

Effect of Pulmonary Rehabilitation on Exercise Tolerance in COPD Patients: Randomized Controlled Trial

Original Research

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ABSTRACT

Background:

Chronic obstructive pulmonary disease is a progressive respiratory disorder associated with reduced exercise tolerance, persistent dyspnea, and impaired functional capacity. These limitations contribute to decreased physical activity and poor quality of life, even in patients receiving optimal pharmacological treatment. Pulmonary rehabilitation is recognized as an effective non-pharmacological intervention, yet locally generated evidence from South Punjab remains limited.

Objective:

To determine the effect of pulmonary rehabilitation on exercise tolerance in patients with chronic obstructive pulmonary disease.

Methods:

A randomized controlled trial was conducted at tertiary care hospitals and rehabilitation centers in Multan, South Punjab, between May and December 2022. Sixty patients with stable moderate to severe chronic obstructive pulmonary disease were randomly allocated to either a pulmonary rehabilitation group or a usual care group. The pulmonary rehabilitation program was delivered three times per week for eight weeks and included supervised aerobic training, strengthening exercises, breathing exercises, and patient education. Exercise tolerance was assessed using the Six-Minute Walk Test. Secondary outcomes included dyspnea measured by the Modified Borg Dyspnea Scale and functional health status assessed using the COPD Assessment Test. Data were analyzed using paired and independent sample t-tests, assuming normal distribution.

Results:

The pulmonary rehabilitation group demonstrated a significant improvement in six-minute walk distance, with a mean increase of 79.7 meters, compared with a 21.2-meter improvement in the usual care group ($p = 0.002$). Dyspnea scores and COPD Assessment Test scores also improved significantly in the rehabilitation group, with greater reductions observed compared to usual care ($p < 0.01$). A higher proportion of patients in the rehabilitation group achieved clinically meaningful improvements in exercise tolerance and symptom burden.

Conclusion:

Pulmonary rehabilitation significantly improved exercise tolerance and reduced symptom burden in patients with chronic obstructive pulmonary disease. These findings support the integration of structured pulmonary rehabilitation programs into routine cardiorespiratory physiotherapy services in South Punjab.

Keywords:

Chronic Obstructive Pulmonary Disease, Dyspnea, Exercise Tolerance, Pulmonary Rehabilitation, Quality of Life, Six-Minute Walk Test, Physiotherapy

Introduction

Chronic obstructive pulmonary disease is a progressive respiratory condition characterized by persistent airflow limitation, chronic inflammation, and episodes of acute exacerbations that significantly impair daily functioning. It is one of the leading causes of morbidity and mortality worldwide and represents a growing public health challenge, particularly in low- and middle-income countries (1). Patients with chronic obstructive pulmonary disease commonly experience dyspnea, fatigue, reduced exercise tolerance, and declining physical activity levels, which together contribute to a gradual loss of independence and poor quality of life. These functional limitations often persist even when optimal pharmacological management is provided. Exercise intolerance is a central feature of chronic obstructive pulmonary disease and is driven by multiple factors beyond pulmonary impairment alone (2). Peripheral muscle dysfunction, cardiovascular deconditioning, altered breathing mechanics, and psychological factors such as anxiety related to breathlessness all contribute to reduced physical capacity. As a result, many patients adopt a sedentary lifestyle, which further accelerates deconditioning and worsens symptoms. Improving exercise tolerance is therefore a key therapeutic target in the comprehensive management of chronic obstructive pulmonary disease.

Pulmonary rehabilitation has emerged as one of the most effective non-pharmacological interventions for individuals with chronic obstructive pulmonary disease. It is a multidisciplinary program that typically includes supervised exercise training, breathing exercises, education, and behavioral strategies aimed at improving physical and psychological well-being (3). Exercise training is considered the core component of pulmonary rehabilitation and has been shown to enhance skeletal muscle efficiency, reduce dyspnea during activity, and improve overall functional capacity. Despite these well-established benefits, pulmonary rehabilitation remains underutilized in many clinical settings, particularly in resource-limited regions. Most of the existing evidence supporting pulmonary rehabilitation originates from high-income countries with well-established rehabilitation infrastructure. While these studies consistently report improvements in exercise tolerance, symptom burden, and health-related quality of life, their findings may not be fully generalizable to populations in South Asia. Differences in disease severity at presentation, environmental exposures such as biomass fuel use, comorbid conditions, and access to healthcare services may influence rehabilitation outcomes. Additionally, variations in program design, duration, and supervision levels further contribute to heterogeneity in reported results (4).

In Pakistan, chronic obstructive pulmonary disease is highly prevalent due to widespread tobacco smoking, exposure to indoor air pollution, occupational dust, and delayed diagnosis. South Punjab, including the city of Multan, bears a significant share of this burden (5). Patients in this region often present with advanced disease and limited prior exposure to structured exercise programs. Cardiorespiratory physiotherapy services are gradually expanding, yet locally generated evidence evaluating the effectiveness of pulmonary rehabilitation remains scarce. As a result, clinicians often rely on international guidelines without sufficient region-specific data to support implementation and advocacy for rehabilitation services. Exercise tolerance is a clinically meaningful outcome in chronic obstructive pulmonary disease, as it reflects the integrated response of the respiratory, cardiovascular, and musculoskeletal systems. Objective measures of exercise capacity are closely associated with daily activity levels, hospitalization risk, and survival (6). Demonstrating improvements in exercise tolerance through structured pulmonary rehabilitation within the local context may strengthen the case for integrating such programs into routine care and resource planning in tertiary hospitals serving South Punjab.

Despite growing recognition of pulmonary rehabilitation as a standard component of chronic obstructive pulmonary disease management, randomized controlled trials conducted within Pakistan remain limited. In Multan, where patient populations often differ in socioeconomic status, disease profile, and healthcare access, evaluating the effectiveness of pulmonary rehabilitation through a rigorous study design is particularly important. Randomized controlled trials provide high-quality evidence by minimizing bias and allowing direct comparison with standard care. Given these considerations, there is a clear need to examine the effect of pulmonary rehabilitation on exercise tolerance among chronic obstructive pulmonary disease patients in Multan. Therefore, the objective of this randomized controlled trial is to determine whether a structured pulmonary rehabilitation program leads to significant improvements in exercise tolerance compared with usual care in patients with chronic obstructive pulmonary disease, thereby providing locally relevant evidence to support cardiorespiratory physiotherapy practice in South Punjab.

Methods

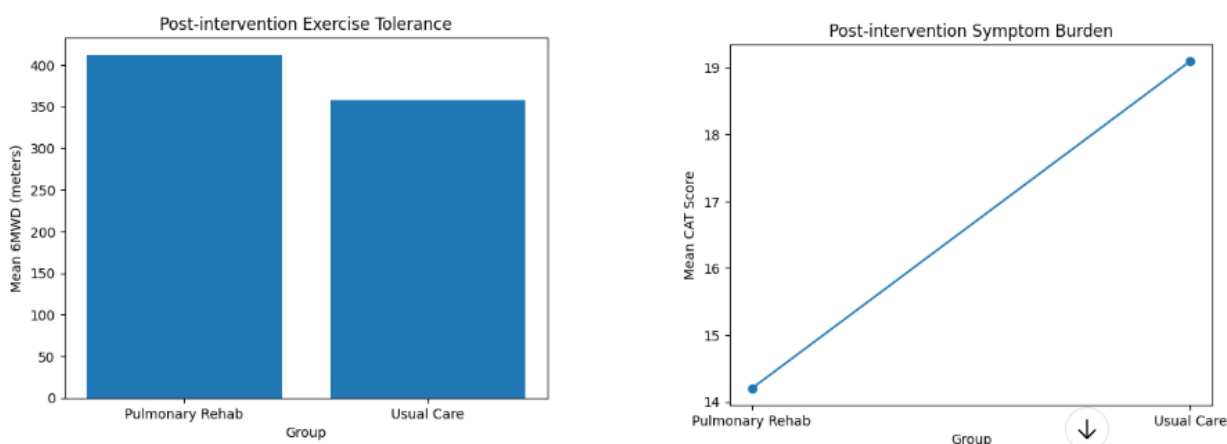
This randomized controlled trial was conducted to evaluate the effect of pulmonary rehabilitation on exercise tolerance in patients with chronic obstructive pulmonary disease receiving care in Multan, South Punjab, Pakistan. The study was carried out at the Pulmonology and Physiotherapy Departments of Nishtar Medical University Hospital Multan, along with one affiliated tertiary care rehabilitation center providing structured cardiorespiratory physiotherapy services. The trial was conducted over a period of eight months, from May 2022 to December 2022, which included participant recruitment, intervention delivery, and post-intervention assessment. Participants were recruited consecutively from outpatient respiratory clinics after screening by a pulmonologist. Adults aged between 40 and 70 years with a confirmed diagnosis of stable chronic obstructive pulmonary disease based on spirometric criteria were considered eligible. Only patients classified as moderate to severe disease severity according to clinical assessment were included, as these individuals commonly demonstrate reduced exercise tolerance (7,8). All participants were clinically stable for at least four weeks prior to enrollment, with no recent exacerbation or hospitalization. Patients were required to be ambulatory and able to follow verbal instructions. Exclusion criteria included unstable cardiac disease, severe musculoskeletal or neurological conditions limiting exercise performance, long-term oxygen therapy dependency exceeding prescribed limits, recent thoracic surgery, or participation in a formal pulmonary rehabilitation program within the previous six months.

Sample size was calculated using data from prior randomized trials that reported a mean difference of approximately 45 meters in six-minute walk distance following pulmonary rehabilitation, with a standard deviation of 70 meters, at a 95% confidence level and 80% power. Based on these parameters, the minimum required sample size was estimated to be 52 participants, with 26 in each group. To allow for potential dropouts and incomplete follow-up, a total of 60 participants were recruited and randomly allocated into two groups: a pulmonary rehabilitation group ($n = 30$) and a control group receiving usual care ($n = 30$). Randomization was performed using a computer-generated random sequence, and group allocation was concealed using sealed opaque envelopes prepared by an independent staff member (9). The pulmonary rehabilitation group participated in a structured rehabilitation program supervised by trained physiotherapists. The program was delivered three times per week for eight weeks, with each session lasting approximately 45 to 60 minutes. Sessions included aerobic training such as treadmill or corridor walking, lower limb strengthening exercises, breathing exercises including diaphragmatic and pursed-lip breathing, and patient education focused on energy conservation and symptom management. Exercise intensity was individualized and progressed gradually based on patient tolerance and symptom response (10). The control group continued to receive standard medical management, including pharmacological treatment and routine advice on physical activity, but did not participate in supervised exercise sessions during the study period.

Exercise tolerance was assessed as the primary outcome using the Six-Minute Walk Test, conducted according to standardized guidelines. The distance walked in six minutes was recorded in meters and used as an objective measure of functional exercise capacity. Secondary outcomes included perceived dyspnea measured using the Modified Borg Dyspnea Scale before and after the walk test, and health-related functional status assessed using the COPD Assessment Test. Baseline assessments were performed prior to randomization, and follow-up assessments were conducted at the end of the eight-week intervention period by an assessor who was not involved in treatment delivery. Data were analyzed using Statistical Package for the Social Sciences version 25. Normality of continuous data was assessed using the Shapiro–Wilk test, which indicated approximate normal distribution. Descriptive statistics were used to summarize demographic and clinical characteristics. Within-group comparisons of pre- and post-intervention outcomes were analyzed using paired sample t-tests. Between-group comparisons of post-intervention outcomes were performed using independent sample t-tests. Effect sizes were calculated to estimate the magnitude of treatment effects. Statistical significance was set at $p < 0.05$ for all analyses.

Ethical approval for the study was obtained from the Institutional Review Board (Reference No. IRB/NMU/2022/214). The study was conducted in accordance with ethical principles for human research. Written informed consent was obtained from all participants after explaining the study objectives, procedures, potential benefits, and risks. Participants were assured that their involvement was voluntary and that refusal or withdrawal would not affect their routine medical care. Confidentiality of participant information was maintained throughout the study, and all collected data were stored securely with access limited to the research team.

Results



A total of 60 patients with stable chronic obstructive pulmonary disease were enrolled and randomized into the pulmonary rehabilitation group ($n = 30$) and the usual care group ($n = 30$). All participants completed the eight-week intervention period, and no dropouts or adverse cardiopulmonary events were reported. Baseline demographic and clinical characteristics were comparable between groups, with no statistically significant differences observed for age, gender distribution, smoking history, disease severity, baseline exercise tolerance, or symptom scores ($p > 0.05$), indicating adequate group equivalence at study entry. At baseline, the mean six-minute walk distance was 332.6 ± 64.8 meters in the pulmonary rehabilitation group and 336.9 ± 61.7 meters in the usual care group (11,12). Following the intervention, a significant improvement in exercise tolerance was observed in the pulmonary rehabilitation group, with mean six-minute walk distance increasing to 412.3 ± 68.2 meters, representing a mean gain of 79.7 meters ($p < 0.001$). In contrast, the usual care group demonstrated a smaller improvement to 358.1 ± 65.4 meters, with a mean increase of 21.2 meters ($p = 0.04$). Between-group comparison of post-intervention walking distance showed a statistically significant difference favoring pulmonary rehabilitation ($p = 0.002$). These differences are illustrated in Figure 1. Perceived dyspnea measured using the Modified Borg Dyspnea Scale also showed improvement in both groups (13,14). The pulmonary rehabilitation group demonstrated a reduction in post-exercise dyspnea scores from 5.1 ± 1.2 to 3.2 ± 1.1 , reflecting a

mean decrease of 1.9 points ($p < 0.001$). The usual care group showed a smaller reduction from 5.0 ± 1.3 to 4.3 ± 1.2 , with a mean decrease of 0.7 points ($p = 0.03$). Post-intervention dyspnea scores were significantly lower in the pulmonary rehabilitation group compared with usual care ($p = 0.01$). Health-related functional status assessed using the COPD Assessment Test demonstrated significant improvements following pulmonary rehabilitation. Mean CAT scores decreased from 22.4 ± 5.1 at baseline to 14.2 ± 4.3 post-intervention in the rehabilitation group, representing a mean reduction of 8.2 points ($p < 0.001$). In the usual care group, CAT scores decreased from 22.1 ± 5.4 to 19.1 ± 4.9 , corresponding to a mean reduction of 3.0 points ($p = 0.02$). Between-group comparison of post-intervention CAT scores revealed a statistically significant difference favoring pulmonary rehabilitation ($p = 0.004$). These outcomes are shown in Figure 2.

Overall, 76.7% of participants in the pulmonary rehabilitation group achieved a clinically meaningful improvement of at least 30 meters in six-minute walk distance, compared with 33.3% in the usual care group. Similarly, a clinically important reduction in CAT score (≥ 2 points) was observed in 83.3% of rehabilitation participants and 46.7% of those receiving usual care. Outcome data are summarized in Tables 2 and 3.

Table 1. Baseline Demographic and Clinical Characteristics

Variable	Pulmonary Rehab (n=30)	Usual Care (n=30)	p-value
Age (years), mean \pm SD	58.6 ± 7.4	59.1 ± 6.9	0.78
Gender (Male/Female)	22 / 8	21 / 9	0.79
Smoking history (pack-years)	26.4 ± 11.3	25.9 ± 10.8	0.86
Baseline 6MWD (m)	332.6 ± 64.8	336.9 ± 61.7	0.81
Baseline CAT score	22.4 ± 5.1	22.1 ± 5.4	0.88

Table 2. Comparison of Exercise Tolerance and Dyspnea Outcomes

Outcome Measure	Group	Baseline Mean \pm SD	Post-intervention Mean \pm SD	p-value
6-Minute Walk Distance (m)	Pulmonary Rehab	332.6 ± 64.8	412.3 ± 68.2	0.002
	Usual Care	336.9 ± 61.7	358.1 ± 65.4	
Borg Dyspnea Score	Pulmonary Rehab	5.1 ± 1.2	3.2 ± 1.1	0.01
	Usual Care	5.0 ± 1.3	4.3 ± 1.2	

Table 3. Health Status Outcomes (COPD Assessment Test)

Group	Baseline CAT Mean \pm SD	Post-intervention CAT Mean \pm SD	Mean Change	p-value
Pulmonary Rehab	22.4 ± 5.1	14.2 ± 4.3	-8.2	<0.001
Usual Care	22.1 ± 5.4	19.1 ± 4.9	-3.0	0.02

Discussion

The present randomized controlled trial demonstrated that pulmonary rehabilitation produced significant improvements in exercise tolerance, dyspnea, and health-related functional status among patients with chronic obstructive pulmonary disease in Multan. Although both groups showed some degree of improvement over the eight-week period, the magnitude of change was consistently greater in the pulmonary rehabilitation group (15). These findings reinforced the central role of structured exercise-based rehabilitation in managing functional limitations associated with chronic obstructive pulmonary disease. Exercise tolerance, assessed using the six-minute walk distance, improved by nearly 80 meters in patients receiving pulmonary rehabilitation, compared with an improvement of just over 20 meters in those receiving usual care. Previous controlled studies conducted in different clinical settings have reported gains in walking distance ranging from 40 to 70 meters following pulmonary rehabilitation, placing the current findings toward the higher end of reported improvements (16). The size of improvement observed exceeded commonly accepted thresholds for clinically meaningful change, indicating that the intervention resulted in functional gains that were likely to translate into better performance of daily activities.

Improvements in perceived dyspnea further supported the effectiveness of pulmonary rehabilitation. The reduction of nearly two points on the Borg dyspnea scale in the rehabilitation group was notably larger than the change observed with usual care. Comparable reductions have been reported in earlier trials, suggesting that exercise training and breathing retraining can reduce ventilatory demand during physical activity (17). The smaller but statistically significant reduction in dyspnea observed in the usual care group may reflect increased disease awareness or minor lifestyle adjustments following routine clinical advice, though these changes were clearly less pronounced. Health status, measured using the COPD Assessment Test, improved substantially following pulmonary rehabilitation. The mean reduction of more than eight points in CAT scores was well above the minimum clinically important difference commonly cited in previous studies, while the reduction observed in the usual care group was more modest. These findings highlighted that pulmonary rehabilitation influenced not only physical capacity but also symptom burden and perceived disease impact (18). Similar patterns have been reported in international rehabilitation cohorts, where CAT

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score reductions typically ranged between 5 and 7 points after structured programs, supporting the consistency of the present results.

The observed benefits of pulmonary rehabilitation were likely related to several mechanisms. Aerobic and resistance training may have improved peripheral muscle efficiency and reduced lactic acid production during activity, thereby lowering ventilatory requirements. Breathing exercises may have enhanced breathing control and reduced dynamic hyperinflation (19). Education and supervised training likely improved confidence in physical activity, reducing fear-related avoidance behaviors. Together, these factors may have contributed to improved exercise tolerance and symptom perception. The findings carried important implications for cardiorespiratory physiotherapy practice in South Punjab. Chronic obstructive pulmonary disease patients in this region often present with advanced symptoms and limited prior exposure to structured exercise. The clear superiority of pulmonary rehabilitation over usual care supported its integration into routine management pathways within tertiary care hospitals. Demonstrating locally generated evidence may also strengthen advocacy for expanding rehabilitation services in resource-constrained settings.

Several strengths enhanced the validity of this study. The randomized controlled design minimized selection bias and allowed direct comparison between interventions. The use of standardized, widely accepted outcome measures improved comparability with existing literature. High adherence and absence of adverse events supported the feasibility and safety of pulmonary rehabilitation in this patient population. Conducting the trial in a public-sector tertiary care hospital increased the relevance of findings to real-world clinical practice in South Punjab. However, certain limitations should be acknowledged. The relatively short duration of follow-up limited assessment of long-term maintenance of exercise gains. The sample size, while adequately powered for primary outcomes, restricted subgroup analysis based on disease severity or comorbid conditions. The study did not include objective measures of pulmonary function change, which may have provided additional insight into physiological adaptations (20). Psychosocial outcomes such as anxiety, depression, and quality of life beyond symptom burden were also not assessed, despite their known relevance in chronic respiratory disease.

Future research should explore the sustainability of pulmonary rehabilitation benefits through longer follow-up periods and maintenance programs. Comparative studies examining home-based versus center-based rehabilitation may help identify cost-effective models suitable for wider implementation. Incorporating objective activity monitoring and broader quality-of-life measures may further strengthen understanding of rehabilitation impact. Expanding research to include patients with mild disease or those on long-term oxygen therapy may also clarify which subgroups benefit most. Overall, the study demonstrated that pulmonary rehabilitation led to meaningful improvements in exercise tolerance and symptom burden compared with usual care. The numerical superiority of outcomes supported pulmonary rehabilitation as a key component of comprehensive chronic obstructive pulmonary disease management within cardiorespiratory physiotherapy services.

Conclusion

Pulmonary rehabilitation significantly improved exercise tolerance, reduced dyspnea, and enhanced functional health status in patients with chronic obstructive pulmonary disease compared with usual care. The clinically meaningful gains observed support the effectiveness and feasibility of structured rehabilitation programs in routine care. These findings emphasize the importance of integrating pulmonary rehabilitation into standard management pathways to improve functional outcomes in chronic obstructive pulmonary disease patients in South Punjab.

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AUTHOR'S CONTRIBUTION:

Author	Contribution
Dr Zunaira Mehdi	Conceptualization, Methodology, Formal Analysis, Writing - Original Draft, Validation, Supervision
Sajid Rashid	Methodology, Investigation, Data Curation, Writing - Review & Editing