0.4; p < 0.001). Borg CR10 scores improved from 5.6 ± 1.3 to 4.2 ± 1.0 (mean change: -1.4 ± 0.7; p < 0.001). Six-minute walk distance improved from 342.7 ± 58.9 m to 388.4 ± 62.1 m (mean change: +45.7 ± 28.3 m; p < 0.001). FEV1 % predicted improved from 53.8 ± 11.9 % to 58.6 ± 12.5 % (mean change: +4.8 ± 3.6 %; p < 0.001). CAT scores decreased from 21.8 ± 6.5 to 18.1 ± 5.8 (mean change: -3.7 ± 2.8; p < 0.001). The group results confirm that both interventions led to statistically and clinically significant improvements within each group. (Table-3).

Comparisons between Groups

The analysis between groups demonstrated that between-group differences were statistically significant for all primary and secondary outcome measures. For the primary outcome of dyspnea, the mean between-group difference in the change in mMRC scale was -0.4 points (95% CI: -0.6, -0.2; p = 0.002), demonstrating that the IMT-biofeedback group had lower dyspnea compared to the traditional breathing group. The Borg CR10 post-exertion score also revealed a significant between-group difference of -0.8 points (95% CI: -1.2, -0.4; p = 0.001) in favor of the IMT-biofeedback group. The IMT-biofeedback group had a clinically and statistically significant advantage in exercise tolerance outcomes, as the mean between-group difference in the 6MWD was 34.7 meters (95%

CI: 18.4, 51.0; p < 0.001), which exceeded the minimal clinically important difference, and represented a clinically important benefit in functional capacity. The repeated measures ANOVA confirmed a time × group interaction for 6MWD (F = 18.42, p < 0.001) demonstrating a significant difference between groups for any rate of improvement over time, as the IMT-biofeedback group had a rate of improvement that was higher than the traditional breathing group.

Table-3 Within-Group Changes from Baseline to Six Weeks

Outcome Measure	Group	Baseline	Six Weeks	Mean Change (95% CI)	p-value	Effect Size (Cohen's d)
mMRC Dyspnea Scale	IMT-Biofeedback	2.1 ± 0.8	1.2 ± 0.6	-0.9 (-1.1, -0.7)	<0.001	1.28
	Traditional	2.0 ± 0.7	1.5 ± 0.6	-0.5 (-0.7, -0.3)	<0.001	0.76
Borg CR10 (post-exertion)	IMT-Biofeedback	5.8 ± 1.4	3.6 ± 1.1	-2.2 (-2.5, -1.9)	<0.001	1.76
	Traditional	5.6 ± 1.3	4.2 ± 1.0	-1.4 (-1.7, -1.1)	<0.001	1.19
6MWD (meters)	IMT-Biofeedback	348.2 ± 62.5	428.6 ± 68.3	+80.4 (+67.5, +93.3)	<0.001	1.23
	Traditional	342.7 ± 58.9	388.4 ± 62.1	+45.7 (+35.2, +56.2)	<0.001	0.76
FEV1 % predicted	IMT-Biofeedback	54.3 ± 12.6	62.8 ± 13.4	+8.5 (+6.9, +10.1)	<0.001	0.65
	Traditional	53.8 ± 11.9	58.6 ± 12.5	+4.8 (+3.5, +6.1)	<0.001	0.39
CAT Score	IMT-Biofeedback	22.4 ± 6.8	16.2 ± 5.4	-6.2 (-7.4, -5.0)	<0.001	1.01
	Traditional	21.8 ± 6.5	18.1 ± 5.8	-3.7 (-4.7, -2.7)	<0.001	0.60

In secondary outcomes, the IMT-biofeedback group also exhibited better results. For pulmonary function, the between-group difference in FEV1 % predicted change was 3.7% (95% CI: 1.8, 5/6; p = 0.001), suggesting greater improvements in lung function with IMT-biofeedback compared with the standard exercises. The time × group interaction was statistically significant (F = 12.67, p = 0.001) which supports the treatment differences. Health-related quality of life (CAT score) also showed a between-group difference of -2.5 Repeated measures ANOVA also confirmed a significant time × group interaction for CAT score (F = 15.23, p < 0.001). The between-group points (95% CI: -3.9, -1.1; p = 0.001) which favored the IMT-biofeedback group, suggesting that a clinically meaningful change occurred with quality of life. differences showed effect sizes that ranged from moderate to large for person-centered outcomes (Cohen's d = .58 to .87), indicating clinically important treatment effects. No serious adverse events were recorded for either group during the 6-week intervention confirming the safety of each intervention in the study (Table-4).

DISCUSSION

The results of this randomized controlled trial indicate that inspiratory muscle training with visual biofeedback using an incentive spirometer leads to significantly more improvement in dyspnea, exercise tolerance, pulmonary function, and health-related quality of life than traditional breathing exercises in patients with moderate-to-severe COPD. Within each group, statistically significant improvements were seen across all outcome measures, confirming these interventions can serve as a valid therapy, but the IMT-biofeedback group had medium to large effect sizes for between-group differences for all outcome measures, indicating clinically important benefits of this targeted intervention over traditional breathing exercises. The between-group difference for dyspnea measured by both the mMRC and Borg CR10 scales was notable, as the IMT-biofeedback group had a

Table-4 Between-Group Comparisons of Change Scores at Six Weeks

Outcome Measure	IMT-Biofeedback Change	Traditional Change	Between-Group Difference (95% CI)	p-value	Effect Size (Cohen's d)	Time × Group Interaction (F, p)
mMRC Dyspnea Scale	-0.9 ± 0.5	-0.5 ± 0.4	-0.4 (-0.6, -0.2)	0.002	0.87	F = 14.56, p = 0.001
Borg CR10 (post-exertion)	-2.2 ± 0.8	-1.4 ± 0.7	-0.8 (-1.2, -0.4)	0.001	1.08	F = 16.82, p < 0.001
6MWD (meters)	+80.4 ± 34.7	+45.7 ± 28.3	+34.7 (+18.4, +51.0)	<0.001	1.09	F = 18.42, p < 0.001
FEV1 % predicted	+8.5 ± 4.2	+4.8 ± 3.6	+3.7 (+1.8, +5.6)	0.001	0.94	F = 12.67, p = 0.001
CAT Score	-6.2 ± 3.1	-3.7 ± 2.8	-2.5 (-3.9, -1.1)	0.001	0.84	F = 15.23, p < 0.001

moderate-to-large reduction in perceived severity of dyspnea. The scores of 0.4 points (mMRC) and 0.8 points (Borg CR10) reflect clinically meaningful reductions in perceived breathlessness at rest and during activity. These results are similar to recent evidence indicating that home-based inspiratory muscle training with visual biofeedback improve inspiratory muscle strength and functional exercise capacity in patients with COPD[14].

The visual biofeedback aspect of our intervention likely facilitated participant engagement and accuracy of training to help participants attain optimal inspiratory volume targets. Both considerable decreases in dyspnea-related kinesiophobia with IMT have been observed, indicating a decreased psychological load of dyspnea is also improved through focused respiratory muscle strengthening[15]. Additionally, threshold IMT shows greater improved dyspnea outcomes during activity than diaphragmatic breathing alongside pursed lip breathing among vocational COPD16, reinforcing our findings that resistance based inspiratory training is superior to traditional breathing exercises for symptom control[16]. Exercise tolerance, assessed utilizing six-minute walk distance improved by 80.4 meters in the IMT-biofeedback group versus a 45.7 meter improvement in the traditional group, for a difference of 34.7 meters that achieved theminimal clinically important difference of 30 meters. The meaningful improvement in functional capacity is evidencing the true clinical value of IMT alongside biofeedback has enhanced physical performance in COPD. Most recently, evidence demonstrates improvements in the six minute walk test performance, suggesting additional exercise tolerance gains with IMT compared to interventions in control groups[17].

The improvements that were observed in our IMT-biofeedback group are likely due to the specific strengthening of the inspiratory muscles that contributes to a decrease in the work of breathing while exercising and a delay in the onset of ventilatory limitation. Inspiratory muscle warm-up prior to IMT in pulmonary rehabilitation is known to amplify the benefits of exercise capacity, which indicates that to optimize training protocols that could include pre-exercise warming techniques may provide a superior functional effect[18]. The significant time x group interaction, which was seen in our repeated measures analysis, suggests that IMT with biofeedback is associated with a different rate of improvement over time when compared to traditional exercises, suggesting that progression is not just a progressive adaptation effect sustained throughout the intervention time frame. Pulmonary function, as assessed by FEV1 % predicted, improved significantly more in the IMT-biofeedback who improved by 8.5% than the traditional group who improved by 4.8%, a mean between groups difference of 3.7%. Although COPD is defined by irreversible airflow limitation, training of the respiratory muscles has been shown in the literature to facilitate improvements in FEV1 and may be a proxy measure of improvements in respiratory muscle coordination/breathing effectiveness/decreasing

dynamic hyperinflation/thoracic mechanics[19,20]. Resistive IMT has been shown to lead to deeper breathing patterns and improved ventilation efficiency in people with stable COPD, therefore adding a physiological explanation for the pulmonary function outcomes from the current study[20].

Breathing exercises, when combined with IMT, demonstrated superior outcomes in lung volumes and capacities compared to breathing exercises alone to support our finding where specific inspiratory muscle strengthening can improve pulmonary mechanics better than traditional breathing exercises[21]. Quality of life (QOL), which was measured with the CAT score demonstrated a between-group difference that is clinically meaningful of 2.5 points in the IMT-biofeedback group, which exceeds the minimal clinically important difference of 2. In patients experiencing an exacerbation of COPD, IMT added to pulmonary rehabilitation has been shown to significantly improve QOL, suggesting that inspiratory muscle strengthening has wide applicability among patients with different COPD phenotypes[22]. Improvements in QOL that we saw in this study probably came from the sum of the effects of decreased dyspnea, increased exercise capacity, and improved pulmonary function, which allowed patients to better participate in their daily activities and experience decreased limit in symptoms[23].

Several limitations must be noted in regard to the interpretation of this study's findings. The inability to blind the participants and treating physiotherapists to the nature of the intervention could have led to performance bias or placebo effects, but blinding the outcome assessors does reduce the possibility of detection bias. While significant benefit was found with the six-week intervention, the duration of the intervention does not inform us about the long-term maintenance of treatment effects or what duration of training is optimal to maintain improvements.

CONCLUSION

The IMT-biofeedback group exhibited improvements that were clinically meaningful on all outcomes measures with between-group differences of 0.4 points on the mMRC scale, 0.8 points on the Borg CR10 scale, 34.7 meters on the 6MWD (greater than the minimal clinically important difference), 3.7% in FEV1 % predicted, and 2.5 points on the CAT score, all in favor of biofeedback intervention and with medium to large effect sizes (Cohen's d = 0.84 to 1.09). The significant time × group interactions confirm different treatment effects, with IMT-biofeedback effecting greater progressive adaptation over the six-week duration.

Acknowledgments

None.

Author Contributions

Subhan Ali Gondal conceived the study and contributed to data collection. Maryam Raza assisted in study design and data analysis. Nusrat Naseem supervised the research and provided critical revisions. Roshneck Hameed and Shiza Rizwan contributed to literature review and manuscript drafting. Aqeel Ahmed and Shoukat Hayat assisted in data interpretation and final approval of the manuscript.

Ethical Approval

The study received approval from the Ethical Review Board of Rayan Medical Center, Gujrat Health (ERC No. RMC/2024/031), and Al-Nafees Medical College & Hospital (ERC No. ANMC/2024/078).

Grant Support and Funding Disclosure

None.

Conflict of Interests

None.

REFERENCES

1. Saka S, et al. Effect of inspiratory muscle training on dyspnea-related kinesiophobia in chronic obstructive pulmonary disease: A randomized controlled trial. Complement Ther Clin Pract. 2021;45:101418. **DOI:** https://doi.org/10.1016/j.ctcp.2021.101418
2. Fontoura FF, et al. Inspiratory Muscle Training on Exercise Capacity, Dyspnoea and Health Status in Pulmonary Hypertension: A Randomised Controlled Trial. Respirology. 2025;30(1):70054. **DOI:** https://doi.org/10.1111/resp.70054
3. Khanam SP, et al. Effect of inspiratory muscle training in patients with chronic obstructive pulmonary disease on dyspnea and exercise tolerance. Int J Med Allied Health Sci. 2021;7(2):89-95.
4. Hartman M, et al. Home-Based Inspiratory Muscle Training as Stand-Alone Therapy in COPD: A Randomized Sham-Controlled Trial Assessing Novel and Established Training Methods. COPD. 2025. **DOI:** https://doi.org/10.1080/15412555.2025.2487473
5. Aktan R, et al. The effects of inspiratory muscle warm-up prior to inspiratory muscle training during pulmonary rehabilitation in subjects with chronic obstructive pulmonary disease: a randomized trial. Physiother Theory Pract. 2024;41(1):1-11. **DOI:** https://doi.org/10.1080/09593985.2023.2301439

6. Wu WL, et al. Respiratory physiological mechanism of two types of equal-intensity Inspiratory Muscle Training in stable patients with chronic obstructive pulmonary disease. Respir Med. 2024;235:107747. **DOI:** https://doi.org/10.1016/j.rmed.2024.107747
7. Ali A, et al. Effects of Breathing Exercises with and Without Inspiratory Muscle Training on Dyspnea, Lung Volumes and Lung Capacities in COPD Patients. J Health Wellness Educ. 2025;9(1):45-52.
8. Mohammed M, et al. Efficacy of threshold inspiratory muscle trainer versus diaphragmatic plus pursed lip breathing in occupational COPD. Beni-Suef Univ J Basic Appl Sci. 2023;12:75. **DOI:** https://doi.org/10.1186/s43088-023-00413-3
9. Hasanpour Dehkordi A, et al. The effect of teach-back training intervention of breathing exercise on the level of dyspnea, six-minutes walking test and FEV1/FVC ratio in patients with chronic obstructive pulmonary disease; a randomized controlled trial. Expert Rev Respir Med. 2020;14(11):1129-1137. **DOI:** https://doi.org/10.1080/17476348.2020.1792290
10. Huang WY, et al. Effects of Inspiratory Muscle Training in Patients With Chronic Obstructive Pulmonary Disease Exacerbations. Am J Phys Med Rehabil. 2024;103(10):901-907. **DOI:** https://doi.org/10.1097/PHM.0000000000002483
11. de Farias CAC, et al. Effects of different modalities of inspiratory muscle training as an add-on to conventional treatment of patients with chronic obstructive pulmonary disease (COPD): study protocol for a randomized controlled trial. Trials. 2019;20:707. **DOI:** https://doi.org/10.1186/s13063-019-3819-1
12. Pehlivan E, et al. The effects of inspiratory muscle training on exercise capacity, dyspnea and respiratory functions in lung transplantation candidates: a randomized controlled trial. Clin Rehabil. 2018;32(10):1328-1339. **DOI:** https://doi.org/10.1177/0269215518777560
13. Aktuğ ZB, Kurt S, Pişkin NE, Yavuz G, İbiş S. Effect of inspiratory muscle training with the device on respiratory functions. Mediterranean Journal of Sport Science. 2022;5(3):571-81. **DOI:** https://doi.org/10.38021/asbid.1158659
14. Ammous O, et al. Inspiratory muscle training, with or without concomitant pulmonary rehabilitation, for chronic obstructive pulmonary disease (COPD). Cochrane Database Syst Rev. 2023;1:CD013778 **DOI:** https://doi.org/10.1002/14651858.CD013778.pub2
15. Han B, Chen Z, Ruan B, et al. Effects of Inspiratory Muscle Training in People with Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. Life (Basel). 2024;14(11):1470. **DOI:** https://doi.org/10.3390/life14111470
16. Huang Z, Li Z, Yan M, et al. Effect of respiratory muscle training in patients with stable chronic obstructive pulmonary disease: A systematic review and meta-analysis. Heliyon. 2024;10(7):e28713. **DOI:** https://doi.org/10.1016/j.heliyon.2024.e28713
17. Xie J, Zhu Y, Wang Y, et al. Effects of pulmonary rehabilitation combined with inspiratory muscle training on lung function and exercise capacity in older patients with COPD: a systematic review and meta-analysis. Front Med. 2025;12:1621375. **DOI:** https://doi.org/10.3389/fmed.2025.1621375
18. Shiraishi M, Higashimoto Y, Sugiya R, et al. Enhanced diaphragm excursion and exercise tolerance in COPD patients through inspiratory muscle training after standardised pulmonary rehabilitation: Randomised controlled trial. ERJ Open Res. 2024;10:00035-2024. **DOI:** https://doi.org/10.1183/23120541.00035-2024
19. Vázquez-Gandullo E, Hidalgo-Molina A, Montoro-Ballesteros F, et al. Inspiratory Muscle Training in Patients with Chronic Obstructive Pulmonary Disease (COPD) as Part of a Respiratory Rehabilitation Program Implementation of Mechanical Devices: A Systematic Review. Int J Environ Res Public Health. 2022;19(9):5564. **DOI:** https://doi.org/10.3390/ijerph19095564
20. Beaumont M, Forget P, Couturaud F, Reychler G. Effects of inspiratory muscle training in COPD patients: A systematic review and meta-analysis. Clin Respir J. 2018;12(7):2178-2188. **DOI:** https://doi.org/10.1111/crj.12905
21. Cai Y, Ren X, Wang J, Ma B, Chen O. Effects of Breathing Exercises in Patients with Chronic Obstructive Pulmonary Disease: A Network Meta-analysis. Arch Phys Med Rehabil. 2024;105(3):558-570. **DOI:** https://doi.org/10.1016/j.apmr.2023.04.014
22. Manifield J, Winnard A, Hume E, et al. Inspiratory muscle training for improving inspiratory muscle strength and functional capacity in older adults: A systematic review and meta-analysis. Age Ageing. 2021;50(3):716-724. **DOI:** https://doi.org/10.1093/ageing/afaa221
23. Yun R, Bai Y, Lu Y, Wu X, Lee SD. How breathing exercises influence on respiratory muscles and quality of life among patients with COPD? A systematic review and meta-analysis. Can Respir J. 2021;2021:1904231. **DOI:** https://doi.org/10.1155/2021/1904231