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Article

Effects of Circuit Training Program on Endurance and Pulmonary Functions in Patients with Chronic Obstructive Pulmonary Disease

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ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory condition characterized by airflow limitation and reduced exercise capacity. While aerobic training is standard in pulmonary rehabilitation, limited evidence exists regarding the comparative efficacy of circuit training on pulmonary function and endurance in COPD patients. **Objective**: To evaluate the effects of a circuit training program on endurance and pulmonary functions—including FEV1, FVC, PEFR, and exercise tolerance—among patients with COPD. **Methods**: A randomized controlled trial was conducted at Gulab Devi Chest Hospital, Lahore, involving 30 clinically stable COPD patients (n = 30), aged 40–60 years, recruited through simple random sampling. Participants were randomly assigned to a circuit training group (Group A) or an aerobic training group (Group B), with interventions carried out thrice weekly for eight weeks. Pulmonary Function Tests (PFTs), Rate of Perceived Exertion (RPE), and Six-Minute Walk Test (6MWT) were used to assess outcomes. Data were analyzed using SPSS v27 with paired and independent t-tests ($p < 0.05$), following ethical approval from Riphah International University and in accordance with the Declaration of Helsinki. **Results**: Group A showed statistically and clinically significant improvements in FEV1 (2.21 ± 0.037 vs. 1.99 ± 0.032 L, $p = 0.000$), FVC (2.40 ± 0.33 vs. 2.03 ± 0.032 L, $p = 0.001$), FEV1/FVC ratio ($p = 0.000$), RPE ($p = 0.004$), and 6MWT distance ($p = 0.020$) compared to Group B. **Conclusion**: Circuit training significantly improves pulmonary function and exercise endurance in COPD patients and offers a superior alternative to aerobic training alone. It presents a promising addition to standard pulmonary rehabilitation for enhancing clinical outcomes and functional independence.

Keywords: Chronic Obstructive Pulmonary Disease, Circuit Training, Pulmonary Function, Aerobic Exercise, Dyspnea, Endurance, Six-Minute Walk Test.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is a progressive respiratory disorder that causes persistent airflow limitation and significantly impairs pulmonary function, leading to reduced exercise capacity and poor quality of life among affected individuals (1). It is a major global health concern associated with increased morbidity, mortality, and a substantial socioeconomic burden (2). The primary etiological factor is prolonged exposure to harmful gases and particulate matter, predominantly tobacco smoke, although other contributors include environmental pollutants, occupational exposures, respiratory infections, and genetic susceptibility (3, 4). The pathophysiology of COPD involves chronic inflammation of the airways, parenchymal destruction, and pulmonary vascular remodeling, ultimately resulting in symptoms such as dyspnea, chronic cough, sputum production, and wheezing that worsen over time (5, 6). Diagnostic confirmation is typically achieved through pulmonary function tests (PFTs), most notably spirometry, which quantifies parameters like forced expiratory volume in one second (FEV1) and forced vital capacity (FVC), offering a reliable method for assessing the degree of airway obstruction (7, 8).

Despite pharmacological interventions offering symptom relief, pulmonary rehabilitation remains a cornerstone of non-pharmacologic management. It enhances functional status, reduces dyspnea and fatigue, and improves overall quality of life (9). Within rehabilitation protocols, aerobic training has long been the standard; however, emerging evidence suggests that circuit training, which combines aerobic and resistance exercises in a high-intensity interval format, may offer superior benefits in enhancing cardiopulmonary function and muscular strength (10). Circuit training involves executing a series of exercises in a cyclical manner with minimal rest periods, thereby maintaining elevated

heart rate and maximizing oxygen utilization. This modality targets both central and peripheral adaptations, including improved ventilatory efficiency, enhanced respiratory muscle strength, and increased peripheral oxygen extraction (11).

Existing literature has highlighted the positive effects of circuit training on cardiovascular fitness and muscle endurance in various chronic conditions, yet specific studies exploring its isolated impact on pulmonary parameters in COPD are relatively scarce. For instance, Eleni et al. demonstrated that circuit training resulted in significant improvements in both respiratory and skeletal muscle function among COPD patients, correlating with better FEV1 and FVC scores (12). Similarly, a systematic review and meta-analysis conducted by Gao in 2022 confirmed the effectiveness of circuit training in improving lung volumes and exercise performance, including VO2peak and peak expiratory flow, thereby reinforcing its clinical relevance in pulmonary rehabilitation (13). Nonetheless, these findings necessitate further investigation through controlled trials to isolate the comparative benefits of circuit training against conventional aerobic regimens.

Considering the chronic progression of COPD and its impact on functional independence, there is a compelling need to examine rehabilitation strategies that can maximize pulmonary recovery and endurance. This study seeks to address the existing knowledge gap by evaluating whether circuit training offers additional improvements in pulmonary functions and exercise tolerance compared to traditional aerobic training in individuals diagnosed with COPD. By focusing on objective outcome measures such as FEV1, FVC, FEV1/FVC ratio, peak expiratory flow rate (PEFR), the Rate of Perceived Exertion (RPE), and the Six-Minute Walk Test (6MWT), this research aims to provide evidence-based insights into the efficacy of circuit training protocols in COPD rehabilitation. The underlying hypothesis is that circuit training will produce significantly greater improvements in pulmonary function and endurance than aerobic training alone.

MATERIAL AND METHODS

This study was designed as a randomized controlled trial (RCT) to evaluate the effects of a structured circuit training program on pulmonary function and endurance in patients diagnosed with mild to moderate Chronic Obstructive Pulmonary Disease (COPD). The trial was conducted prospectively at Gulab Devi Chest Hospital, Lahore, following appropriate methodological standards to ensure internal validity. Participants were selected through simple random sampling using a sealed opaque envelope method. A total of 34 participants were recruited after sample size estimation using the Epi Tool Sample Size Calculator, accounting for a potential attrition rate. Eligibility criteria included individuals aged between 40 and 60 years, previously diagnosed with stable COPD as per GOLD criteria and capable of independent ambulation. Patients were excluded if they had experienced acute exacerbations in the past four weeks, had comorbid conditions contraindicating exercise (e.g., uncontrolled hypertension, cardiac instability), or were already engaged in a structured rehabilitation program. Informed written consent was obtained from all participants after a detailed explanation of study procedures, risks, and benefits. Ethical approval for the trial was granted by the Institutional Review Board of Riphah International University, Lahore, in compliance with the Declaration of Helsinki.

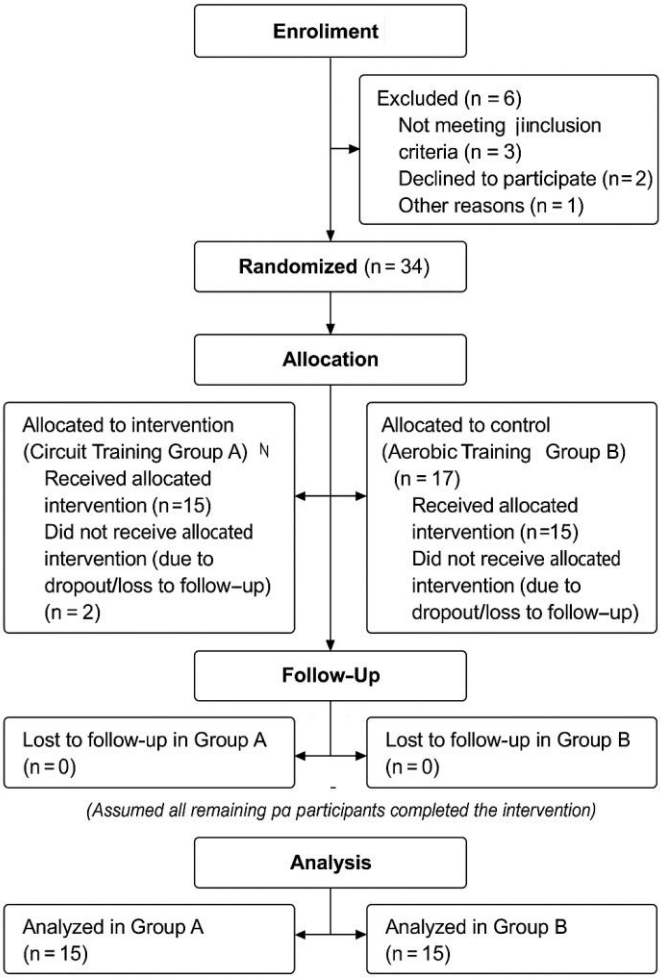

Figure 1 CONSORT Flowchart

The primary outcomes of the study included spirometric values such as Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), and FEV1/FVC ratio. Secondary outcomes included Peak Expiratory Flow Rate (PEFR), the Rate of Perceived Exertion (RPE) assessed on the Borg 6–20 scale, and functional endurance evaluated using the Six-Minute Walk Test (6MWT). Pulmonary function tests (PFTs) were performed using a calibrated spirometer under the supervision of a respiratory therapist. The RPE and 6MWT were conducted in accordance with American Thoracic Society guidelines to ensure reliability and standardization. Additional variables collected included sociodemographic details, smoking history, body mass index (BMI), and history of respiratory illness. Data collection tools included the Breathlessness, Cough and Sputum Scale (BCSS), Modified Medical Research Council (mMRC) Dyspnea Scale, and the SF-36 Quality of Life Questionnaire to provide a comprehensive clinical profile of participants. All assessments were performed at baseline and repeated after the 8-week intervention period. Intervention fidelity was monitored through supervised sessions conducted thrice weekly.

Data were analyzed using SPSS version 27. Prior to analysis, data were screened for completeness and normality using the Shapiro-Wilk test. Parametric tests were applied based on the normal distribution of the data. Paired sample t-tests were used to

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compare pre- and post-intervention values within each group, while independent sample t-tests were used to compare outcomes between groups. For ordinal or non-normally distributed secondary data, the Mann-Whitney U test was used. Statistical significance was set at $p<0.05$. No imputation was required for missing data as all participants completed the intervention and follow-up assessments. Potential confounders such as age, gender distribution, baseline BMI, and severity of disease were controlled through randomization and checked through baseline comparisons. Confidentiality was maintained by anonymizing all participant data using coded identifiers, and access to sensitive information was restricted to the research team only.

RESULTS

This study investigated the comparative effects of circuit training combined with aerobic training versus aerobic training alone on pulmonary function, perceived exertion, and exercise endurance in patients with chronic obstructive pulmonary disease (COPD). A total of 30 participants completed the study protocol over an 8-week intervention period. Baseline comparability between the two groups was assessed and confirmed. The primary outcomes included spirometric measures—Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and the FEV1/FVC ratio. Secondary outcomes included Peak Expiratory Flow Rate (PEFR), Rate of Perceived Exertion (RPE), and Six-Minute Walk Test (6MWT) distance. All outcome measures were analyzed for within-group and between-group differences using appropriate statistical tests, with significance set at $p < 0.05$.

The two groups were comparable in terms of age, height, weight, BMI, and smoking history. Both groups predominantly comprised male smokers from middle- to lower-socioeconomic backgrounds. No statistically significant differences were found in any baseline demographic variable, ensuring that observed differences in outcomes can be attributed to the intervention.

Table 1. Demographic and Anthropometric Characteristics of Study Participants

Variable	Group A (CT + AT) Mean ± SD	Group B (AT) Mean ± SD	t-value	Mean Difference	p-value
Age (years)	53.63 ± 6.73	55.21 ± 4.26	-0.974	-1.583	0.335
Height (m)	1.67 ± 0.115	1.61 ± 0.15	1.579	0.061	0.121
Weight (kg)	53.63 ± 7.37	50.08 ± 7.08	1.698	3.542	0.096
BMI (kg/m²)	19.45 ± 3.25	20.89 ± 5.09	-1.176	-1.448	0.246

Interpretation: No statistically significant differences were observed in demographic characteristics ($p > 0.05$), confirming the effectiveness of randomization and baseline equivalence between the groups. Spirometric parameters were significantly improved in the experimental group (Group A) compared to the control group (Group B). Notably, FVC, FEV1, and the FEV1/FVC ratio showed statistically significant improvements in Group A, with no clinically meaningful improvements in Group B.

Table 2. Comparison of Pulmonary Function Outcomes Pre- and Post-Intervention

Outcome	Group	Pre-Treatment Mean ± SD	Post-Treatment Mean ± SD	p-value (within-group)
FVC (L)	A	2.04 ± 0.035	2.40 ± 0.33	0.000
FVC (L)	B	2.04 ± 0.031	2.03 ± 0.032	0.600
FEV1 (L)	A	1.96 ± 0.033	2.21 ± 0.037	0.000
FEV1 (L)	B	1.97 ± 0.033	1.99 ± 0.032	0.000
FEV1/FVC (%)	A	95.98 ± 1.15	98.40 ± 1.26	0.000
FEV1/FVC (%)	B	96.39 ± 0.407	96.17 ± 0.754	0.268
PEFR (L/min)	A	422.66 ± 44.70	461.70 ± 59.70	0.000
PEFR (L/min)	B	421.20 ± 44.43	443.86 ± 43.67	0.000

Table 3. Between-Group Comparison of Post-Intervention Outcomes

Variable	Group A Mean ± SD	Group B Mean ± SD	p-value (Independent t-test)
FVC (L)	2.40 ± 0.33	2.03 ± 0.032	0.001
FEV1 (L)	2.21 ± 0.037	1.99 ± 0.032	0.000
FEV1/FVC (%)	98.40 ± 1.26	96.17 ± 0.754	0.000
PEFR (L/min)	461.70 ± 59.70	443.86 ± 43.67	0.020
RPE (6–20 scale)	12.13 ± 2.50	14.13 ± 2.10	0.004
6MWT (meters)	536.33 ± 71.52	506.50 ± 56.73	0.020

Interpretation: Statistically and clinically significant differences were found between the two groups in pulmonary function and endurance outcomes. The greater reduction in RPE and improvement in 6MWT distance in Group A indicate enhanced exercise tolerance and reduced perceived exertion. Interpretation. The experimental group showed marked and statistically significant improvements in FVC, FEV1, and FEV1/FVC, with effect sizes suggesting clinical relevance. Although PEFR improved significantly within both groups, between-group comparison (see Table 3) showed greater benefit in Group A. Between-group analyses demonstrated statistically significant superiority of

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circuit training with aerobic exercise (Group A) over aerobic training alone (Group B) in most measured outcomes, including FVC, FEV1, FEV1/FVC ratio, PEFR, RPE, and 6MWT distance. The symptom and activity scores revealed further benefits in the experimental group. Post-intervention PFT and symptom scores were significantly better in Group A. Mann-Whitney U tests were used to analyze non-parametric data.

Table 4. Pre- and Post-Intervention Clinical Scores

Variable	Group A Mean ± SD	Group B Mean ± SD	p-value
PFT Score (Post)	76.06 ± 4.50	83.10 ± 5.76	0.000
Symptom Score (Post)	69.56 ± 10.92	79.14 ± 13.16	0.009
Activity Score (Post)	18.23 ± 14.83	30.77 ± 12.89	0.002
6MWT Distance (Post Rank)	34.77	14.23	0.000

Interpretation: The symptom burden and activity limitations were reduced significantly more in the experimental group, highlighting the functional advantages of the circuit-based intervention. The significant drop in symptom and activity scores aligns with the physiological improvements reported.

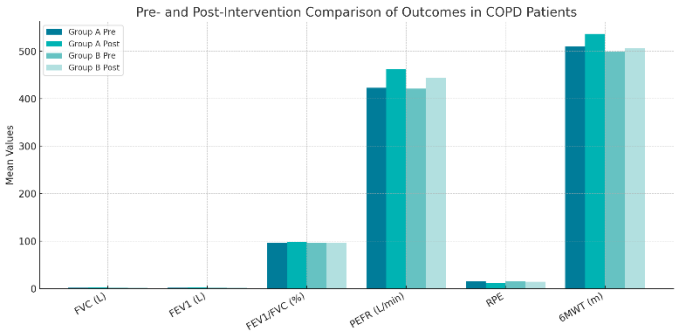

Figure 2 Pre-Post Outcomes Comparison

Collectively, the results demonstrated that both circuit and aerobic training protocols provided statistically significant improvements in spirometric indices and endurance capacity among COPD patients. However, the circuit training group consistently outperformed the aerobic-only group across nearly all outcome measures. Clinically, improvements in FEV1 and 6MWT distance surpass the minimal clinically important difference (MCID) thresholds typically reported in COPD rehabilitation studies, underscoring the practical value of circuit training as an adjunct or alternative to standard aerobic protocols.

DISCUSSION

This randomized controlled trial demonstrated that circuit training combined with aerobic exercise significantly improved pulmonary function, perceived exertion, and exercise endurance in patients with chronic obstructive pulmonary disease (COPD) compared to aerobic training alone. The observed enhancements in FEV1, FVC, FEV1/FVC ratio, PEFR, and 6-minute walk distance (6MWT), alongside reductions in symptom burden and perceived exertion, underscore the clinical superiority of circuit-based interventions in pulmonary rehabilitation. These findings reinforce the evolving understanding that multifaceted exercise modalities, incorporating both aerobic and resistance elements, can yield superior physiological and functional outcomes in COPD management.

The results are consistent with existing literature that supports the role of structured exercise programs in improving cardiorespiratory efficiency in COPD. Previous studies, such as that by Eleni et al., also reported significant gains in respiratory muscle strength, FEV1, and overall functional capacity following circuit-based interventions (12). Similarly, a meta-analysis by Min Gao in 2022 concluded that circuit training, which combines high-intensity aerobic intervals with resistance tasks, significantly enhances pulmonary parameters, particularly FEV1, FVC, and VO2peak (13). The current study advances this literature by providing a direct comparison between circuit training and aerobic-only protocols under controlled conditions and demonstrating that the former offers clinically meaningful benefits in reducing dyspnea and improving endurance—two core impairments in COPD.

Mechanistically, circuit training imposes intermittent stress on the cardiopulmonary and muscular systems, leading to favorable adaptations in oxygen uptake, ventilatory efficiency, and respiratory muscle recruitment. The incorporation of upper and lower limb strengthening exercises may contribute to reduced thoracic stiffness and enhanced thoracoabdominal coordination, thereby supporting more efficient ventilation. Furthermore, regular interval-based training improves peripheral muscle oxygen utilization, which can delay the onset of fatigue and reduce overall exertional dyspnea during activities of daily living. From a theoretical standpoint, the integrated training model aligns with the principle of specificity in rehabilitation, targeting both central (cardiopulmonary) and peripheral (musculoskeletal) limitations that characterize COPD (9).

The study holds important clinical implications for physiotherapy and pulmonary rehabilitation programs. Given the burden of COPD on healthcare systems and the limited sustainability of pharmacological management alone, circuit training offers a viable, scalable, and non-pharmacologic strategy that can enhance patient outcomes. The significant post-intervention improvements in 6MWT distance and reductions in Rate of Perceived Exertion (RPE) reflect not only statistical but also functional and quality-of-life benefits. Such changes may translate into improved autonomy, reduced hospitalizations, and potentially greater long-term adherence to physical activity in COPD populations.

Despite its strengths, including a randomized design, standardized protocols, and use of validated outcome measures, this study has limitations that warrant consideration. The relatively small sample size, while statistically powered, may limit generalizability, particularly to individuals with severe or very severe COPD. Additionally, the study population was drawn from a single center with a predominantly male and smoker profile, which may not

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reflect broader demographic or disease variability. The absence of long-term follow-up restricts conclusions regarding the durability of training effects, and future studies should consider integrating post-intervention surveillance to assess maintenance of benefits. Methodological limitations also include the lack of blinding, which, although difficult in exercise interventions, may introduce performance or detection bias. Furthermore, objective measures such as VO2peak or electromyographic analysis of respiratory muscles could provide deeper insights into the physiological underpinnings of the observed improvements.

Future research should explore circuit training in diverse COPD cohorts, including females, non-smokers, and patients with comorbidities such as cardiovascular disease or diabetes. Larger multicenter trials with extended follow-up periods would help determine the long-term efficacy and adherence potential of circuit-based programs. Investigations into the neuropsychological impact of combined training—such as its effects on anxiety, depression, or cognitive decline—would further broaden the understanding of its multidimensional benefits. Additionally, studies comparing home-based versus supervised circuit training could inform healthcare policy and accessibility models, particularly in low-resource settings.

CONCLUSION

This study concludes that a circuit training program, when integrated with aerobic exercise, significantly enhances endurance and pulmonary function in patients with chronic obstructive pulmonary disease (COPD), as evidenced by improvements in FEV1, FVC, PEFR, and exercise tolerance. These findings align with the study objective and underscore the superiority of circuit training over conventional aerobic protocols in COPD rehabilitation. Clinically, incorporating circuit training into pulmonary rehabilitation programs offers a more effective approach to reducing dyspnea and improving functional capacity, thereby enhancing patients' quality of life and potentially reducing healthcare utilization. From a research perspective, the results support further exploration into long-term outcomes, diverse patient populations, and implementation strategies for circuit-based interventions in routine clinical practice.

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