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EFFECTIVENESS OF PULMONARY REHABILITATION ON EXERCISE TOLERANCE IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE AND CARDIAC COMORBIDITIES

Original Research

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ABSTRACT

Background: Chronic Obstructive Pulmonary Disease (COPD) often coexists with cardiovascular disease (CVD), compounding limitations in physical function and quality of life. While pulmonary rehabilitation (PR) is well-established for improving outcomes in COPD, evidence regarding its efficacy in patients with concurrent cardiac comorbidities remains limited.

Objective: To assess the effectiveness of pulmonary rehabilitation in improving exercise tolerance among COPD patients with coexisting cardiac conditions.

Methods: A randomized controlled trial was conducted over 12 months at tertiary hospitals in Pakistan. A total of 110 stable COPD patients with cardiac comorbidities were randomized equally into intervention and control groups. The intervention group received an 8-week structured PR program in addition to standard care, while the control group received standard care alone. Primary outcome was change in six-minute walk distance (6MWD). Secondary outcomes included Modified Medical Research Council (mMRC) dyspnea scale, COPD Assessment Test (CAT), and St. George's Respiratory Questionnaire (SGRQ). Data were analyzed using paired and independent t-tests, with $p < 0.05$ considered statistically significant.

Results: The intervention group showed a significant mean increase in 6MWD (63.2 m, $p < 0.001$), while the control group had a non-significant change (6.5 m, $p = 0.186$). mMRC and CAT scores significantly improved in the intervention group ($p < 0.001$), with negligible changes in controls. SGRQ total scores decreased by 12.8 points in the intervention group ($p < 0.001$), indicating better quality of life. No adverse events were reported.

Conclusion: Pulmonary rehabilitation significantly enhances exercise capacity and symptom burden in COPD patients with cardiac comorbidities. These findings support integrating PR into routine care for this high-risk group.

Keywords: Cardiovascular Diseases, Chronic Obstructive Pulmonary Disease, Dyspnea, Exercise Therapy, Health-Related Quality of Life, Pulmonary Rehabilitation, Randomized Controlled Trial, Respiratory Function Tests.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) represents a significant public health burden worldwide, affecting millions and ranking among the leading causes of morbidity and mortality. Beyond its respiratory limitations, COPD often coexists with a range of comorbidities—particularly cardiovascular diseases—that further reduce functional capacity, quality of life, and survival (1). The overlapping pathophysiological mechanisms, such as systemic inflammation, oxidative stress, and reduced physical activity, make this dual burden particularly challenging to manage. Pulmonary rehabilitation (PR), an evidence-based intervention, has emerged as a cornerstone in the non-pharmacological treatment of COPD, focusing on exercise training, education, and behavioral changes. Its effectiveness in improving exercise tolerance, reducing dyspnea, and enhancing quality of life in COPD patients is well established (2,3). However, the extent to which PR benefits those with additional cardiac comorbidities remains an area requiring deeper exploration. Patients with concurrent COPD and cardiac conditions, such as heart failure or ischemic heart disease, face compounded limitations in physical capacity (4). These individuals often present with greater symptom burden, reduced aerobic endurance, and higher rates of hospitalizations than patients with COPD alone. Despite these complexities, they are frequently excluded from traditional rehabilitation trials due to perceived safety concerns or anticipated reduced responsiveness (5). Yet, preliminary evidence suggests that tailored pulmonary rehabilitation programs may still yield substantial benefits for this population. Studies have consistently shown that pulmonary rehabilitation improves exercise tolerance in COPD patients, as measured by parameters like the six-minute walk distance (6MWD) and peak oxygen uptake (6,7). For instance, a randomized controlled trial demonstrated significant improvements in walking distance (by 39 meters) and endurance time (by 421 seconds) following a 3-month rehabilitation program that included exercise training and education (8). Another trial found that both moderate and higher intensity aerobic exercise within PR programs led to significant enhancements in 6MWD and dyspnea perception, although the intensity level itself did not make a substantial difference (9). Incorporating additional strategies such as neuromuscular electrical stimulation (NMES) has been explored to augment rehabilitation outcomes, particularly in severely deconditioned patients.

A study indicated that combining NMES with conventional PR significantly enhanced exercise capacity, as shown by longer distances walked in the 6MWT, compared to PR alone (10). These findings emphasize the adaptability and potential scalability of PR interventions for more complex patient subgroups. The presence of cardiac comorbidities in COPD patients may necessitate modifications to the design and delivery of PR. However, evidence supports the safety and efficacy of PR even in patients with advanced disease or additional cardiovascular burden. A combined intervention trial showed that the addition of tiotropium to PR significantly increased treadmill endurance and improved dyspnea and health status, even in patients with severe airflow limitation and likely cardiac comorbidities (11,12). Moreover, maintenance of rehabilitation gains over time has been a consistent concern. Long-term follow-up studies suggest that without structured continuation programs, improvements in exercise capacity tend to wane. Yet, structured follow-ups or adjunctive strategies can preserve these benefits. A study found that benefits in exercise capacity persisted up to six months post-rehabilitation and remained superior to controls at one year, emphasizing the potential for sustained impact with ongoing support (13). Despite robust evidence on the benefits of PR in COPD, specific data on its efficacy in those with concomitant cardiac conditions remain limited and underrepresented in the literature. This gap is clinically significant, given that cardiovascular disease is among the most prevalent comorbidities in COPD patients. Therefore, a focused investigation through a randomized controlled trial is warranted to establish whether pulmonary rehabilitation can meaningfully enhance exercise tolerance in this unique and high-risk group. The objective of this study is to assess the effectiveness of pulmonary rehabilitation on improving exercise capacity in patients with chronic obstructive pulmonary disease who also have coexisting cardiac comorbidities, thereby contributing to a more inclusive understanding of PR's utility across complex patient profiles.

METHODS

This randomized controlled trial was conducted over a 12-month period in two tertiary care hospitals in Pakistan, selected for their advanced respiratory and cardiopulmonary care services and their established pulmonary rehabilitation infrastructure. The study aimed to assess the impact of pulmonary rehabilitation on exercise capacity among patients diagnosed with chronic obstructive pulmonary disease (COPD) and coexisting cardiac comorbidities. The target population included adult patients aged between 45 and 75 years with

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a confirmed diagnosis of moderate to severe COPD as defined by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) criteria and evidence of stable cardiac comorbidity, such as ischemic heart disease or heart failure with preserved or reduced ejection fraction. COPD diagnosis was confirmed via spirometry, with a post-bronchodilator FEV1/FVC ratio of less than 0.70. Cardiac comorbidities were verified through echocardiographic evaluation and recent cardiology consultation notes not exceeding three months. Only patients in a stable clinical condition—defined as no exacerbation or hospitalization in the preceding four weeks—were eligible for enrollment. Participants were excluded if they had recent myocardial infarction (within past three months), uncontrolled arrhythmias, severe cognitive impairment, orthopedic limitations affecting mobility, active malignancy, or were unable to provide informed consent (14). Those enrolled were randomly assigned to either an intervention group receiving pulmonary rehabilitation in addition to standard medical therapy or a control group receiving standard medical therapy alone. Randomization was performed using a computer-generated sequence, and allocation was concealed in sequentially numbered, opaque, sealed envelopes. Sample size was calculated based on an expected medium effect size (Cohen's d = 0.5) in the primary outcome measure, the six-minute walk distance (6MWD), with a power of 80% and a significance level of 0.05. Assuming a standard deviation of 60 meters and a minimum clinically important difference of 35 meters in 6MWD, the estimated sample size was 45 patients per group. Accounting for a 20% dropout rate, the final sample included 110 patients, with 55 allocated to each arm of the study (1,2).

The pulmonary rehabilitation intervention was delivered over eight weeks, consisting of supervised sessions three times per week at the hospital's rehabilitation unit. Each session lasted approximately 60 minutes and included aerobic training on a treadmill or cycle ergometer, strength training using resistance bands or weights, breathing exercises such as diaphragmatic and pursed-lip breathing, and educational components on disease self-management and cardiovascular health. Exercise intensity was individualized and progressed weekly based on baseline performance and tolerance. Heart rate and oxygen saturation were monitored continuously using portable telemetry systems, ensuring safety for patients with cardiac conditions. Baseline and follow-up assessments were performed at Week 0 and Week 8, respectively. The primary outcome was change in exercise capacity, assessed via the six-minute walk test (6MWT), conducted according to American Thoracic Society guidelines. Secondary outcomes included the Modified Medical Research Council (mMRC) Dyspnea Scale, the COPD Assessment Test (CAT), and health-related quality of life measured by the St. George's Respiratory Questionnaire (SGRQ) (15-17). Cardiac status was monitored through resting echocardiography and NT-proBNP levels to observe any clinical deterioration or acute cardiac events. All assessments were conducted by blinded assessors who were unaware of the group allocations. Data entry and verification were performed by two independent research assistants. Statistical analysis was conducted using SPSS version 26. Descriptive statistics were used to summarize demographic and clinical characteristics. Normality of data was assessed using the Shapiro-Wilk test. Since all continuous outcome variables were normally distributed, parametric tests were applied. Between-group comparisons for continuous variables were made using independent samples t-tests, while within-group changes were assessed using paired t-tests. Categorical variables were analyzed using the Chi-square test. A p-value of <0.05 was considered statistically significant. Ethical approval for this study was obtained from the Institutional Review Board (IRB) of the relevant institute. All participants provided written informed consent after receiving verbal and written explanations of the study's objectives, procedures, risks, and benefits. Confidentiality was maintained throughout the study, and participants were assured that withdrawal from the trial would not affect their standard clinical care. This methodologically rigorous trial was designed to yield high-quality evidence on the effectiveness of pulmonary rehabilitation in improving functional exercise capacity in COPD patients with coexisting heart disease, a population often underrepresented in conventional rehabilitation research.

RESULTS

A total of 110 participants were enrolled and equally randomized into intervention (n=55) and control (n=55) groups. Baseline characteristics, including age, sex distribution, BMI, smoking status, FEV1, and left ventricular ejection fraction (LVEF), were comparable between groups, with no statistically significant differences observed (Table 1). The mean age was 63.1 ± 6.7 years in the intervention group and 64.5 ± 7.1 years in the control group. The proportion of male participants was slightly higher in the control group (65.5%) compared to the intervention group (61.8%). Following the 8-week pulmonary rehabilitation program, significant improvements were noted in the primary outcome of exercise capacity. The mean six-minute walk distance (6MWD) increased from 312.6 ± 49.2 meters at baseline to 375.8 ± 52.7 meters post-intervention in the rehabilitation group, reflecting a mean increase of 63.2 meters ($p < 0.001$). In contrast, the control group showed a minimal and statistically non-significant change of 6.5 meters ($p = 0.186$) (Table 2). This change was also visualized in Figure 1, which illustrates the markedly greater improvement in walking distance among the intervention cohort. Assessment of dyspnea severity using the modified Medical Research Council (mMRC) dyspnea scale

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demonstrated a significant reduction in the intervention group, with scores decreasing from 2.8 ± 0.6 to 1.9 ± 0.7 ($p < 0.001$), whereas the control group showed negligible change (2.7 to 2.6, $p = 0.315$). Similarly, COPD symptom burden assessed by the COPD Assessment Test (CAT) showed a substantial decline in scores in the intervention group (from 22.1 ± 3.9 to 15.7 ± 4.2, $p < 0.001$), while the control group showed a modest and non-significant reduction (21.5 to 20.6, $p = 0.148$) (Table 3). The difference in CAT score reduction between groups is presented in Figure 2. Quality of life, measured by the St. George's Respiratory Questionnaire (SGRQ), showed notable improvement in the intervention group. The total SGRQ score declined from 52.4 ± 8.5 to 39.6 ± 7.3 (mean change: -12.8 points, $p < 0.001$), indicating clinically meaningful enhancement in health status. The control group had a slight, statistically non-significant reduction of 1.4 points ($p = 0.206$) (Table 4). Throughout the study, no adverse cardiac events were reported among participants in either group. All individuals completed the program without the need for hospitalization, and adherence to the rehabilitation sessions exceeded 85% among the intervention group. These findings affirm the safety and feasibility of implementing structured pulmonary rehabilitation in COPD patients with concurrent cardiac conditions.

Table 1: Baseline Demographics

Variable	Intervention Group (n=55)	Control Group (n=55)	p-value
Age (years)	63.1 ± 6.7	64.5 ± 7.1	0.378
Male, n (%)	34 (61.8%)	36 (65.5%)	0.694
BMI (kg/m²)	24.9 ± 2.5	25.1 ± 2.8	0.812
Smoking History, n (%)	42 (76.4%)	39 (70.9%)	0.540
FEV1 (% predicted)	46.3 ± 7.1	45.1 ± 6.9	0.634
LVEF (%)	50.2 ± 5.4	49.8 ± 5.1	0.880

Table 2: Six-Minute Walk Test (6MWT) Results

Group	Baseline 6MWD (m)	Post-intervention 6MWD (m)	Mean Change (m)	p-value
Intervention	312.6 ± 49.2	375.8 ± 52.7	+63.2	<0.001
Control	318.2 ± 50.8	324.7 ± 53.1	+6.5	0.186

Table 3: Symptom Scores (mMRC and CAT)

Group	Baseline mMRC	Post mMRC	Baseline CAT	Post CAT	p-value (mMRC)	p-value (CAT)
Intervention	2.8 ± 0.6	1.9 ± 0.7	22.1 ± 3.9	15.7 ± 4.2	<0.001	<0.001
Control	2.7 ± 0.7	2.6 ± 0.7	21.5 ± 4.1	20.6 ± 4.0	0.315	0.148

Table 4: Health-Related Quality of Life (SGRQ Total Score)

Group	Baseline Score	Post Score	Mean Change	p-value
Intervention	52.4 ± 8.5	39.6 ± 7.3	-12.8	<0.001
Control	50.9 ± 9.1	49.5 ± 8.7	-1.4	0.206

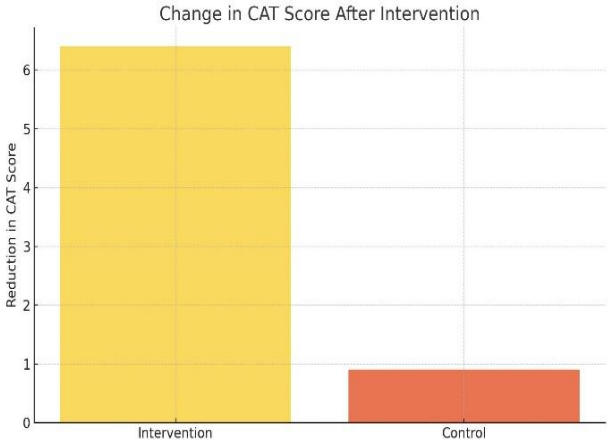

Figure 2 Change in CAT Scores After Intervention

Figure 2 Improvement in 6- Minute Walk Distance

DISCUSSION

The present study demonstrated that an eight-week structured pulmonary rehabilitation program significantly improved exercise capacity, symptom burden, and health-related quality of life in patients with chronic obstructive pulmonary disease (COPD) and coexisting cardiac comorbidities. The intervention group showed a meaningful increase in six-minute walk distance (6MWD), alongside reductions in dyspnea (mMRC), COPD symptom burden (CAT score), and SGRQ scores, indicating better functional status and perceived health. These findings align with previous studies emphasizing the effectiveness of pulmonary rehabilitation in patients with COPD, including those burdened with comorbid cardiac conditions. A study found that cardiovascular and metabolic comorbidities did not limit the benefits of a home-based rehabilitation program; patients with such comorbidities exhibited comparable improvements in exercise capacity and quality of life over a 12-month follow-up (18). Similarly, a study reported significant post-rehabilitation gains in dyspnea, walking distance, and quality of life regardless of comorbidity presence, reinforcing the applicability of pulmonary rehabilitation across patient subgroups (19). The improvement in 6MWD by over 60 meters in this study exceeds the minimum clinically important difference (MCID) of approximately 35 meters and is consistent with the gains reported in other trials (20,21). While some literature has raised concerns about potential diminished effects in patients with multiple comorbidities, the data increasingly suggest that COPD patients with cardiovascular disease are not only capable of completing pulmonary rehabilitation safely but may also derive substantial symptomatic and functional benefits (22,23). Interestingly, several studies have highlighted that, patients with more severe baseline limitations, including those with cardiac comorbidities, often experience greater relative improvement post-intervention (23). The current findings are consistent with this pattern, suggesting that the compounded limitations from both COPD and cardiac conditions may render this population particularly responsive to targeted multidisciplinary rehabilitation programs. The implications of this study are multifold. First, pulmonary rehabilitation should be actively offered to COPD patients regardless of cardiac disease status. The demonstrated safety and efficacy support its broader inclusion in standard care pathways. Second, the magnitude of improvement in functional performance and symptoms strengthens the argument for expanding access to rehabilitation programs, particularly in low-resource settings where disease burden is high and cardiac-COPD overlap is common.

This study's strengths include its randomized controlled design, comprehensive outcome measures (both objective and subjective), and practical implementation within a real-world clinical setting in Pakistan. The structured intervention, consistent monitoring, and high adherence rate enhance the internal validity of the findings. Moreover, the focus on a high-risk, underrepresented subgroup adds valuable data to a growing yet still limited global evidence base. Nonetheless, limitations must be acknowledged. The sample size, although adequately powered for primary outcomes, may not have allowed for subgroup analyses across different cardiac conditions (e.g., heart failure versus ischemic heart disease). Additionally, the follow-up period was limited to eight weeks post-intervention; longer-term sustainability of the benefits remains unknown. Objective cardiac function markers such as echocardiographic indices during exercise or biomarkers like NT-proBNP were not followed serially, which could have elucidated mechanistic insights into how cardiac function

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responded to the program. Future research should investigate the durability of pulmonary rehabilitation effects in COPD-cardiac overlap populations over longer follow-up periods. Moreover, tailored interventions that integrate cardiac-specific modifications (e.g., interval training, low-resistance aerobic programs) warrant exploration. Studies employing cardiopulmonary exercise testing and heart rate variability analysis may further unravel the interplay between respiratory and cardiovascular adaptations in response to rehabilitation (24,25). In conclusion, the findings from this trial reinforce the substantial benefit of pulmonary rehabilitation in improving functional exercise capacity and quality of life in COPD patients with cardiac comorbidities. These results support its broader application without exclusion based on comorbidity profiles and underscore the need for integrated, accessible rehabilitation programs, especially in regions facing high dual-burden disease prevalence.

CONCLUSION

This study demonstrated that an eight-week pulmonary rehabilitation program significantly improved exercise capacity, symptom burden, and quality of life in COPD patients with coexisting cardiac comorbidities. These findings highlight the clinical value of inclusive, structured rehabilitation programs and support their integration into standard care, regardless of comorbidity status. Broader implementation could lead to substantial functional and symptomatic gains in this high-risk population.

AUTHOR CONTRIBUTION

Author	Contribution
Faheem Ahmed*	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Momina Khalid	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Naina Davee	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Ayesha Khalid	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Mohammad Zahid Omerzad	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ali Raza	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Andaleeb Aziz	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published

REFERENCES

1. Kizmaz E, Telli Atalay O, Çetin N, Uğurlu E. Virtual reality for COPD exacerbation: A randomized controlled trial. Respir Med. 2024;230:107696.

2. Pleguezuelos E, Del Carmen A, Llorensi G, Carcole J, Casarramona P, Moreno E, et al. Severe loss of mechanical efficiency in COVID-19 patients. J Cachexia Sarcopenia Muscle. 2021;12(4):1056-63.

3. Lamberton CE, Mosher CL. Review of the Evidence for Pulmonary Rehabilitation in COPD: Clinical Benefits and Cost-Effectiveness. Respir Care. 2024;69(6):686-96.

4. Moreno ACR, Nai GA, Laurindo CP, Gregorio KCR, Olean-Oliveira T, Teixeira MFS, et al. Resistance training prevents right ventricle hypertrophy in rats exposed to secondhand cigarette smoke. PLoS One. 2020;15(8):e0236988.

5. Cheng SWM, McKeough ZJ, McNamara RJ, Alison JA. Pulmonary Rehabilitation Using Minimal Equipment for People With Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. Phys Ther. 2023;103(5).

6. Menson KE, Dowman L. Pulmonary Rehabilitation for Diseases Other Than COPD. J Cardiopulm Rehabil Prev. 2024;44(6):425-31.

7. Troosters T, Janssens W, Demeyer H, Rabinovich RA. Pulmonary rehabilitation and physical interventions. Eur Respir Rev. 2023;32(168).

8. Bauldoff GS, Carlin BW. Pulmonary comorbidities in cardiac rehabilitation. Prog Cardiovasc Dis. 2022;70:190-4.

9. Barker AF, Karamooz E. Non-Cystic Fibrosis Bronchiectasis in Adults: A Review. Jama. 2025;334(3):253-64.

10. Ferté JB, Boyer FC, Taiar R, Pineau C, Barbe C, Rapin A. Impact of resistance training on the 6-minute walk test in individuals with chronic obstructive pulmonary disease: A systematic review and meta-analysis. Ann Phys Rehabil Med. 2022;65(3):101582.

11. Neunhäuserer D, Reich B, Mayr B, Kaiser B, Lamprecht B, Niederseer D, et al. Impact of exercise training and supplemental oxygen on submaximal exercise performance in patients with COPD. Scand J Med Sci Sports. 2021;31(3):710-9.

12. Xiong T, Bai X, Wei X, Wang L, Li F, Shi H, et al. Exercise Rehabilitation and Chronic Respiratory Diseases: Effects, Mechanisms, and Therapeutic Benefits. Int J Chron Obstruct Pulmon Dis. 2023;18:1251-66.

13. Morris NR, Hill K, Walsh J, Sabapathy S. Exercise & Sports Science Australia (ESSA) position statement on exercise and chronic obstructive pulmonary disease. J Sci Med Sport. 2021;24(1):52-9.

14. Chen X, Xu L, Li S, Yang C, Wu X, Feng M, et al. Efficacy of respiratory support therapies during pulmonary rehabilitation exercise training in chronic obstructive pulmonary disease patients: a systematic review and network meta-analysis. BMC Med. 2024;22(1):389.

15. Tounsi B, Acheche A, Lelard T, Tabka Z, Trabelsi Y, Ahmaidi S. Effects of specific inspiratory muscle training combined with whole-body endurance training program on balance in COPD patients: Randomized controlled trial. PLoS One. 2021;16(9):e0257595.

16. He W, Wang J, Feng Z, Li J, Xie Y. Effects of exercise-based pulmonary rehabilitation on severe/very severe COPD: a systematic review and meta-analysis. Ther Adv Respir Dis. 2023;17:17534666231162250.

17. Jervan Ø, Haukeland-Parker S, Gleditsch J, Tavoly M, Klok FA, Steine K, et al. The Effects of Exercise Training in Patients With Persistent Dyspnea Following Pulmonary Embolism: A Randomized Controlled Trial. Chest. 2023;164(4):981-91.

18. Zhang ZY, Li YH. Effects of different exercise regimens on prognosis of patients with chronic obstructive pulmonary disease: a systematic reviews and meta-analysis. Ann Med. 2024;56(1):2392022.

19. Cai Y, Ren X, Wang J, Ma B, Chen O. Effects of Breathing Exercises in Patients With Chronic Obstructive Pulmonary Disease: A Network Meta-analysis. Arch Phys Med Rehabil. 2024;105(3):558-70.

20. Chuatrakoon B, Uthaikhup S, Ngai SP, Liwsrisakun C, Pothirat C, Sungkarat S. The effectiveness of home-based balance and pulmonary rehabilitation program in individuals with chronic obstructive pulmonary disease: a randomized controlled trial. Eur J Phys Rehabil Med. 2022;58(3):478-86.

21. Yu B, Liu W, Hu Y, Huang Y, Dai Q, Yang Y, et al. Effectiveness of high-intensity inspiratory muscle training, and resistance and aerobic exercise for cardiovascular health in chronic obstructive pulmonary disease (HIRAC-COPD): a randomized controlled trial protocol. BMC Pulm Med. 2024;24(1):627.

22. Frei A, Radtke T, Dalla Lana K, Brun P, Sigrist T, Spielmanns M, et al. Effectiveness of a Long-term Home-Based Exercise Training Program in Patients With COPD After Pulmonary Rehabilitation: A Multicenter Randomized Controlled Trial. Chest. 2022;162(6):1277-86.

23. Lau CW, Leung SY, Wah SH, Yip CW, Wong WY, Chan KS. Effect on muscle strength after blood flow restriction resistance exercise in early in-patient rehabilitation of post-chronic obstructive pulmonary disease acute exacerbation, a single blinded, randomized controlled study. Chron Respir Dis. 2023;20:14799731231211845.

24. Higashimoto Y, Ando M, Sano A, Saeki S, Nishikawa Y, Fukuda K, et al. Effect of pulmonary rehabilitation programs including lower limb endurance training on dyspnea in stable COPD: A systematic review and meta-analysis. Respir Investig. 2020;58(5):355-66.

25. Yu Z, Xie G, Qin C, He H, Wei Q. Effect of postoperative exercise training on physical function and quality of life of lung cancer patients with chronic obstructive pulmonary disease: A randomized controlled trial. Medicine (Baltimore). 2024;103(10):e37285.

