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EFFECTIVENESS OF INSPIRATORY MUSCLE TRAINING VERSUS RESPIRATORY PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION ON PULMONARY FUNCTION PARAMETERS AND FUNCTIONAL TOLERANCE AMONG PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT
Chronic obstructive pulmonary disease or COPD is a progressive respiratory illness characterized by limited exercise capacity, respiratory muscle dysfunction and limitation in airflow that is destructive in nature. These symptoms greatly reduce quality of life. Inspiratory Muscle Training (IMT) and respiratory Proprioceptive Neuromuscular Facilitation (PNF) have become common rehabilitation strategies, yet comparative evidence is scarce. The randomized controlled trial aims to assess the effect of respiratory PNF & IMT on pulmonary function & functional exercise capacity in stable COPD subjects. A total of forty patients with GOLD Stage II and III COPD between the ages of 45 and 60 were randomized into two groups. Group A received IMT using a threshold device at 30% of maximal inspiratory pressure, while Group B received respiratory PNF techniques. Both interventions were administered for 20 minutes, three times daily, over four weeks. Forced Vital Capacity (FVC), FEV1/FVC ratio, Forced Expiratory Volume in One Second (FEV1) and Six-Minute Walk Distance (6MWD) were some of the outcome measures used. All the end results showed significant improvements in both groups ($p < 0.001$). However, when looking at FEV1 ($p < 0.001$), FVC ($p = 0.012$), FEV1/FVC ratio ($p = 0.013$) and 6MWD ($p < 0.001$), the PNF group performed much better than the IMT group. These results imply that respiratory PNF may be more efficient than IMT in enhancing pulmonary function and functional exercise capacity in COPD patients.

KEYWORDS: Chronic Obstructive Pulmonary Disease, Inspiratory Muscle Training, Respiratory Proprioceptive Neuromuscular Facilitation, Pulmonary Function Test, Six-Minute Walk Test

INTRODUCTION
Chronic obstructive pulmonary disease or COPD, is a lung condition that slowly gets worse over time. It causes difficulty in breathing because the airways become narrow and inflamed. The lungs also change in structure, making it harder for air to move in and out. COPD is often caused by long-term exposure to harmful substances like cigarette smoke, polluted air and other chemicals found in the environment or at work (1). COPD remains a major concern in global health, leading to high morbidity, mortality and a significant burden on the healthcare system (2). The Global Initiative for Chronic Obstructive Lung Disease (GOLD) says COPD is one of the leading causes of death around the world. More people are getting it because of older populations, continued exposure to harmful factors and more people living in cities (3).

Individuals with COPD commonly exhibit signs including breathlessness, persistent cough, sputum generation and diminished stamina, all of which severely affect daily functioning and the quality of life (4,5). Physical deconditioning, dependency rise and psychological distress are commonly observed alongside disease progression (6). These changes alter respiratory mechanics, resulting in diaphragmatic flattening and reduced efficiency of inspiratory muscles (7).

Respiratory muscle dysfunction plays a crucial role in exercise intolerance for people with COPD. Inspiratory muscle weakness increases the work of breathing and contributes to early fatigue and dyspnoea during physical activity (8). Therefore, improving respiratory muscle performance is a critical component of COPD management. Pulmonary rehabilitation is universally acknowledged as a fundamental component of non-pharmacological therapy, integrating exercise programs, respiratory strategies, educational components and behavioural interventions to enhance functional ability and improving quality of life (9).

Among the methods used in rehabilitation, Inspiratory Muscle Training (IMT) has become very popular because it helps strengthen the muscles used for breathing, lessens the feeling of breathlessness and boosts the ability to perform physical activities (10-12). IMT applies a resistive load to the inspiratory muscles, promoting physiological adaptations similar to skeletal muscle training. On the other hand, respiratory Proprioceptive Neuromuscular Facilitation (PNF) techniques aim to optimize breathing mechanics through manual facilitation, stretching and resistance applied to the thoracic cage. These techniques enhance neuromuscular coordination, improve chest wall mobility and facilitate efficient breathing patterns (13).

Although both IMT and respiratory PNF are widely used in pulmonary rehabilitation and have demonstrated individual effectiveness, there is limited comparative evidence evaluating their relative efficacy in improving respiratory function and functional capacity in COPD patients. Most existing studies have investigated these interventions independently, leaving a gap in direct clinical comparison.

This study aims to check how well Inspiratory Muscle Training and respiratory Proprioceptive Neuromuscular Facilitation work in improving lung function and exercise ability in people with chronic obstructive pulmonary disease who are in a stable condition. The results of this study could help improve physiotherapy treatments used in lung rehabilitation and support better, evidencebased care in clinical settings.

METHODOLOGY

Study Design

A study compared the effectiveness of Inspiratory Muscle Training (IMT) and Respiratory Proprioceptive Neuromuscular Facilitation (PNF) on lung function and ability to exercise in people with Chronic Obstructive Pulmonary Disease (COPD). The study was approved by the Institutional Scientific Review Board at Saveetha Institute of Medical and Technical Sciences (Ref No: 035/05/2025/ISRB/PGSR/SCPT). Before taking part in the study, all participants gave their consent, following the guidelines from the Declaration of Helsinki.

Participants

Forty patients who were diagnosed with Chronic Obstructive Pulmonary Disease (COPD) at GOLD Stage II or III, aged between 45 and 60 years, were selected using convenience sampling from the outpatient department. The sample size was determined using G*Power software (version 3.1.9.7) with an expected effect size of 0.55, an alpha level of 0.05 and a statistical power of 0.95 for a comparison between two groups. The minimum required sample size was 38, so 40 participants were included in the study. All participants were in a stable condition and able to undergo pulmonary function tests and the Six-Minute Walk Test (6MWT). Each participant gave written informed consent before joining the study. They were chosen through convenience sampling from the outpatient department and then randomly assigned to one of two groups using a simple random method.

Inclusion and Exclusion Criteria

Participants were included if they were found to have Chronic Obstructive Pulmonary Disease (COPD) based on spirometry and clinical evaluation, classified under GOLD Stage II and III and aged between 45 and 60 years. Only clinically stable individuals, with no recent exacerbations, who were able to perform pulmonary rehabilitation exercises and outcome assessments such as pulmonary function testing (PFT) and the Six-Minute Walk Test (6MWT), were considered. Informed consent was mandatory for all participants prior to their participation. Participants were excluded if they had an acute exacerbation of COPD requiring hospitalization, severe cardiovascular conditions that contraindicated exercise, significant musculoskeletal disorders limiting mobility, neurological or cognitive impairments affecting their ability to follow instructions or severe psychiatric illness that could interfere with participation in the rehabilitation program.

Study procedure

After getting approval from an ethics review board, people who met the study’s requirements were selected through convenience sampling from the outpatient area. Each person was told about the study process in a clear way and they had to sign a document agreeing to take part. Before starting, they had some tests to check their lung function, like FEV1, FVC and the FEV1/FVC ratio using a spirometer. They also did the Six-Minute Walk Test (6MWT) to measure how well their lungs work during exercise, following standard methods.

Participants were then randomly allocated into two groups (n = 20 each) using a simple randomization method. The Inspiratory Muscle Training (IMT) group underwent training using a Threshold IMT device set at 30% of maximal inspiratory pressure (MIP). Participants were instructed to perform slow, deep inhalation against resistance, followed by relaxed exhalation. The training was conducted in a seated position, ensuring proper posture and diaphragmatic breathing pattern. Load progression and technique were supervised to maintain consistency and effectiveness.

The Respiratory Proprioceptive Neuromuscular Facilitation (PNF) group received therapistadministered respiratory PNF techniques, including intercostal stretch, posterior basal lift, rhythmic initiation, timing for emphasis and diaphragmatic facilitation. Manual contacts, resistance and verbal cues were applied to enhance chest wall expansion, improve neuromuscular coordination and facilitate efficient breathing patterns. A trained physiotherapist administered all techniques to ensure standardization.

Both interventions were performed for 20 minutes per session, three times daily, over a period of four weeks under supervision. Participants were monitored throughout the intervention period to ensure adherence, correct technique and safety and any adverse events were noted.

Following the four-week intervention, all outcome measures were reassessed with procedures identical to those used at baseline. The collected data were recorded systematically and prepared for statistical analysis.

Outcome Measures

Primary outcome measures included pulmonary function parameters assessed using spirometry. FEV_1, Forced Vital Capacity (FVC) and by using a calibrated spirometer according to standardized testing protocols the ratio of FEV_1 to FVC were measured. Participants were instructed to perform maximal inhalation followed by a forceful and sustained expiration. The best value out of three acceptable trials was recorded for analysis.

Functional exercise capacity was assessed as a secondary outcome using the Six-Minute Walk Test (6MWT). Participants were instructed to walk at their own pace along a measured corridor for six minutes and the total distance covered was recorded in meters. Standardized instructions and encouragement were provided and rest periods were allowed if required. All outcome measures were recorded at baseline (pre-test) and after four weeks of intervention (post-test) using the same standardized procedures.

Statistical Analysis

Using SPSS 27.0, the data were analyzed and normality was checked with the Shapiro-Wilk test, showing normal distribution ($p > 0.05$). Mean ± standard deviation was used to express the statistics. Paired t-tests evaluated differences within the same groups between pre-test and posttest values, while independent t-tests were applied for comparisons between different groups. A pvalue less than 0.05 was accepted as statistically meaningful.

RESULTS Baseline Comparison

At the start, there were no statistically detectable discrepancies between the Inspiratory Muscle Training (IMT) group and the Respiratory Proprioceptive Neuromuscular Facilitation (PNF) group regarding any of the outcome assessments. The mean FEV_1 was 1.1735 ± 0.0659 L in the IMT group and 1.1690 ± 0.0663 L in the PNF group ($p = 0.831$). Similarly, FVC values were 2.0535 ±
0.0980 L and 2.0240 ± 0.0953 L ($p = 0.341$) and the FEV_1/FVC ratio was 57.60 ± 2.703% and 58.10 ± 2.732% ($p = 0.564$) in the IMT and PNF groups, respectively. The Six-Minute Walk Distance (6MWD) was also comparable between the IMT group (306.45 ± 8.22 m) and the PNF group (308.60 ± 7.77 m) ($p = 0.401$). These findings indicate that both groups were homogeneous prior to the intervention.

Between-Group Comparison

Following a four-week period of intervention, differences were identified in all outcome metrics between the groups (Table 1). The PNF group demonstrated significantly greater improvements compared to the IMT group. Post-intervention FEV_1 was higher in the PNF group (1.4170 ± 0.0783 L) than in the IMT group (1.3240 ± 0.0761 L) ($p < 0.001$). Similarly, FVC was significantly greater in the PNF group (2.3185 ± 0.1138 L) compared to the IMT group (2.2260 ± 0.1103 L) ($p = 0.012$). The FEV_1/FVC ratio was also higher in the PNF group (62.15 ± 3.281%) than in the IMT group (59.80 ± 2.419%) ($p = 0.013$). Functional exercise capacity, as measured by 6MWD, showed a marked improvement in the PNF group (368.65 ± 7.77 m) compared to the IMT group (339.35 ±
8.22 m) ($p < 0.001$).

Within-Group Comparison

Following the intervention, both groups exhibited statistically significant improvements across all outcome measures (Table 2). In the IMT group, FEV_1 improved from 1.1735 ± 0.0659 L to 1.3240 ± 0.0761 L and FVC increased from 2.0535 ± 0.0980 L to 2.2260 ± 0.1103 L ($p < 0.001$). The FEV_1/FVC ratio increased from 57.60 ± 2.703% to 59.80 ± 2.419% ($p < 0.001$), while 6MWD improved from 306.45 ± 8.22 m to 339.35 ± 8.22 m ($p < 0.001$).

Similarly, the PNF group showed significant improvements, with FEV_1 increasing from 1.1690 ± 0.0663 L to 1.4170 ± 0.0783 L and FVC from 2.0240 ± 0.0953 L to 2.3185 ± 0.1138 L ($p < 0.001$). The FEV_1/FVC ratio improved from 58.10 ± 2.732% to 62.15 ± 3.281% ($p < 0.001$) and 6MWD increased from 308.60 ± 7.77 m to 368.65 ± 7.77 m ($p < 0.001$).

DISCUSSION

The current study looked at how Inspiratory Muscle Training (IMT) and respiratory Proprioceptive
Neuromuscular Facilitation (PNF) affect lung function and how well people with stable Chronic Obstructive Pulmonary Disease (COPD) can perform daily activities. COPD is a long-term condition that causes difficulty in breathing, ongoing lung inflammation and gradual weakening of the muscles used for breathing. These issues make it hard for people to exercise and lower their overall quality of life. Changes in the structure of the lungs and overinflation of the airways reduce the efficiency of the diaphragm, make breathing more difficult and result in shortness of breath and less ability to do everyday tasks.

COPD is a progressive and heterogeneous disease that requires a comprehensive and individualized management approach. Current worldwide recommendations advocate for the combination of pharmacological and non-pharmacological approaches, such as pulmonary rehabilitation and patient education, with the objectives of symptom management, exacerbation prevention and quality of life enhancement (14). These guidelines emphasize a multidisciplinary, patient-centered approach, where treatment is tailored according to disease severity and exacerbation risk (15).

Among non-drug treatments, problems with the muscles used for breathing play a major role in limiting how well someone can function. Inspiratory Muscle Training (IMT) has become a useful treatment that helps with weak breathing muscles.

This training greatly improves the strength of the muscles used to breathe, reduces shortness of breath and helps people recover better, especially those who have had serious flare-ups of COPD, as shown by past studies (16). Systematic reviews further indicate that IMT can improve respiratory muscle performance and may provide modest benefits in exercise tolerance and dyspnoea, although outcomes may vary depending on training protocols and patient characteristics (17). Using IMT along with pulmonary rehabilitation leads to better results in improving exercise ability and reducing symptoms than using just one of these treatments by itself (18).

Pulmonary rehabilitation remains a key part of treating COPD because there is strong evidence showing it helps people exercise more, reduces the need for hospital visits and improves their quality of life (19). Good quality research shows that pulmonary rehabilitation leads to meaningful improvements in shortness of breath, how well someone can do daily activities and their overall sense of well-being, regardless of how severe their COPD is (20). Additionally, it has been demonstrated that starting pulmonary rehabilitation as soon as possible after acute exacerbations greatly lowers hospital readmission rates and enhances recovery (21).

Beyond pulmonary impairment, COPD is becoming more widely acknowledged as a systemic illness with extra pulmonary symptoms like weight loss, cardiovascular comorbidities and skeletal muscle weakness, all of which lower functional ability and raise mortality (22). This systemic involvement further reinforces the need for comprehensive rehabilitation strategies that address both respiratory and peripheral muscle dysfunction.

In addition, inspiratory muscle training has been shown to enhance the effectiveness of ventilatory support strategies, improving exercise tolerance and dyspnoea control in COPD patients, suggesting a synergistic benefit when combined with assisted ventilation techniques (23). Overall, current evidence consistently supports that optimal COPD management requires a multidisciplinary approach combining pharmacological therapy, pulmonary rehabilitation and targeted respiratory muscle training. While pulmonary rehabilitation improves functional ability and quality of life, IMT helps strengthen respiratory muscles and lessen dyspnoea. These therapies have synergistic and additive advantages when combined, making them an essential part of contemporary COPD therapy techniques (24,25).

The limitations of the current study should be considered when interpreting the results. In comparison to the estimated sample size, the sample size was rather small (n = 40), which would restrict how far the findings can be applied. The intervention period was limited to four weeks and long-term effects were not assessed. Participants were recruited using convenience sampling from a single centre, which may introduce selection bias. Furthermore, other significant clinical outcomes including the severity of dyspnea and quality of life were not assessed; instead, the study mainly concentrated on pulmonary function and functional exercise capacity. Because of the nature of the therapies, which could have generated performance bias, it was not possible to blind participants and therapists.

Future studies are recommended to include larger sample sizes with multicentre recruitment to enhance generalizability. Longer follow-up durations are necessary to determine the sustainability of treatment effects. Further research should incorporate additional outcome measures such as dyspnoea scales, quality of life assessments and respiratory muscle strength evaluation to provide a more comprehensive understanding. Studies exploring the combined effects of respiratory Proprioceptive Neuromuscular Facilitation and Inspiratory Muscle Training may help identify potential synergistic benefits. Standardization of intervention protocols and objective monitoring of adherence are also recommended to strengthen clinical applicability.

CONCLUSION

The results of this study show that in patients with stable Chronic Obstructive Pulmonary Disease (COPD), both respiratory Proprioceptive Neuromuscular Facilitation (PNF) and Inspiratory Muscle Training (IMT) are beneficial in enhancing pulmonary function and functional exercise capacity. Respiratory PNF, on the other hand, considerably outperformed IMT in all assessed outcomes, demonstrating its higher efficacy in improving respiratory mechanics and functional tolerance.

These results suggest that incorporating respiratory PNF techniques into pulmonary rehabilitation programs may provide additional clinical benefits and improve patient outcomes. The study supports the use of evidence-based physiotherapy interventions in the comprehensive management of COPD to optimize functional performance and quality of life.

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Conflict of interest

The authors doesn't have any conflicts of interest.

Declaration of Artificial Intelligence (AI) Assistance

The authors declare that the ideas, data and text of their research are all their own. They only used AI tools to help with writing in English and to fix grammar. The authors are completely responsible for making sure the work is accurate, honest and original.

Authors Contribution
Author 1: Conceptualization, Methodology, Software, Validation, Formal Analysis, Investigation,
Writing - Original Draft Preparation; Author 2: Methodology, Investigation, Data Curation, Writing - Original Draft Preparation; Author 3: Validation, Formal Analysis, Writing - Review and Editing.; Author 4: Supervision, Conceptualization, Writing - Review and Editing, Project Administration. All authors have read and agreed to the published version of the manuscript; Author 5: Guidance to clear ethical approval

Ethical Approval
The Saveetha Institute of Medical and Technical Sciences' Institutional Scientific Review Board approved the study (Reference Number: 035/05/2025/ISRB/PGSR/SCPT). Following the Declaration of Helsinki, every participant gave written consent before taking part in the study.

Data Availability
Upon reasonable request, the corresponding author will provide the data supporting the study's conclusions.

Abbreviations
COPD: Chronic Obstructive Pulmonary Disease; IMT: Inspiratory Muscle Training; PNF: Proprioceptive Neuromuscular Facilitation; PFT: Pulmonary Function Test; FEV_1: Forced Expiratory Volume in one second; FVC: Forced Vital Capacity; 6MWT: Six-Minute Walk Test; 6MWD: Six-Minute Walk Distance; MIP: Maximal Inspiratory Pressure.

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Tables

Table 1: Comparison of pulmonary function and functional capacity between IMT and PNF groups

Parameter	**Test**	**IMT (Mean ± SD)**	**PNF (Mean ± SD)**	**t value**	**df**	**p value**
FEV_1 (L)	Pre	1.1735 ± 0.0659	1.1690 ± 0.0663	0.214	38	0.831
	Post	1.3240 ± 0.0761	1.4170 ± 0.0783	-3.876	38	<0.001
FVC (L)	Pre	2.0535 ± 0.0980	2.0240 ± 0.0953	0.965	38	0.341
	Post	2.2260 ± 0.1103	2.3185 ± 0.1138	-2.640	38	0.012
FEV_1/FVC (%)	Pre	57.60 ± 2.703	58.10 ± 2.732	-0.582	38	0.564
Parameter	**Test**	**IMT (Mean ± SD)**	**PNF (Mean ± SD)**	**t value**	**df**	**p value**
	Post	59.80 ± 2.419	62.15 ± 3.281	-2.589	38	0.013
6-Minute Walk Distance (m)	Pre	306.45 ± 8.22	308.60 ± 7.77	-0.850	38	0.401
	Post	339.35 ± 8.22	368.65 ± 7.77	-11.920	38	<0.001

Note: Values are expressed as mean ± standard deviation. IMT: Inspiratory Muscle Training; PNF: Proprioceptive Neuromuscular Facilitation; FEV_1: Forced Expiratory Volume in one second; FVC: Forced Vital Capacity. df: degrees of freedom. $p < 0.05$ considered statistically significant.

Table 2: Within-group comparison of pulmonary function and functional capacity in IMT and PNF groups (pre- and post-intervention)

Parameter	**Group**	**Pre (Mean ± SD)**	**Post (Mean ± SD)**	**t value**	**p value**
FEV_1 (L)	IMT	1.1735 ± 0.0659	1.3240 ± 0.0761	-32.608	<0.001
	PNF	1.1690 ± 0.0663	1.4170 ± 0.0783	-53.649	<0.001
FVC (L)	IMT	2.0535 ± 0.0980	2.2260 ± 0.1103	-26.944	<0.001
	PNF	2.0240 ± 0.0953	2.3185 ± 0.1138	-36.831	<0.001
Parameter	**Group**	**Pre (Mean ± SD)**	**Post (Mean ± SD)**	**t value**	**p value**
FEV_1/FVC (%)	IMT	57.60 ± 2.703	59.80 ± 2.419	-14.139	<0.001
	PNF	58.10 ± 2.732	62.15 ± 3.281	-12.650	<0.001
6-Minute Walk Distance (m)	IMT	306.45 ± 8.22	339.35 ± 8.22	-131.462	<0.001
	PNF	308.60 ± 7.77	368.65 ± 7.77	-302.750	<0.001

Note: Values are expressed as mean ± standard deviation. IMT: Inspiratory Muscle Training; PNF: Proprioceptive Neuromuscular Facilitation; FEV_1: Forced Expiratory Volume in one second; FVC: Forced Vital Capacity. $p < 0.05$ considered statistically significant.