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Article

Comparative Effects of Inspiratory Muscle Training vs Expiratory Muscle Training Along with Aerobic Interval Training on Functional Performance and Fatigue Level in COPD Patients

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ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) significantly impairs respiratory function and quality of life, with growing emphasis on non-pharmacological interventions such as pulmonary rehabilitation. However, limited evidence directly compares the differential impact of inspiratory versus expiratory muscle training, particularly when combined with aerobic interval training, on functional performance and fatigue in COPD patients. **Objective**: To compare the effects of Inspiratory Muscle Training (IMT) versus Expiratory Muscle Training (EMT), each combined with Aerobic Interval Training (AIT), on functional performance and fatigue severity in patients with moderate-stage COPD. **Methods**: A randomized controlled trial was conducted at Al-Zahra Rehabilitation Center, Lahore, including 53 patients aged 30–55 years with GOLD stage II–III COPD. Participants were randomly assigned to IMT+AIT (n=27) or EMT+AIT (n=26). Outcome measures included the Karnofsky Performance Scale (KPS), Fatigue Severity Scale (FSS), Modified Medical Research Council (mMRC) Dyspnea Scale, 6-Minute Walk Test (6MWT), and Forced Expiratory Volume in 1 second (FEV1), assessed pre- and post-intervention. Ethical approval was obtained and procedures adhered to the Declaration of Helsinki. Statistical analysis was performed using SPSS v25, applying t-tests and non-parametric tests where appropriate ($p<0.05$). **Results**: EMT+AIT significantly outperformed IMT+AIT in improving KPS ($p<0.001$), reducing FSS ($p=0.011$), decreasing mMRC scores ($p=0.018$), enhancing 6MWT distance ($p=0.005$), and increasing FEV1 ($p=0.022$), indicating superior clinical efficiency. **Conclusion**: EMT combined with AIT is more effective than IMT+AIT in enhancing functional capacity, reducing fatigue and dyspnea, and improving pulmonary function in COPD patients, supporting its integration into targeted rehabilitation programs.

Keywords: Chronic Obstructive Pulmonary Disease, Respiratory Muscle Training, Aerobic Exercise, Dyspnea, Fatigue, Pulmonary Rehabilitation, Functional Performance.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a globally prevalent respiratory disorder characterized by progressive airflow limitation that impairs the lungs' ability to effectively expel air. The World Health Organization estimates that over 384 million individuals are affected globally, with more than 3 million deaths attributed to the disease annually (1). COPD poses significant economic and societal burdens, particularly in low- and middle-income countries where air pollution, tobacco use, and aging populations contribute to its rising incidence. Definitions by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) and the Lower Limit of Normal (LLN) present slightly varied criteria for diagnosis, with prevalence rates varying accordingly (1). Beyond its hallmark symptoms of breathlessness and chronic cough, COPD can present with wheezing, chest tightness, muscle wasting, and peripheral edema, often further complicated by comorbidities such as cardiovascular disease, diabetes, and psychological disorders (2–10). These comorbidities exacerbate the clinical manifestations of COPD, reduce quality of life, and necessitate a comprehensive, multidisciplinary approach to patient care (11–14).

Environmental and occupational exposures, including pollutants and workplace irritants, significantly impact disease development and progression (15–18). Seasonal variations and climatic factors also influence symptom severity, underscoring the need for geographically tailored management strategies (19, 20). Public health efforts aimed at improving air quality and smoking cessation are essential preventive measures (21). Nutrition and weight management further modulate symptom severity and respiratory muscle function, demonstrating the need for integrated lifestyle interventions in COPD management (22). While COPD in pediatric populations is rare, early detection and intervention are vital, and elderly patients require careful consideration due to polypharmacy and functional limitations (23–26). Pulmonary rehabilitation (PR), as defined by the American Thoracic and European Respiratory Societies, encompasses individualized exercise training, education, and behavioral strategies to enhance physical and psychological outcomes (27). Fatigue and muscle dysfunction are common in COPD, particularly affecting the lower limbs, necessitating interventions to restore ventilatory efficiency and exercise capacity (28, 29). Tools like incentive spirometers have demonstrated improvements in lung capacity and respiratory muscle strength, supporting their utility in PR (30–33).

Exercise interventions such as aerobic and resistance training have been shown to improve functional outcomes and reduce dyspnea. Robotic and virtual reality-based training, along with traditional modalities, provide flexible delivery of PR programs (34–36). Quadriceps strength is a crucial determinant of physical performance in COPD, and aerobic training, especially when paired with pharmacological management, has shown notable benefits (29, 37–39). Recent studies also support the use of high-intensity interval training (HIIT) and suggest that tolerability and reliability can be achieved with appropriately adjusted protocols (40). Maintenance of these exercise programs is vital for sustaining long-term benefits in functional capacity and quality of life (41, 42). Breathing exercises such as pursed-lip and diaphragmatic breathing complement exercise training, providing further relief from dyspnea and improving respiratory efficiency (43, 44). Strength training, especially when integrated with aerobic conditioning, has been correlated with enhanced muscular strength, oxygen uptake, and reduced cardiovascular risk (45–48). Combining muscle-strengthening and aerobic activities is increasingly recognized for its preventive potential against chronic conditions (49).

Moreover, behavioral modification strategies, such as physical activity coaching, have been effective in enhancing daily activity levels and reinforcing self-management behaviors (50, 51). However, gains in muscle strength do not always translate into increased daily activity, indicating a need for targeted behavioral strategies within PR frameworks (52). Aerobic exercises like walking and cycling improve cardiorespiratory fitness, breathlessness, and endurance, despite not directly improving lung function (53–56). Proper supervision and adherence to exercise prescriptions are essential for safety and effectiveness (57). Strengthening peripheral muscle groups and respiratory muscles through resistance training and interval training further improves exercise capacity and reduces breathlessness (58, 59). Sprint interval training and non-invasive ventilation techniques offer additional improvements in blood flow, oxygenation, and inflammation control (60, 61). Educational components of PR, including medication adherence and lifestyle habits, further empower patients in their disease management (62, 63). Adoption of health-promoting behaviors such as vaccination, nutrition, and tele-rehabilitation platforms enhance accessibility and outcomes (64–66).

Psychosocial interventions like mindfulness, stress management, and music therapy enrich the rehabilitation experience, reducing anxiety and improving adherence (67). Tailored PR programs for elderly patients and those with frequent exacerbations can address their unique needs effectively. Devices such as breather tools allow for targeted respiratory muscle training, with some studies suggesting more pronounced effects with expiratory muscle training (68–70). However, evidence remains varied regarding the comparative effectiveness of inspiratory versus expiratory training, especially in combination with aerobic protocols. This study addresses this gap by comparing the effects of inspiratory and expiratory muscle training, each coupled with aerobic interval training, on functional performance and fatigue severity in COPD patients. By doing so, it aims to provide clinicians with evidence-based guidance on optimizing rehabilitation strategies, thereby improving patient compliance, reducing fatigue, and enhancing daily living activities in individuals with COPD.

MATERIALS AND METHODS

This randomized clinical trial was conducted to compare the effects of inspiratory muscle training (IMT) versus expiratory muscle training (EMT), each in combination with aerobic interval training (AIT), on functional performance and fatigue levels in patients with chronic obstructive pulmonary disease (COPD). The study was carried out at Al-Zahra Rehabilitation Center, Gulab Devi Teaching Hospital, Lahore, over a period of seven months following protocol approval. A total of 53 participants diagnosed with COPD, classified as GOLD stage II or III, aged between 30 and 55 years, were included in the study based on predefined eligibility criteria. Participants with a history of cardiovascular, neurological, orthopedic, or neuromuscular disorders, or those who had experienced an exacerbation of COPD within the past three months, were excluded. Participants were recruited through simple random sampling and enrolled after obtaining written informed consent. The study protocol was reviewed and approved by the institutional ethical committee, and all procedures complied with the ethical standards of the Declaration of Helsinki. Participant confidentiality was maintained by anonymizing data during storage and analysis.

Eligible participants were randomly assigned to two intervention groups using the lottery method. Group A received inspiratory muscle training using a breather device, performed as 3 sets of 10 inhalations with a 3-second hold per inhalation and 1-minute rest between sets, six days per week. This was paired with aerobic interval training on alternate days following a structured weekly progression in exercise duration.

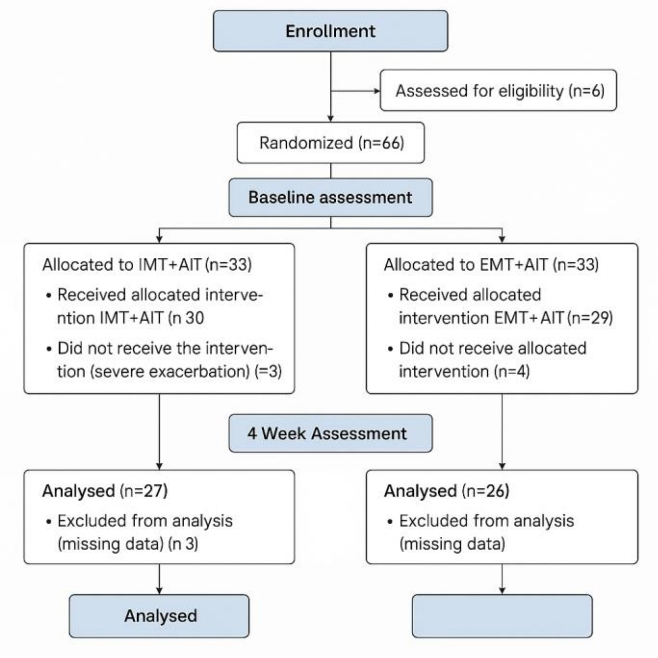

Figure 1 CONSORT Flowchart

Group B performed expiratory muscle training with the same frequency and intensity, alongside the same aerobic interval training protocol. The aerobic interval training component common to both groups was delivered using a 4×4 circuit training model, including stair climbing, side lifts, sit-to-stand exercises, and jumping jacks, with rest periods in dyspnea-relieved positions. Each session included a warm-up and cool-down segment incorporating upper and lower limb stretching exercises. The training duration progressed weekly: 25 minutes in week one, 30–35 minutes in week two, 40–45 minutes in week three, and 45–60 minutes in week four.

Primary outcomes included functional performance and fatigue severity, assessed using validated tools. The Karnofsky Performance Scale (KPS) was used to measure functional independence, while the Fatigue Severity Scale (FSS) evaluated fatigue impact. Dyspnea severity was recorded using the Modified Medical Research Council (mMRC) Dyspnea Scale. Aerobic capacity and endurance were measured through the 6-Minute Walk Test (6MWT), and pulmonary function was assessed using a digital spirometer to measure Forced Expiratory Volume in one second (FEV1). Baseline assessments were conducted prior to the intervention and repeated after the four-week intervention period. Demographic data including age, gender, BMI, smoking exposure, and disease duration were also recorded.

All statistical analyses were performed using SPSS version 25. The Kolmogorov–Smirnov test was applied to assess normality. For within-group comparisons, paired sample t-tests were used for normally distributed variables (e.g., FSS), and Wilcoxon Signed-Rank Tests were applied for non-normally distributed data (e.g., KPS, mMRC, 6MWT, FEV1). Between-group comparisons were conducted using independent sample t-tests for normally distributed variables and Mann–Whitney U tests for others. A p-value of less than 0.05 was considered statistically significant. The analysis was conducted on a complete-case basis, and no imputation was performed for missing data, as the follow-up was completed for all participants.

RESULTS

A total of 53 participants completed the study, with a mean age of 43.25 ± 7.28 years, BMI of 26.16 ± 3.40 kg/m^2, smoking exposure of 64.25 ± 12.66 pack-years, and mean disease duration of 5.43 ± 1.23 years. Gender distribution showed a slight predominance of females (54.7%) compared to males (45.3%), and oxygen therapy had been administered to 45.3% of the participants at some stage of their treatment.

Table 1. Descriptive Statistics of Study Participants

Variable	Minimum	Maximum	Mean ± SD
Age (years)	30	55	43.25 ± 7.28
BMI (kg/m^2)	19.71	33.11	26.16 ± 3.40
Smoking Exposure (pack-years)	39	93	64.25 ± 12.66
Disease Duration (years)	2.9	7.9	5.43 ± 1.23

Table 2. Frequency Distribution of Gender and Oxygen Therapy

Category	Frequency	Percentage (%)
Male	24	45.3
Female	29	54.7
Received Oxygen Therapy	24	45.3
Did Not Receive Oxygen Therapy	29	54.7

Tests of normality using the Kolmogorov–Smirnov test indicated that FSS was normally distributed (p = 0.163), whereas the other outcome variables (KPS, mMRC, 6MWT, FEV1) were not and were analyzed using non-parametric tests where appropriate. Within-group comparisons revealed improvements in both intervention groups; however, a statistically significant enhancement in KPS was only observed in Group B (EMT+AIT), with a median increase from 77 to 85 (p = 0.003), compared to a non-significant change in Group A (IMT+AIT) from 75 to 76 (p = 0.056). Fatigue severity, measured using the FSS, showed significant reductions within both groups. Group A's mean FSS decreased from 48.67 ± 13.99 to 41.19 ± 8.40 (p < 0.001), and Group B improved from 45.58 ± 11.77 to 34.73 ± 9.50 (p < 0.001), confirming the effectiveness of both interventions in reducing fatigue. Post-intervention between-group comparisons revealed statistically significant differences in all outcomes favoring Group B. KPS showed a significant improvement in Group B ($p < 0.001$). FSS scores were lower ($p = 0.011$), indicating reduced fatigue. Dyspnea levels measured by mMRC were also significantly reduced ($p = 0.018$). Group B additionally outperformed Group A in the 6MWT ($p = 0.005$) and demonstrated superior gains in FEV1 ($p = 0.022$).

Table 3. Kolmogorov–Smirnov Normality Test Results

Variable	Statistic	p-value	Normal Distribution
Pre-KPS	0.183	0.000	No
Pre-FSS	0.109	0.163	Yes
Pre-mMRC	0.249	0.000	No
Pre-6MWT	0.134	0.019	No
Pre-FEV1	0.159	0.002	No

Table 4. Within-Group Comparison of KPS Scores

Group	Pre-KPS Median	Post-KPS Median	Z-Score	p-value	Interpretation
Group A (IMT+AIT)	75	76	-1.913	0.056	Not Significant
Group B (EMT+AIT)	77	85	-2.998	0.003	Significant

Table 5. Within-Group Analysis for Fatigue Severity (FSS)

Group	Pre-FSS Mean ± SD	Post-FSS Mean ± SD	t-value	p-value	Interpretation
Group A (IMT+AIT)	48.67 ± 13.99	41.19 ± 8.40	6.402	<0.001	Significant
Group B (EMT+AIT)	45.58 ± 11.77	34.73 ± 9.50	13.252	<0.001	Significant

Table 6. Between-Group Post-Intervention Comparisons

Outcome Measure	Test Used	p-value	Significance
Post-KPS	Mann-Whitney U	<0.001	Yes
Post-FSS	Independent t-test	0.011	Yes
Post-mMRC	Mann-Whitney U	0.018	Yes
Post-6MWT	Mann-Whitney U	0.005	Yes
Post-FEV1	Mann-Whitney U	0.022	Yes

DISCUSSION

The findings of this study demonstrate that expiratory muscle training (EMT) combined with aerobic interval training (AIT) leads to more substantial improvements in functional performance, fatigue severity, dyspnea, and pulmonary function among patients with moderate-stage COPD when compared to inspiratory muscle training (IMT) combined with AIT. These results contribute valuable insight to the growing evidence base supporting pulmonary rehabilitation modalities tailored to respiratory muscle training and reinforce the multidimensional benefits of targeted interventions. The superior gains observed in the EMT+AIT group—reflected in significantly enhanced Karnofsky Performance Scores, reduced Fatigue Severity Scores, improved 6-minute walk distances, and elevated FEV1 values—highlight the potential of EMT as a central component of COPD rehabilitation protocols. These results resonate with earlier meta-analyses that have underscored the benefits of expiratory muscle strength training in improving expiratory pressure, cough efficacy, and dyspnea management, such as those reported by Templeman et al. and Neves et al. (121, 124).

A possible explanation for the observed efficacy of EMT may lie in the biomechanics of respiratory muscle recruitment. Expiratory muscles, particularly the abdominal and intercostal groups, play a pivotal role in active ventilation during exertion and contribute directly to airway clearance mechanisms and ventilatory drive. Training these muscles may reduce the mechanical load on the diaphragm, enhancing breathing efficiency and reducing the sensation of dyspnea, especially during physical exertion. The statistically significant reduction in modified Medical Research Council (mMRC) dyspnea scores in the EMT group supports this physiological rationale.

This observation aligns with the work of Brunton et al., who reported decreased neuromuscular fatigability and exertional dyspnea following lower limb resistance training in COPD, as well as with findings by Zhang et al., where respiratory muscle training notably improved dyspnea during daily activities (71, 79).

Moreover, the integration of AIT with EMT may produce additive effects by improving cardiovascular fitness and muscular endurance, which are typically impaired in COPD patients due to systemic inflammation, oxidative stress, and muscle deconditioning. Prior studies, including those by Na et al. and Nymand et al., have demonstrated the feasibility and benefits of structured aerobic protocols in enhancing physical tolerance in COPD patients, though their design did not specifically compare inspiratory versus expiratory muscle activation in a controlled fashion (39, 40). Our study advances this field by using a randomized design to isolate the additive value of expiratory training within a standardized aerobic framework, suggesting that functional and ventilatory adaptations are more pronounced with EMT. While inspiratory muscle training has been extensively studied and supported in multiple reviews for improving inspiratory pressures and endurance, its comparative effect when measured against expiratory strategies in the context of full pulmonary rehabilitation is less defined. Our findings diverge from studies such as those by Figueiredo et al. and Mota et al.,

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which emphasized IMT's role in improving inspiratory strength and suggested equivalent or greater benefit than expiratory-focused training (81, 127). This discrepancy may be attributed to differing outcome measures, training intensities, or population characteristics. Notably, our study prioritized real-world functional outcomes, including 6MWT and KPS, rather than isolated maximal inspiratory pressures, offering a broader view of daily life impact. These variations highlight the need for further head-to-head comparisons employing standardized protocols and long-term follow-up.

Clinically, the results underscore the relevance of EMT+AIT as a cost-effective, non-invasive, and feasible intervention for outpatient rehabilitation settings. By improving multiple facets of COPD disability—including endurance, dyspnea, and lung function—this strategy may reduce hospitalizations and dependence on pharmacologic therapies, enhancing patient autonomy and quality of life. Nonetheless, the study's strength in rigorous design and detailed measurement is tempered by some limitations. The sample size, although adequately powered for primary outcomes, was relatively small, which may affect generalizability. The four-week intervention period, while sufficient to demonstrate short-term gains, does not allow conclusions about sustained benefits or adherence over time. Furthermore, the lack of long-term follow-up precludes understanding of relapse prevention and maintenance effects.

Potential confounding factors such as individual variations in comorbidities, medication adherence, or motivation levels were not fully controlled and may have influenced outcomes. While randomization and blinding of outcome assessors strengthen the validity, future studies could benefit from stratified randomization and larger multicenter designs to increase robustness. Additionally, incorporating objective measures such as maximal expiratory pressure (MEP), blood gas analysis, and biomarkers of inflammation may elucidate mechanistic underpinnings of observed improvements.

Moving forward, future research should explore the optimal frequency, duration, and intensity of EMT within multidisciplinary rehabilitation programs and assess its impact across different GOLD stages. Comparative trials evaluating EMT, IMT, and combined modalities, especially with longer follow-up and cost-effectiveness analysis, will inform clinical guidelines. Investigation into how respiratory muscle training interacts with nutritional, psychological, and environmental factors in COPD management would also provide a more comprehensive framework for personalized care. Overall, this study contributes important evidence favoring expiratory muscle activation strategies as a superior approach for improving holistic outcomes in COPD rehabilitation.

CONCLUSION

This randomized clinical trial concluded that expiratory muscle training (EMT) combined with aerobic interval training (AIT) is more effective than inspiratory muscle training (IMT) with AIT in improving functional performance and reducing fatigue levels in patients with moderate-stage COPD. The EMT+AIT group demonstrated superior outcomes across multiple clinical measures, including the Karnofsky Performance Scale, Fatigue Severity Scale, 6-Minute Walk Test, mMRC dyspnea score, and FEV1, underscoring its potential as a preferred rehabilitation strategy. These findings highlight the clinical relevance of incorporating expiratory-focused respiratory muscle training into pulmonary rehabilitation programs to enhance exercise tolerance, respiratory efficiency, and quality of life in COPD populations. From a research perspective, the study supports further exploration of optimized EMT protocols and long-term outcomes to inform evidence-based, cost-effective interventions in chronic respiratory care.

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