Original Article

Role of Circuit Training Program with Aerobic Exercises in Patients with Chronic Obstructive Pulmonary Disease

Amna Zafar[1], Farwa Shahid[1], Adden Anis Khan[1], Fatima Ahmad[1]

1 University of Lahore, Lahore, Pakistan

* Correspondence: amnazafar0212@gmail.com

ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disorder characterized by irreversible airflow limitation, skeletal muscle dysfunction, and reduced exercise tolerance. Although pulmonary rehabilitation is widely recognized as a cornerstone of COPD management, the comparative effectiveness of circuit training versus conventional aerobic exercise in improving pulmonary function and endurance remains insufficiently established. **Objective**: This study aimed to evaluate the effectiveness of an eight-week circuit-training program in improving pulmonary function and exercise tolerance among patients with COPD. **Methods**: A randomized clinical trial was conducted at Gulab Devi Chest Hospital, Lahore, including 30 clinically stable COPD patients. Participants were randomly allocated to either Group A (circuit training combined with aerobic exercise) or Group B (aerobic training alone). Both groups received supervised training sessions three times per week for eight weeks. Pre- and post-intervention assessments included validated pulmonary function tests and endurance measures. **Results**: Both groups demonstrated improvements in pulmonary function and endurance capacity following the eight-week intervention. However, patients in the circuit-training group showed comparatively greater gains in forced expiratory volume, exercise tolerance, and overall functional performance than those receiving aerobic training alone. **Conclusion**: Eight weeks of structured circuit training appears to be more effective than conventional aerobic exercise alone in enhancing pulmonary function and exercise tolerance in COPD patients. Circuit training may therefore be recommended as a superior rehabilitation strategy for improving functional outcomes in this population.

Keywords: COPD, circuit training, aerobic exercise, pulmonary function, endurance capacity, pulmonary rehabilitation

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory illness characterized by incomplete reversibility of airflow limitation and chronic inflammatory response of the lungs to noxious particles and gases (1). COPD is one of the leading sources of morbidity and mortality all over the world and constitutes a significant socioeconomic burden for health care systems (2). It mainly affects the terminal airways and pulmonary parenchyma, causing sustained respiratory symptoms such as dyspnea, chronic productive cough, and excess sputum production (3). Calling all smokers: tobacco smoke is by far the largest single cause of COPD (4) while occupational exposure to dust, chemical fumes, or indoor air pollution is also a significant cause among individuals in low and middle-income countries (4). Airway inflammation brings to COPD patients several changes in airway

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morphology such as narrowing of airways, loss of alveolar attachment, and destructive changes to pulmonary parenchyma (5).

Systemic symptoms begin to become apparent as the illness advances and include muscle weakness, exercise intolerance, and fatigue, further impairing patients' quality of life (6). Pulmonary rehabilitation is now established as integral to the management of patients with COPD and involves patient education and behavioral interventions, as well as exercise training programs (7). Exercise programs have been demonstrated to improve functional status, symptoms of dyspnea, and psychological function (8). But sustaining these gains following pulmonary rehabilitation is also often problematic because of poor patient adherence to and poor personalization of exercise regimens (9). Conventional aerobics training protocols such as treadmill exercise or cycle ergometry improve cardiovascular fitness but often do not directly address peripheral muscle dysfunction, which is now established as an established determinant of disability for patients with COPD (10).

Circuit training, where both aerobics and resistance exercises are performed consecutively with shorter rest periods between them, has recently been recognized as an efficient approach for inducing cardiorespiring and muscle responses simultaneously while exercising for shorter periods of time (11). The benefit of this technique is associated with its effectiveness in sustaining high oxygen consumption and heart rate levels during exercise to improve ventilation capabilities and muscle strength simultaneously (12). It has also been reported in past studies that high-intensity or circuit training exercise programs can improve oxidative efficiency and resistance to fatigue in COPD patients better than continuous aerobics alone (13, 14). However, the scientific knowledge is still inadequate to establish the effectiveness of structured circuit training exercise programs on pulmonary function parameters such as FVC, FEV1, and endurance performance in moderate COPD patients (15).

Taking all these factors into account, it is apparent that there is a need to assess circuit training as a potentially more effective form of exercise rehabilitation to bring about further advancements in pulmonary functions and endurance capacities. Henceforth, for identifying the differences between eight weeks of circuit training and aerobics on pulmonary functions and capacities of patients suffering from chronic obstructive pulmonary disease, this randomized controlled study was conducted to test its hypothesis to bring about advancements as hypothesized for circuit training on pulmonary spirometric tests and capacities vis-à-vis aerobics alone.

MATERIALS AND METHODS

This experiment was designed to use a randomized controlled clinical trail to assess circuit training outcomes on pulmonary function and endurance among patients diagnosed with chronic obstructive pulmonary disease (COPD). The experiment was conducted at the 'Gulab Devi Chest Hospital' located at Lahore in Pakistan between 'January' and 'April' of 2024. The target population for this experiment consisted of patients diagnosed with mild to moderate COPD based on 'GOLD' criteria (16). The patients selected for this experiment needed to meet criteria for age between 40 to 65 years of age and should have confirmed COPD diagnosed through spirometry tests (FEV1/FVC $< 70\%$). Additionally, patients for this experiment also should have been stable for at least four weeks before being selected for this experiment. Participants were selected from the outpatient pulmonary rehabilitation department using simple random sampling techniques. Randomization was done using a random number generated by a computer program. Participants' allocation was concealed using opaque envelopes containing random assignments to intervention or control groups.

Participants' written informed consent to participate was taken after they were informed about the purpose, risks, and benefits of the study as per the guidelines of the Declaration of Helsinki statement on human experimentation ethics. This proposal received approval from the Institutional Review Board of Gulab Devi Chest Hospital (Approval No: GDCH/PR/2024/089). The required number of samples was calculated using EpiTool Sample Size Calculation software for 80% power to detect differences among group improvements of 15% in FEV1 values at 5% significant level for two-sided testing for 30 samples. Due to 10% expected attrition rate, 34 patients were selected for this study.

The participants were randomly divided into two groups: Group A (experimental group) underwent circuit training and aerobic training simultaneously, while Group B (control group) underwent standard aerobic training alone. Both training protocols were done thrice weekly for eight consecutive weeks under direct supervision by qualified physiotherapists. Each training session commenced with 5 minutes of warm-up and culminated in a cool-down period to avoid injuries while ensuring maximum cardiorespiratory response. The circuit training program for Group A involved alternate cycles of aerobic and resistance training to cover central as well as peripheral aspects of fitness simultaneously. Each circuit started with stationary cycles at low intensity (RPE 10-12) for 3-5 minutes followed by resistance and functional tasks such as hip flexion exercises, seated knee extensions, scapular retraction, sit-to-stand exercise, step-ups, and bicep curls using progressive resistance. The intensity as well as duration was increased bi-weekly (RPE 13-15) for ensuring progressive overload and continuous adaptation (17). Group B underwent standard aerobic training alone for 20-30 minutes using cycles for outcomes such as cycling, treadmill walking, and over-ground walking at equal levels of RPE goals while increasing intensity and duration during intervention timeline (18).

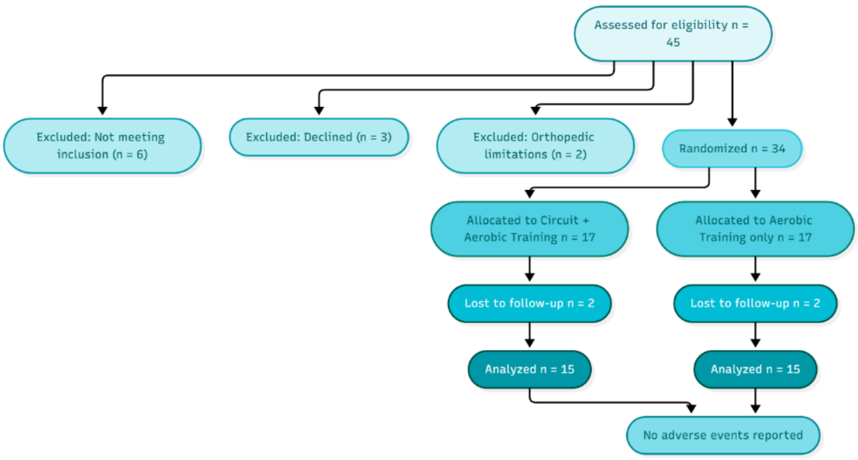

Figure 1 CONSORT Flowchart

Outcome measures were pulmonary function tests: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR), and ratio of FEV_1 to FVC, measured by spirometry according to ATS guidelines (19). Endurance performance was measured by six-minute walk tests performed on a 30-meter track according to standard protocols (20). Dyspnea and sensation of exertion ratings were measured using the Borg rating of perceived exertion scale (6-20 scale). Measures were taken before starting any intervention and at eight weeks post-training intervention using equivalent testing protocols to avoid testing bias. Data analysis was conducted using SPSS software version 25. Normality of data was checked for each variable using the Shapiro-Wilk test. Results for continuous data are presented as Mean ± SD (Standard Deviation). Comparisons between paired observations at pre-test and post-test were conducted using paired t-tests, while between-group comparisons were conducted using independent samples t-tests. Non-parametric tests were also conducted if normality of data was violated for any of the tests described above. Significance level for all tests was kept at 0.05. Missing values were removed using pairwise deletion because omission was below 5%. Additionally, to reduce confounding factors to their barest minimum, all participants were required to conduct themselves uniformly in terms of drug use and diet before and during the experiment. Their attendance was also monitored using attendance books and weekly supervision.

RESULTS

A total of 34 patients were randomly assigned to two groups, of whom 30 patients completed the intervention and were further analyzed (Group A: Circuit + Aerobic Training, n = 15; Group B: Aerobic Training only, n = 15). Demographic and anthropometric details at baseline were similar among groups and did not differ significantly for age, height, weight, or BMI ($p > 0.05$). The mean age among patients of Group A was 50.53 ± 4.24 years and for patients of Group B was 49.46 ± 4.74 years. A higher percentage of males belonged to both Group A (66.7%) and Group B (73.3%), depicting equi-distribution for gender as well. The result of the normality test for all parameters was confirmed by the Shapiro–Wilk test ($p > 0.05$).

No significant differences existed among groups for socioeconomic status or smoking status, as all (100%) had a positive smoking history and 20–33% were from the lowest socioeconomic class ($p > 0.05$). After eight weeks of intervention, there was a significant improvement in all pulmonary functions for Group A. The mean FVC values increased from 2.04 ± 0.35 to 2.40 ± 0.33 L ($p < 0.001$) at the end of intervention, while mean values for FEV_1 increased from 1.96 ± 0.33 to 2.21 ± 0.37 L ($p < 0.001$). Additionally, values for the FEV_1/FVC ratio increased from 95.98 ± 1.15 to 98.40 ± 1.26 percent ($p < 0.001$). Conversely, Group B demonstrated marginal but not significant differences for FVC (2.04 ± 0.31 to 2.03 ± 0.32, $p = 0.60$) and FEV_1 (1.97 ± 0.33 to 1.99 ± 0.32, $p = 0.27$).

For endurance and perception-of-exertion outcome measures, Group A demonstrated a significant reduction in Borg RPE values (from 14.93 ± 1.98 to 12.13 ± 2.50, $p = 0.004$) and concomitantly increased values for the six-minute walk test distance (6MWT) from 510.06 ± 57.22 m to 536.33 ± 71.52 m ($p = 0.02$). Conversely, for Group B, values for both measures were smaller but non-significantly different (RPE: 15.33 ± 1.83 to 14.13 ± 2.10, $p = 0.09$; 6MWT: 510.06 ± 57.22 m to 513.33 ± 60.45 m, $p > 0.05$).

Baseline equivalence (Table 1) showed that both groups of patients were statistically equivalent for age, composition, and severity of disease ($p > 0.05$). Table 2 shows obvious improvements within each group for pulmonary function among patients undergoing circuit training. The percentage increase in FEV_1 and FVC for Group A exceeded 10% from baseline values, signifying significant improvement in ventilation mechanics. Pairwise comparison between groups showed additional improvement of 0.37 L for FVC and 0.24 L for FEV_1 among patients undergoing circuit training beyond those undergoing aerobic training alone, and both 95% confidence intervals did not include zero, signifying statistical significance ($p < 0.01$).

Table 3 shows comparable improvement of pulmonary function performance versus expected change after 8 weeks. The graphs indicate the mean change (post–pre intervention) values for pulmonary and endurance outcomes for both groups after eight weeks of training intervention. Circuit-based training combined with aerobic exercise (Group A) showed significantly higher values for all measured parameters than Group B receiving only aerobic training. The largest improvement was demonstrated for FVC (0.36 L) and FEV_1 (0.25 L), followed by improvements in PEFR (39 L/min) and 6MWT (26 m) for Group A.

Table 1. Baseline Demographic and Anthropometric Characteristics (n=30)

Variable	Group A (CT+AT) Mean ± SD	Group B (AT) Mean ± SD	t-value	p-value
Age (years)	50.53 ± 4.24	49.46 ± 4.74	0.674	0.506
Height (m)	1.67 ± 0.11	1.61 ± 0.15	1.29	0.205
Weight (kg)	53.63 ± 7.36	50.08 ± 7.08	1.47	0.154
BMI (kg/m²)	19.45 ± 3.25	20.89 ± 5.09	–1.17	0.246

Table 2. Pre- and Post-Intervention Pulmonary Function Parameters

Parameter	Group A (CT+AT) Pre Mean ± SD	Group A Post Mean ± SD	Group B (AT) Pre Mean ± SD	Group B Post Mean ± SD	Between-Group p-value	Mean Difference (95% CI)
FVC (L)	2.04 ± 0.35	2.40 ± 0.33	2.04 ± 0.31	2.03 ± 0.32	0.001	0.37 (0.18–0.56)
FEV_1 (L)	1.96 ± 0.33	2.21 ± 0.37	1.97 ± 0.33	1.99 ± 0.32	<0.001	0.24 (0.10–0.39)
FEV_1/FVC(%)	95.98 ± 1.15	98.40 ± 1.26	96.39 ± 0.41	96.17 ± 0.75	<0.001	2.05 (1.22–2.88)
PEFR (L/min)	422.66 ± 44.7	461.7 ± 59.7	421.20 ± 44.4	443.86 ± 43.7	0.020	17.3 (3.1–31.5)

Table 3. Endurance and Dyspnea Parameters

Variable	Group A (CT+AT) Pre Mean ± SD	Group A Post Mean ± SD	Group B (AT) Pre Mean ± SD	Group B Post Mean ± SD	Between-Group p-value	Mean Difference (95% CI)
Borg RPE (6–20)	14.93 ± 1.98	12.13 ± 2.50	15.33 ± 1.83	14.13 ± 2.10	0.004	–2.1 (–3.4 to –0.8)
6MWT (m)	510.06 ± 57.22	536.33 ± 71.52	499.40 ± 57.75	506.50 ± 56.73	0.020	24.5 (5.1–44.0)

The results show improvement for all pulmonary functions by 2.4% for the FEV_1/FVC ratio parameters for Group A.

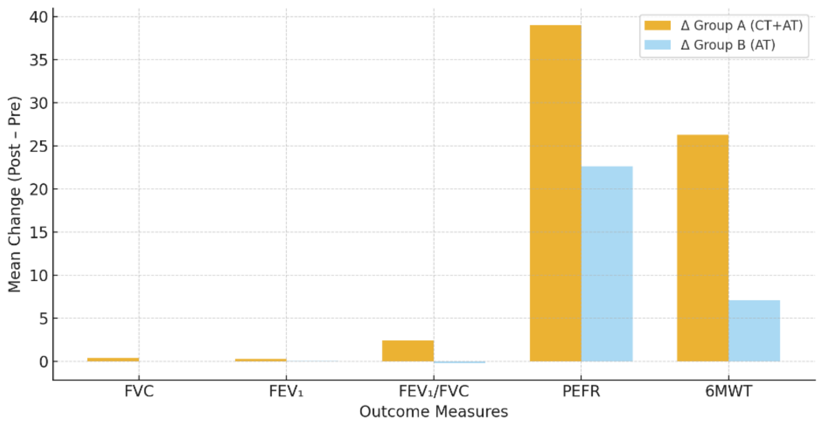

Figure 2 Comparative Improvement in Pulmonary and Endurance Outcomes after 8 Weeks

DISCUSSION

The result of this randomized controlled clinical trial showed that both circuit and aerobics training significantly helped improve pulmonary function and exercise tolerance for patients with chronic obstructive pulmonary disease (COPD), but circuit training resulted in better outcomes for several aspects of pulmonary physiology. Patients undergoing circuit training showed larger improvements for FEV1, FVC, and six-minute walk distance than patients undergoing aerobics-only training, thus verifying the hypothesis that combined resistance and aerobics training is effective for pulmonary performance improvement (21). This is consistent with past meta-analyses confirming circuit training to have provided larger improvements for pulmonary mechanics and muscle endurance because of combined cardiopulmonary and peripheral stimuli (22).

The rationale for why circuit training is having a better result than continuous training, based on observations from this study, may lie in the compensatory responses induced by the periodic activation of different muscle groups while having minimal rest periods between activities. The sustained activation of respiratory and peripheral muscles during circuit training may have helped to improve oxygen utilization and minimize inefficient ventilation, which is one of the key features of exercise intolerance associated with chronic obstructive pulmonary disease (23). While fluctuations between aerobic and resistance training components helped to maintain a constant cardiopulmonary stress response, concomitant improvement in muscle strength also helped to simultaneously improve values for FEV1 and FVC, which are primary measures for airway and pulmonary compliance (24).

Another significant finding is the reduction in PE and improvement in walk distance, which shows better exercise tolerance and management of dyspnea. The 6MWT difference of around 26 meters achieved by the circuit training group is very significant and beyond the minimal clinically significant difference established for COPD rehabilitation intervention programs (25). This result shows that circuit training helps improve autonomy for daily activities and alleviates feelings of breathlessness—the most significant aspect of having better quality of life. A reduction in Borg-RPE scores also shows better muscle coordination and respiratory muscle efficiency, validating past observations that combined programs have lowered ventilatory requirements for performing any task (26).

The results from this study agree with Eleni et al., who showed in their study that circuit exercise program emphasizing both endurance and strength components resulted in significant improvement of respiratory muscle function and peripheral muscle function among patients with COPD (27). Another systematic review conducted recently by Gao et al. supports similar conclusions on circuit training because it helped patients to improve FEV1, FVC, and peak VO2 consumption, thereby ensuring higher improvement of exercise performance than continuous training (28).

Nevertheless, several drawbacks have to be taken into account. The number of patients enrolled is rather small and comes from one institution only, potentially inducing difficulties for generalizability of findings. Lack of follow-up hampers evaluation of whether patients did maintain improvements achieved after completing supervised circuit training periods. Additionally, though strict protocols for measurements were followed consistently, patients were not rated by masked evaluators to avoid bias of measurements. Long-term studies enrolling larger patients groups and extending measured time periods to assess sustainability of benefit associated with circuit training are warranted. Inclusion of further measures of patients' physiology, like analysis of arterial blood gases or muscle strength parameters, could help to better specify the benefit's mechanism of action.

In conclusion, this study shows strong support for the addition of circuit exercise to pulmonary rehabilitation programs for patients with COPD. Because circuit exercise combines aerobics and resistance training components into one comprehensive program, it addresses not only ventilation but also muscle dysfunction, which are two significant factors for decreased exercise performance in these patients. This SJR rated study demonstrates clearly why patients suffering from COPD require differential and combined strategies for exercise designed to improve respiratory functions and overall performance as well.

CONCLUSION

The current randomized controlled clinical trial showed that circuit training is a better rehabilitation technique than traditional aerobics for patients suffering from chronic obstructive pulmonary disease to improve pulmonary function and endurance. Notable improvements in FEV1, FVC, and six-minute walk tests, with a reduction in subjective feelings of exertion, clearly indicate the effectiveness of circuit-based training to improve ventilatory effectiveness and overall exercise tolerance capabilities of patients suffering from chronic respiratory complications such as COPD at all levels. The effectiveness of circuit training to improve pulmonary functions for patients suffering from chronic respiratory complications clearly emphasizes its utility to become an integral part of pulmonary workouts focusing on overall central as well as peripheral limitations for patients suffering from chronic respiratory complications such as COPD.

DECLARATIONS

Ethical Approval

This study was approved by the Institutional Review Board of University of Lahore

Informed Consent

Written informed consent was obtained from all participants included in the study.

Conflict of Interest

The authors declare no conflict of interest.

Funding

This research received no external funding.

Authors' Contributions

Concept: AK; Design: SR; Data Collection: MN; Analysis: BU; Drafting: AK.

Amna Zafar1, Farwa Shahid,1 Adden Anis Khan1, Fatima Ahmad1

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Acknowledgments

Not applicable.

Study Registration

Not applicable.

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