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COMPARATIVE EFFECT OF DIAPHRAGMATIC BREATHING AND PURSED-LIP BREATHING, EACH DELIVERED ALONGSIDE INSPIRATORY MUSCLE TRAINING, ON PULMONARY FUNCTION, DYSPNEA, AND FUNCTIONAL CAPACITY IN CHRONIC OBSTRUCTIVE PULMONARY DISEASE: A RANDOMIZED COMPARATIVE STUDY

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is a progressive condition marked by ongoing airflow restriction, breathlessness, and declining functional capacity. Clinicians often pair inspiratory muscle training (IMT) with breathing-retraining approaches such as diaphragmatic breathing (DB) and pursed-lip breathing (PLB) to strengthen pulmonary rehabilitation outcomes, yet head-to-head evidence comparing these two pairings is sparse.

Objective: To compare DB paired with IMT against PLB paired with IMT with respect to pulmonary function, dyspnea, blood oxygen levels, and walking capacity in people living with moderate COPD.

Methods: This randomized, comparative, pre-post trial enrolled 60 patients with GOLD stage 2 COPD (ages 18–80) from a tertiary care hospital, split evenly by a chit-based random draw into two arms. Group A (n=30) practiced DB together with breather-device IMT, and Group B (n=30) practiced PLB together with the same device-based IMT, each for 15–20 minutes twice a day across two weeks. The six-minute walk distance (6MWD), Modified Borg Dyspnea Scale, peak expiratory flow rate (PEFR), and arterial oxygen saturation (SpO_2) were captured before and after the intervention period. Pre-post shifts within each arm were tested with the Wilcoxon signed-rank test, arm-to-arm differences with the Mann-Whitney U test, and baseline-controlled comparisons with analysis of covariance (ANCOVA).

Results: Both arms improved significantly from baseline across every measure ($p<0.001$). Group B's gains exceeded Group A's for PEFR (mean change 205.00±45.69 vs. 87.33±29.00 L/min), SpO_2 (7.93±2.83% vs. 3.00±1.49%), Modified Borg score (−1.80±0.78 vs. −0.93±0.58), and 6MWD (156.17±38.50 m vs. 85.83±21.50 m), with all between-arm comparisons reaching $p<0.001$. After controlling for baseline value, age, and gender, ANCOVA confirmed a statistically significant advantage for Group B on all four measures (all $p<0.001$).

Conclusion: Both breathing strategies paired with IMT delivered clinically worthwhile short-term gains for people with COPD, but the PLB-plus-IMT combination outperformed DB-plus-IMT by a clear margin. Device-assisted PLB may therefore be a practical, inexpensive addition to pulmonary rehabilitation programs for patients with moderate COPD.

KEYWORDS: chronic obstructive pulmonary disease; pursed-lip breathing; diaphragmatic breathing; inspiratory muscle training; six-minute walk test; peak expiratory flow rate; pulmonary rehabilitation

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a widespread, largely preventable illness marked by lasting respiratory symptoms and reduced airflow, arising from abnormalities of the airways and/or alveoli that most commonly follow substantial exposure to harmful particles or gases [1]. The 2023 Global Initiative for Chronic Obstructive Lung Disease (GOLD) report estimates that roughly 384 million people worldwide live with COPD, with India contributing an estimated 55 million of these cases, and the condition remains one of the world's leading sources of chronic illness and death [1,2]. Cigarette smoking is still the dominant risk factor in industrialized countries, but epidemiological evidence shows that between one-quarter and nearly half of COPD patients have never smoked, pointing to biomass fuel smoke, workplace pollutants, ambient air pollution, and early-life lung insults as meaningful contributors, especially in lower- and middle-income settings [3].

The disease's core pathological feature is persistent airway inflammation, which thickens airway walls, increases mucus production, and destroys alveolar tissue (emphysema); together these changes cause expiratory airflow limitation, dynamic lung hyperinflation, and air trapping [4]. Such mechanical changes place the diaphragm and the accessory muscles of inspiration at a disadvantage, raising the effort needed to breathe and driving exertional breathlessness, poorer exercise tolerance, and progressive physical decline [4,5]. For this reason, therapies that target respiratory muscle performance and breathing patterns form a core part of pulmonary rehabilitation.

Inspiratory muscle training (IMT), typically delivered through resistive or threshold devices such as the Breather, is a well-recognized way to build inspiratory muscle strength and endurance, and has been shown to ease breathlessness and improve quality of life among people with COPD [6,7]. Breathing-retraining methods are commonly used together with IMT to further refine ventilatory mechanics. Diaphragmatic breathing (DB) emphasizes abdominal, diaphragm-led inhalation to lessen dependence on accessory muscles and sharpen ventilatory efficiency [8]. Pursed-lip breathing (PLB), on the other hand, involves a lengthened exhalation through partly closed lips, generating positive pressure that props the airways open for longer, slows dynamic airway collapse, limits air trapping, and reduces breathing rate — collectively improving alveolar ventilation and gas exchange [9,10].

Although the separate benefits of DB, PLB, and IMT are individually documented, the literature remains mixed, and few trials have directly pitted DB+IMT against PLB+IMT while using one consistent resistive device and outcome battery [11,12]. Determining which pairing yields greater benefit carries practical weight for clinicians building time- and resource-constrained rehabilitation protocols, particularly in inpatient and subacute settings. We therefore designed a randomized comparative trial evaluating DB with IMT against PLB with IMT, both delivered through a breather device, on pulmonary function (PEFR), oxygen saturation (SpO_2), dyspnea (Modified Borg Dyspnea Scale), and walking capacity (six-minute walk test) among patients with moderate (GOLD stage 2) COPD. We hypothesized that the two approaches would produce differing results across these outcome domains.

2. MATERIALS AND METHODS

2.1 Study design and setting

This randomized, comparative, pre-post trial ran across 12 months within the general medicine, respiratory medicine, and pulmonary medicine wards, as well as the critical care, intensive care, surgical intensive care, and medical intensive care units, of a tertiary care teaching hospital in Bangalore, Karnataka, India. Institutional Ethics Committee approval was secured beforehand, and every participant provided signed informed consent before joining, in line with the Declaration of Helsinki.

2.2 Participants

Sixty patients of either sex, aged 18–80 years, with a confirmed clinical and spirometric diagnosis of moderate (GOLD stage 2) COPD and the ability to follow verbal instructions and exercise independently, were recruited. Patients were not eligible if they had a history of pulmonary tuberculosis, lung abscess, pneumothorax, haemothorax, pulmonary embolism, pleural effusion, COVID-19 or another communicable illness, rib fracture, a restrictive lung condition, osteoporosis, unstable angina, a recent heart attack, spinal cord injury, diastasis recti, lung cancer, or an inability to understand or complete study procedures.

2.3 Sample size

The sample size was calculated from the mean and standard deviation of a comparable outcome reported in earlier work, using a two-sided alpha of 0.05 and 90% power ($Z\alpha$=1.96, $Z\beta$=1.28); the resulting figure was rounded up to 30 participants in each arm, giving a total of 60.

2.4 Randomization and group allocation

Group assignment used simple random allocation via a chit draw: 60 chits (30 labeled Group A, 30 labeled Group B) were placed in a box, and each participant drew one chit without replacement to fix their group.

2.5 Interventions

Both arms followed a structured two-week program, with two 15–20 minute sessions daily.

Group A (DB + IMT): participants performed diaphragmatic breathing while semi-reclined, one hand on the upper chest and one on the abdomen, taking slow diaphragm-led breaths in over two seconds for 5–6 repetitions across five sets, followed by resistive breather-device IMT performed upright and seated (forceful two-to-three second inhalation and exhalation with a brief pause, 10 repetitions across two sets, at a resistance that avoided fatigue).

Group B (PLB + IMT): participants performed pursed-lip breathing while seated comfortably or semi-reclined, inhaling through the nose over two seconds and exhaling slowly through pursed lips for 5–6 repetitions across five sets, followed by the same breather-device IMT routine used for Group A.

Each participant received a breather device free of charge, which was washed with warm water and mild detergent after every session for hygiene.

2.6 Outcome measures

All measures were recorded at baseline (day 1, before intervention) and again at the close of the two-week program, by an assessor following a standardized protocol.

Six-minute walk test (6MWT): conducted per the 2002 American Thoracic Society guidelines on a flat, 30-metre marked corridor; total distance walked in six minutes (6MWD, in metres) served as the functional exercise capacity measure.

Modified Borg Dyspnea Scale: a 0–10 category-ratio scale rating perceived breathlessness intensity, where higher scores reflect greater dyspnea.

Peak expiratory flow rate (PEFR): recorded with a Wright peak flow meter, taking the best of three forced expiratory attempts, in litres per minute.
Arterial oxygen saturation (SpO_2): recorded with a pulse oximeter.

2.7 Statistical analysis
Analyses were carried out in Python 3 using the pandas, SciPy, and statsmodels libraries; a p-value below 0.05 was treated as statistically significant. Continuous variables are summarized as mean ± standard deviation. Baseline comparability between arms was checked for age with the Mann-Whitney U test and for sex distribution with the chi-square test of independence. Within-arm pre-to-post changes for each measure were tested with the Wilcoxon signed-rank test, while arm-to-arm comparisons of pre-, post-, and change scores used the Mann-Whitney U test. Analysis of covariance (ANCOVA) was also run for every outcome, entering the post-intervention value as the dependent variable, group as the fixed factor, and the matching baseline value, age, and sex as covariates, to yield baseline-adjusted group estimates.

3. RESULTS
All sixty enrolled participants (30 per arm) completed the study, with no dropouts. The two arms were statistically comparable at baseline for age (Group A: 62.10±12.77 years; Group B: 60.17±11.33 years; Mann-Whitney U=401.50, p=0.477) and sex distribution (Group A: 73.3% male; Group B: 50.0% male; χ^2=3.45, df=1, p=0.063), indicating the randomization was successful (Table 1, Table 2).

3.1 Baseline comparability

Table 1. Baseline demographic comparability between groups.

Variable	Group A (DB+IMT)	Group B (PLB+IMT)	Test statistic	p-value
Age, years (mean ± SD)	62.10 ± 12.77	60.17 ± 11.33	U = 401.50	0.477
Male, n (%)	22 (73.3%)	15 (50.0%)	χ^2 = 3.45	0.063
Female, n (%)	8 (26.7%)	15 (50.0%)		

3.2 Within- and between-group outcome changes
Both arms showed statistically significant within-group gains from baseline to two weeks on every outcome (Wilcoxon signed-rank test, p<0.001 in each case). When change scores were compared across arms using the Mann-Whitney U test, Group B showed a larger magnitude of improvement than Group A for every measure (Table 2).

Table 2. Within-group (pre→post, mean±SD) and between-group change-score comparisons for all outcomes. All within-group comparisons (Wilcoxon signed-rank test) reached p<0.001.

Outcome	Group A pre→post	Group B pre→post	Mean change A vs B	Between-group U	p-value
PEFR (L/min)	137.67±27.88 → 225.00±36.37	223.00±55.66 → 428.00±65.62	87.33±29.00 vs 205.00±45.69	13.50	<0.001
SpO_2 (%)	93.53±2.37 → 96.53±1.78	90.60±3.74 → 98.53±1.31	3.00±1.49 vs 7.93±2.83	41.50	<0.001
Modified Borg score	4.77±0.57 → 3.83±0.53	3.13±1.17 → 1.33±0.88	−0.93±0.58 vs −1.80±0.78	161.50	<0.001
6MWD (m)	320.00±16.19 → 405.83±24.36	321.00±15.39 → 477.17±36.14	85.83±21.50 vs 156.17±38.50	49.00	<0.001

Percentage gains from baseline were consistently higher in Group B than Group A: PEFR rose by 91.93% in Group B against 63.43% in Group A; SpO_2 rose by 8.75% versus 3.21%; Modified Borg score fell by 57.51% versus 19.71%; and 6MWD rose by 48.65% versus 26.82% (Table 3).

Table 3. Percentage change from baseline for each outcome, by group.

Outcome	% change, Group A	% change, Group B	Direction of benefit
PEFR	63.43%	91.93%	Increase = better
SpO_2	3.21%	8.75%	Increase = better
Modified Borg score	−19.71%	−57.51%	Decrease = better
6MWD	26.82%	48.65%	Increase = better

3.3 Baseline-adjusted (ANCOVA) analysis
To account for potential confounding from baseline value, age, and sex, an ANCOVA model was fitted separately for each outcome. Even after this adjustment, Group B retained significantly better post-intervention estimates than Group A across all four measures (Table 4).

Table 4. ANCOVA-adjusted group means (adjusted for baseline value, age, and sex) and between-group differences for all outcomes.

Outcome	Adj. mean A	Adj. mean B	Adj. diff (B−A)	95% CI	F	p
6MWD (m)	404.61	478.39	73.78	57.64 to 89.92	83.92	<0.001
Modified Borg	3.41	1.76	−1.65	−2.06 to −1.24	65.78	<0.001

Outcome	Adj. mean A	Adj. mean B	Adj. diff (B−A)	95% CI	F	p
PEFR (L/min)	260.69	392.31	131.62	103.51 to 159.72	88.09	<0.001
SpO_2 (%)	96.05	99.02	2.97	2.35 to 3.58	94.23	<0.001

Taken together, the unadjusted within-group results, the unadjusted between-group change-score comparisons, and the baseline-adjusted ANCOVA all point to the same conclusion: both interventions produced meaningful improvement, but pairing PLB with IMT produced a consistently larger benefit than pairing DB with IMT across pulmonary function, oxygenation, dyspnea, and walking capacity.

4. DISCUSSION

This randomized comparative trial found that two weeks of either diaphragmatic breathing or pursed-lip breathing, each paired with resistive-device inspiratory muscle training, yielded statistically and clinically meaningful gains in pulmonary function, breathlessness, blood oxygen levels, and walking capacity among patients with moderate COPD. Notably, the PLB-plus-IMT pairing outperformed the DB-plus-IMT pairing on every outcome measured, a pattern that held even after controlling for baseline values, age, and sex through ANCOVA.

The larger benefit seen with PLB fits with known respiratory physiology. Extending exhalation through partly pursed lips builds back-pressure in the airways that keeps small airways open longer, curbs expiratory flow limitation and dynamic air trapping, and slows breathing rate while raising tidal volume — all of which improve alveolar ventilation and gas exchange [9,10,13]. These mechanisms offer a plausible explanation for the larger PEFR and SpO_2 gains recorded in Group B. Bianchi and colleagues likewise reported favorable shifts in chest wall movement and reduced breathlessness with PLB in COPD patients, while Nield and colleagues found PLB eased dyspnea and improved health-related quality of life compared with usual care [13,14]. Our findings also align with the meta-analysis by Yang and colleagues, which reported that pairing PLB with diaphragmatic breathing yielded worthwhile gains in lung function and exercise tolerance among COPD patients, and with the randomized trial by Ceyhan and Tekinsoy Kartin, where breathing exercises incorporating PLB lessened dyspnea severity and raised quality of life [15,16].

Diaphragmatic breathing, by comparison, aims to reduce reliance on accessory inspiratory muscles by encouraging abdominal, diaphragm-led inhalation, and earlier work has linked it to gains in respiratory function and exercise tolerance in COPD [17,18]. That said, some authors note that DB can be less effective — or even counterproductive — for certain patients with advanced hyperinflation, since a flattened, mechanically compromised diaphragm may instead trigger asynchronous or "paradoxical" abdominal wall movement during attempted diaphragmatic breathing; this may help account for the comparatively modest gains seen with DB in our sample [18,19]. Even so, the within-group improvement in Group A was itself considerable and statistically significant, supporting DB as a useful, if less powerful, complement to IMT.

Adding IMT to both breathing methods likely drove much of the overall improvement seen in both arms. In a systematic review and meta-analysis, Han and colleagues concluded that IMT meaningfully strengthens inspiratory muscles, eases dyspnea, and raises quality of life for people with COPD, while Mohammed and colleagues reported that threshold IMT produced greater gains in walking distance, lung function, and breathlessness than a combined DB-plus-PLB protocol lacking device-based resistance training — underscoring the importance of resistance-based inspiratory training as a central rehabilitation element [6,20]. The Breather device used here provides adjustable, non-fatiguing resistance during both inhalation and exhalation and has been described elsewhere as an effective, non-invasive way to strengthen respiratory muscles and improve breathing efficiency [7].

Our results are further supported by Mulyadi and colleagues, who reported improved functional capacity and quality of life in stable COPD patients following a structured program combining PLB and DB, and by Sulistyanto and colleagues, who observed higher SpO_2 and lower respiratory rate with PLB practice — findings that echo the PEFR, SpO_2, and dyspnea gains seen in the present study [21,22]. Mendes and colleagues similarly found that combined PLB and DB favorably shifted chest wall motion and oxygenation, while Mohamed reported that positioning strategies combined with PLB eased dyspnea and anxiety, reinforcing the broader case for integrating breathing retraining into routine COPD care [23,24].

From a practical standpoint, both interventions are low-cost, need no specialized equipment beyond an inexpensive resistive breather device, can be taught in a single session, and can be practiced by patients largely on their own, making them well suited to inpatient and outpatient pulmonary rehabilitation pathways, particularly where resources are limited. Given the size of the advantage seen for PLB with IMT across all four outcome domains in this study, clinicians might reasonably favor PLB when only one breathing technique can be taught within limited rehabilitation time, while still recognizing that DB offers real benefit where PLB is not tolerated or preferred.

4.1 LIMITATIONS

Several limitations merit consideration. First, the enrolled sample of 60 participants (30 per arm), although sufficient to detect within-group change, may have offered limited power to detect subtler between-arm differences, particularly for SpO_2 and Modified Borg Dyspnea Scale scores. Second, the intervention lasted only two weeks; while gains were clear within this window, whether they persist beyond it was not assessed, and longer follow-up would help clarify whether benefits are sustained or grow with continued practice. Third, the outcome battery excluded validated, patient-reported quality-of-life tools such as the St. George's Respiratory Questionnaire or the COPD Assessment Test, which would have captured broader effects on daily functioning and psychological wellbeing. Fourth, this single-center study was conducted at one tertiary care hospital, which may limit how well the findings generalize to other settings, regions, or patient groups. Fifth, the Modified Borg Dyspnea Scale is inherently subjective and can be shaped by a patient's mood or motivation, introducing possible measurement bias despite standardized administration. Finally, although sessions were supervised, adherence and technique accuracy during unsupervised practice depended on self-report, and small deviations in technique could have added variability to the outcomes across participants.

5. CONCLUSION

In patients with moderate COPD, both diaphragmatic breathing and pursed-lip breathing, each paired with resistive-device inspiratory muscle training, produced statistically significant gains in pulmonary function, oxygen saturation, breathlessness, and walking capacity across a two-week period. However, the pursed-lip breathing and IMT combination produced consistently larger gains across every outcome measured, a result that held up after adjusting for baseline values, age, and sex. These findings support pairing pursed-lip breathing with inspiratory muscle training as a simple, low-cost, effective element of pulmonary rehabilitation for patients with moderate COPD, while also confirming that diaphragmatic breathing paired with IMT offers real, if comparatively smaller, benefit. Larger multicenter trials with longer intervention and follow-up periods and validated quality-of-life measures are needed to confirm these results and clarify how durable the treatment effects are.

DECLARATIONS

Ethics approval and consent to participate

The Institutional Ethics Committee reviewed and approved the study before it began, and every participant (or a legal guardian, where relevant) gave written informed consent prior to enrolment.

Consent for publication

Not applicable.

Availability of data and materials

The datasets produced and examined in this study can be obtained from the corresponding author upon reasonable request.

Competing interests

The authors report no competing interests.

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Authors' contributions

MS: conceptualization, data collection, formal analysis, original draft. PS: supervision, study design, methodology, review and editing. KHK: clinical supervision, patient screening, review and editing. All authors reviewed and approved the final manuscript.

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