Effects of Multimodal Rehabilitation Intervention in Elderly COPD Patients: A Clinical and Imaging-Based Evaluation

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Abstract: - To evaluate the effectiveness of a multimodal rehabilitation treatment (MT) that integrates structured exercise and imaging-based assessment on clinical outcomes in elderly patients with stable chronic obstructive pulmonary disease (COPD). A total of 104 elderly patients with stable COPD were randomized to a Test group (n=52, MT intervention) and a control group (n=52, standard care). Outcomes were assessed at baseline, week 6, and week 12, including the 6-minute walk test (6MWT), dyspnea (modified Medical Research Council scale, mMRC), anxiety and depression (HADS-A/D), self-efficacy for exercise scale (SEE), exercise benefits/barriers scale (EBBS), COPD assessment test (CAT), and lung structural changes assessed by CT imaging. Assessments were conducted at baseline, six weeks, and twelve weeks. After completing the test for 12 weeks, the exercise endurance of the Test group increased significantly, and the level of dyspnea decreased dramatically compared to the control group. The negative emotions of the Test group were significantly lower than those of the control group (p<0.05). In addition, they reported significantly higher levels of exercise self-efficacy, perceived exercise behavior, and quality of life than the control group (p<0.05). The clinical indicators and imaging examination results of the experimental group were significantly improved compared with those of the control group. Patients in the Test group had an exercise adherence rate of 91.84% over the 6-week study period and 97.96% over the 12-week study period. Mixed-effects modeling supported

significant group-by-time interactions across key endpoints. The use of MT in geriatric pulmonary rehabilitation has been shown to reduce dyspnea and emotional distress, increase exercise endurance, improve positive perceptions of exercise behavior, and improve quality of life in elderly patients with COPD.

Key-Words: - Exercise Intervention, COPD, Elderly Patients, MT, Exercise Tolerance.

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1 Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic inflammatory lung disease, where medical imaging, such as computed tomography (CT) scans and chest X-rays, plays a crucial role in assessing the extent of lung damage and monitoring disease progression. COPD primarily affects the lungs and causes damage to other organs, with main symptoms including dyspnea, chronic cough, and fatigue, [1], [2]. Despite being preventable, COPD remains a leading cause of disability and worldwide mortality rate, requiring both pharmacological and non-pharmacological treatments. However, medication alone does not halt disease progression, [3]. Thus, comprehensive care combining non-pharmacological treatments, particularly pulmonary rehabilitation, is widely used. Pulmonary rehabilitation includes condition assessment, exercise, oxygen therapy, respiratory muscle training, nutritional support, and disease education, [4], [5]. Exercise is a key component, improving lung function, reducing dyspnea, and enhancing endurance, [6]. Aerobic exercise has been shown to significantly improve lung function and exercise endurance, strength training helps reduce muscle wasting and loss of balance, and stretching and flexibility training improve posture and reduce the risk of falls, [7], [8]. Recent studies have applied computational modeling to predict COPD patients' exercise tolerance, providing novel tools for tailoring rehabilitation interventions, [9]. However, the current form of exercise intervention applied to COPD in China is relatively one-sided, and the exercise strategy combined with multimodal treatment (MT) is not perfect. The study intends to investigate the clinical therapeutic efficacy of exercise intervention in older COPD patients in light of the aforementioned aspects. Additionally, the study aims to optimize and improve the exercise rehabilitation program for COPD patients by integrating control and analysis. The study's novelty lies in the application of the MT intervention program to pulmonary rehabilitation in senior COPD patients. Additionally, the viability of the MT intervention program in the treatment of COPD was investigated with respect to various forms of exercise.

The research's innovations are primarily reflected in the following aspects: First, in response to the absence of a unified exercise rehabilitation model for elderly patients with stable COPD in China, an MT program was developed. This program systematically integrates aerobic training, strength training, balance training, and stretching. It also provides personalized exercise prescriptions to promote comprehensive functional rehabilitation. Second, a high-resolution CT quantitative analysis is introduced to evaluate COPD rehabilitation outcomes in the elderly. This analysis objectively measures emphysema severity and airway wall thickness. This is combined with scales and motor function indicators to form a multidimensional efficacy evaluation framework. Third, integrating the WeChat platform's compliance management and real-time feedback mechanism enhances patient engagement and continuity of intervention through online check-ins, symptom reporting, and psychological support. Finally, the study uses a randomized controlled design to collect comprehensive data at multiple time points: baseline, 6 weeks, and 12 weeks. This data includes clinical, psychological, quality of life, and imaging information. Statistical indicators such as effect size and confidence interval are introduced to enhance the clinical interpretability and promotional value of the conclusions.

2 Information and Methods

2.1 General Information

To ensure that the study had sufficient statistical power, sample size estimation was performed during the design phase of the study using G*Power 3.1 software. Based on earlier publications and preliminary testing, a medium effect size of 0.6 was assumed, with the significance threshold fixed at $\alpha = 0.05$ and power maintained at 80%. It was calculated to require at least 45 cases in each group. Considering the possibility of shedding during the actual study (about 10%), 52 cases were finally

included in each group, and the total sample size was 104 cases. Elderly patients with stable COPD hospitalized from May to November 2023 were selected by convenience sampling. Using the lottery method, 104 patients were randomly assigned to the test and control group (n=52 each). During implementation, full blinding of patients was not possible due to differences in the form of the intervention, but a single-blind design was used to reduce observer bias. The researcher responsible for the statistics and analysis of the data remained unaware of the patient subgroups and analyzed the process only based on the coded data. In addition, clinical raters were not involved in the intervention process to the extent possible. The test group received MT intervention, while the control group received routine care. The test group included 11 females and 41 males (aged 64–74), and the control group had 10 females and 42 males (aged 63-73).

Inclusion criteria: (1) Diagnosed with stable COPD per relevant guidelines. (2) Age > 60. (3) Normal cognitive function and ability to complete the intervention. (4) Proficient use of smart devices by patient or family. (5) Written informed consent was signed by the patients or an authorized legal representative before study enrollment.

Exclusion criteria: (1) Severe COPD complications. (2) History of mental illness, inability to self-care, or cooperate. (3) Other diseases affecting respiratory function, exercise capacity, or emotional state.

Dropout criteria: (1) Poor compliance with the study protocol. (2) Health deterioration requiring withdrawal.

2.2 Test Method

2.1.1 Control Group

The control group received exercise intervention based on standard COPD nursing routines, including: (1) Education on proper use of medication and oxygen therapy, covering dosage, methods, timing, precautions, side effects, and oxygen use guidelines. (2) Nutritional guidance, encouraging high-calorie, high-protein, easily digestible foods, while avoiding gas-producing items like soy, carrots, and bananas. (3) Exercise recommendations: appropriate activities and physical condition standards were recommended, such as lip-contraction breathing and abdominal breathing exercises for 10 minutes twice a day. Patients perform low-intensity walking for 15 minutes, twice a day. Moreover, patients perform simple limb joint activities such as arm lifting, leg lifting, and stretching. (4) Psychological support via WeChat, phone calls, and other communication channels.

2.1.2 MT Test Group

The exercise intervention treatment for the patients in the trial group utilized the MT intervention. It mainly included: (1) Preparation and assessment before exercise. Once the COPD patients' condition was stabilized, the doctors and researchers could inform the patients of the benefits of exercise for their recovery, the contents of the study, and the essentials of the exercise program. They could also provide one-on-one explanations and demonstrations of the action essentials to patients and accompanying family members. Patients exercised at home and had timely access to exercise matters and regular exercise workout punch cards in the WeChat group. Before patients are discharged from the hospital, the static heart rate, height, weight, respiratory status, and exercise tolerance level are measured and assessed. (2) The exercise package mainly included warm-up, aerobic training, strength training, balance training, and stretching. The weekly training frequency was 2d, and each movement was trained 8-12 times/set a week for 12 weeks. (3) Exercise intensity was controlled between 4 and 6 points on the Borg Subjective Fatigue Perception Assessment Scale.

During the trial, Test group patients stopped MT immediately if they experienced discomfort such as shortness of breath, dizziness, or chest pain. They could pause at any time if unwell. Psychological support was provided via a WeChat group to address concerns promptly, and patients with good outcomes were encouraged to share their experiences.

2.3 Observation Indicators

(1) Basic Information: Name, age, occupation, education, exercise habits, and frequency.

(2) Exercise Endurance: Evaluated using the 6-minute walk test (6MWT). 6MWT could objectively reflect the patient's lung function first, and changes in exercise capacity.

(3) Dyspnea: Evaluated using the modified Medical Research Council scale (mMRC). The mMRC accurately captured changes in patients' subjective symptoms and is suitable for use in pre- and post-intervention comparisons.

(4) Negative Emotions: Measured with the Hospital Anxiety and Depression Scale (HADS). Scores: 0–7 (normal), 8–10 (possible), 11–21 (definite), [10]. Cronbach’s α: 0.82 (HADS-A), 0.842 (HADS-D).

(5) Self-Efficacy: Evaluated using the Self-Efficacy for Exercise Scale (SEE), Cronbach's α: 0.75–0.90. The SSE scale measured the level of confidence patients have in themselves to perform exercise, [11].

(6) Perceived Exercise Behavior: Assessed with the Chinese version of the Exercise Benefits/Barriers Scale (EBBS), covering benefits (29–116) and barriers (14–56), [12]. The EBBS was suitable for assessing patients' subjective attitudes and external resistance to exercise behaviour.

(7) Quality of Life (QL): Measured by the COPD Assessment Test (CAT), score range 0–40, [13]. Higher scores indicated worse QL. Cronbach's α: 0.82.

(8) Exercise Adherence: Based on daily WeChat exercise logs. Minimum standards: 25 min/day (weeks 1–6), 35 min/day (weeks 7–12). Compliance was calculated as the percentage meeting the standard.

(9) Medical Imaging: Chest X-ray and CT scans were performed pre- and post-trial to assess lung structural changes. Interpretation was performed by an imaging physician with the title of associate chief physician or higher, [14]. Chest radiographs were used for preliminary screening of pulmonary structural abnormalities. High-resolution spiral CT scans (1.25 mm slice thickness, covering the lung apex to the diaphragmatic dome) were performed. Moreover, parameter measurements were performed using the built-in 3D quantitative analysis software on the Syngo.via VB60A medical imaging workstation (Siemens Healthineers, Germany). Emphysema severity was calculated as the percentage of low-attenuation area (% LAA-950), and airway wall thickness was automatically determined using a standardized airway segmentation and measurement algorithm. The results were averaged from two independent analyses. Radiologists manually corrected any unclear boundaries or artifacts found during the automated segmentation. The evaluation was performed independently by two radiologists with the title of associate chief physician or higher. Interobserver agreement was assessed using the kappa coefficient.

2.4 Statistical Methods

Statistical analyses were performed using SPSS 22.0 (IBM, USA) and R 4.3.1 software. Continuous variables were tested for normality using the Shapiro-Wilk test. Data that was normally distributed was presented as the mean±standard deviation. Intergroup comparisons were performed using an independent samples t-test. Non-normally distributed data were presented as median and interquartile range, and the Mann-Whitney U test was used. Categorical data were presented as the number of cases and percentages. Intergroup comparisons were performed using either the chi-square test or Fisher's exact test. For repeated measures at multiple time points (baseline, 6 weeks, and 12 weeks), a two-factor mixed-effects model (group×time) was used to analyze intergroup differences and time effects. Post hoc comparisons were performed with Bonferroni correction when necessary. Subjects were used as random intercepts in the model to account for within-subject correlations. Effect sizes were calculated using Cohen's d, and 95% Confidence Intervals (95% CIs) are reported. For the main effects in the mixed-effects model, partial eta-squared (η^2) was calculated as an effect size indicator. Sample size calculation for the primary outcome measure (6MWT) was based on an expected medium effect size (0.6). After the study concluded, a post hoc power analysis was conducted. The results showed a statistical power of 0.87, indicating that the sample size was sufficient to detect a significant difference at the intended effect size. A two-sided significance level was set at $p<0.05$.

3 Results

3.1 Comparison of Patients' General Information

Three patients in the Test group of MT were dislodged. Among these, 2 patients were unwilling to cooperate and had poor compliance. One patient's condition worsened during the study. Two patients in the control group were withdrawn, one of whom deteriorated and one of whom was lost. A total of 99 elderly patients with stable COPD were finally enrolled in the study. There were 50 and 49 cases in the control group and Test group, respectively, with a combined shedding rate of 4.90%, which was within the predicted range and did not affect the results of the study. Table 1 (Appendix) presents the baseline characteristics of participants in the test and control groups. No statistically significant differences in gender or age were found between the control and Test groups. Residence, education level, smoking status, weekly exercise frequency, each exercise duration, and pulmonary function (PF) grading were not statistically significant in the Test group and control group ($p>0.05$).

3.2 Comparison of Exercise Endurance Metrics

Comparisons of 6MWT results between the two groups at different stages of the trial are shown in Figure 1 and Table 2 (Appendix). There was no statistically significant difference between the two groups before the test (p=0.94, Cohen's d=0.01, 95% CI [-0.37, 0.39]). At 6 weeks, the experimental group showed significant improvement compared with the control group (p=0.021, Cohen's d=0.39, 95% CI [0.06, 0.72]). This difference further increased at 12 weeks (p<0.001, Cohen's d=0.86, 95% CI [0.51, 1.21]). Mixed-effects model analysis revealed a significant group×time interaction effect (F(2,194)=14.72, p<0.001, η^2p=0.13), suggesting that the multimodal rehabilitation intervention significantly improved patients' walking endurance over time.

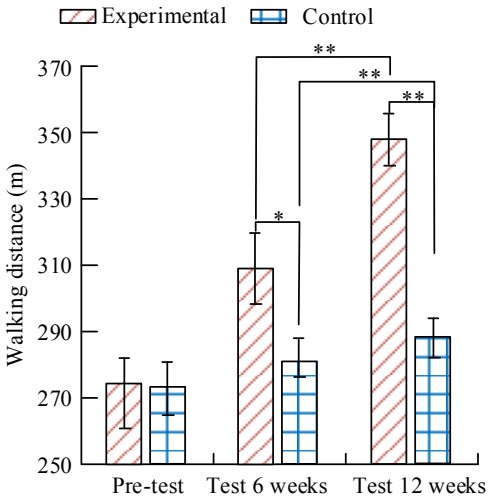

Fig. 1: Comparison of 6MWT results between the two groups of patients at different trial stages
Note: * indicates p<0.05. ** indicates p<0.01.
Source: created by the authors

3.3 Comparison of Dyspnea Indicators

Table 3 (Appendix) shows the comparison of the results of mMRC scores of patients at different trial stages. Pre-test, there was no significant difference between the two groups (p=0.88, Cohen's d=0.02, 95% CI [-0.36,0.40]). The difference between the two groups remained non-significant at 6 weeks (p=0.24, Cohen's d=0.28, 95% CI [0.05,0.60]). However, at 12 weeks, the score in the experimental group was significantly lower than that in the control group (p<0.001, Cohen's d=-4.34, 95% CI [-5.16,-3.52]). The mixed-effects model showed a significant interaction effect (F(2,194)=19.85, p<0.001, η^2p=0.17).

3.4 Comparison of Negative Sentiment Indicators

Figure 2 (Appendix) and Table 4 (Appendix) show the HADS-A and HADS-D comparisons between the Test group and the control group at different trial stages. At 12 weeks, the HADS-A score was 2.13 points lower in the experimental group compared with the control group (p=0.004, Cohen's d=-0.56, 95% CI [-0.90,-0.22]). The HADS-D score was 1.95 points lower at 12 weeks (p=0.008, Cohen's d=-0.51, 95% CI [-0.85,-0.17]). Mixed-effects models showed significant interaction effects for both groups (HADS-A: F(2,194)=9.42, p<0.001; HADS-D: F(2,194)=8.11, p<0.001).

3.5 Comparative Analysis of Exercise Behavior, Self-efficacy, and Quality of Life

Table 5 (Appendix) demonstrates the results of the between-group comparisons of the three core scale indicators at different time points. At pre-test, no significant differences were found between the two groups in the three core scale scores (p>0.05). After 6 weeks of intervention, the experimental group showed a significant improvement in SEE (p=0.024, Cohen's d=0.46, 95% CI [0.12, 0.79]), a significant increase in EBBS (p=0.019, Cohen's d=0.48, 95% CI [0.14, 0.81]), and a significant decrease in CAT (p=0.002, Cohen's d=-0.65, 95% CI [-1.00, -0.31]). By 12 weeks, the differences in the three indicators had further widened, with the experimental group showing significantly higher SEE and EBBS scores (p<0.001), while the CAT score was significantly lower (p<0.001). The results of the mixed-effects model analysis showed that the group×time interaction effect was statistically significant in all three core scales (all p<0.001). It suggested that multimodal rehabilitation intervention had significant and cumulative effects over time in enhancing exercise self-efficacy, improving perceived exercise behavior, and reducing disease burden.

Table 6 (Appendix) presents the CAT dimension scores comparison between the test group and the control group using the nonparametric rank sum test. Before the trial, no significant differences were found in cough, sputum, or ability to go out (p>0.05). At 6 weeks, significant differences emerged in chest tightness, physical agility, and self-care ability (p<0.05). By 12 weeks, the test group showed significantly better scores in energy, chest tightness, physical agility, and self-care (p<0.05).

3.6 Imaging Analysis

Table 7 (Appendix) shows the imaging results of both groups. At week 12, the experimental group had a significant increase in total lung capacity (p<0.001, Cohen's d=2.91, 95% CI [2.28, 3.54]), and a significant improvement in emphysema severity and airway wall thickness (p<0.05). The imaging analyses were well-concordant (kappa=0.87).

4 Conclusion

COPD is a common chronic inflammatory lung disease where medication can relieve dyspnea but has a limited effect on reversing physical decline. Pulmonary rehabilitation helps reduce fatigue and dyspnea while improving patients' self-management, [15], [16]. Early structured rehab programs can prevent physical deterioration by retraining peripheral and respiratory muscles, [17], [18]. The study, [19], found that Baduanjin exercise improved exercise capacity, lung function, and quality of life in COPD patients, though their sample lacked focus on the elderly. The study, [20], a meta-analysis of 494 studies, confirmed that exercise reduces fatigue in COPD patients. However, in China, multimodal exercise is rarely applied in elderly COPD rehabilitation, with programs often lacking diversity. This study aims to explore new approaches to optimize exercise rehabilitation for elderly COPD patients.

Ninety-nine elderly patients with stable COPD were randomly assigned to a test and control group via lottery, with no significant differences in baseline data (p>0.05). The male-to-female ratio was 5.19:1, aligning with COPD epidemiology. Exercise capacity reflected physical health, treatment response, and prognosis, [21]. After 12 weeks, 6MWT scores were 348.12±65.44 (test group) and 288.33±74.59 (control group), demonstrating statistical significance (p<0.05), indicating better endurance in the test group. Dyspnea improved in the test group after 6 weeks. However, intergroup differences were not statistically significant (p>0.05), likely related to the low intensity of early training. By 12 weeks, the test group had a significantly lower mMRC score (1.32±0.12, p<0.05), confirming MT's effectiveness. These results aligned with [22], who also found that exercise improved tolerance and reduced dyspnea in COPD patients.

The COPD treatment cycle was long and had a great negative impact on patients' mental health. Therefore, the study analyzed the effect of MT intervention on anxiety and depression conditions in COPD patients with the HADS scale, [23]. After 12 weeks of the trial, the patients in the test group had a HADS-A score of 6.99±2.01 and a HADS-D score of 8.28±3.41. Their HADS-A scores were significantly higher compared to the pre-test (p<0.05), and there was a SSD between the HADS-A scores and HADS-D scores of the test group and those of the control group (p<0.05). This suggested that utilizing MT intervention as a rehabilitation training for COPD patients could significantly alleviate patients' negative emotions. The findings of Au et al. showed that pulmonary rehabilitation training could significantly improve the QL of COPD patients, [24]. In the study, there was a significant difference in the CAT scores of the test group and control group after 12 weeks of the trial from those before the trial (p<0.05). The CAT score after 12 weeks of trial was 15.43±5.07 in the test group and 20.65±5.32 in the control group (p<0.05). CAT score comparisons showed that MT intervention significantly improved energy, chest tightness, mobility, and daily living ability in COPD patients. The imaging results from the study showed significant improvements in emphysema severity and airway wall thickness in the experimental group compared to the control group. The reduction in emphysema severity indicates less alveolar destruction, which is likely due to the exercise intervention improving respiratory muscle function, promoting pulmonary ventilation, and reducing air retention. The reduction in airway wall thickness suggests a reduction in airway inflammation and structural remodeling. These imaging improvements were consistent with decreased CAT and mMRC dyspnea scores. This indicates that imaging measures can serve as objective evidence of structural improvement and reflect improvements in patients' symptoms and quality of life.

Table 8 (Appendix) compares the proposed method with previous COPD rehabilitation studies conducted both domestically and internationally. This study significantly expands the intervention model, assessment dimensions, and compliance management compared with previous COPD rehabilitation studies at home and abroad. Previous studies mostly focused on single exercise training or lifestyle interventions, with limited application of imaging assessments, relying solely on functional measurements and subjective scales. This study integrated multiple exercise training models and introduced a quantitative analysis of HRCT, combining lung structural changes with clinical indicators, psychological status, and improvements in quality of life to create a comprehensive, multidimensional efficacy evaluation system. In

addition, the use of the WeChat platform for intervention process management and psychological support significantly improved patient compliance and long-term participation. These designs not only improved the sustainability of the intervention effect but also provided a scalable operational path for COPD rehabilitation management in the elderly. It was worth noting that although CAT scores and imaging indicators showed that the intervention was effective, the sample source was concentrated in a single region, and patient compliance was high, which may have led to an overestimation of the intervention effect. In addition, indicators such as mMRC did not show significant differences in the early phase, suggesting that the initial effect of the intervention may be influenced by the intensity of the training or the adaptation period of the patients. In conclusion, the MT intervention for elderly patients with stable COPD could alleviate their dyspnea and negative emotions, improve their exercise endurance and efficacy, and enhance their perceived ability to exercise, as well as their QL. It could therefore be concluded that the MT intervention protocol proposed by the study was effective for elderly patients with stable COPD.

However, due to economic constraints and other factors, the study did not further test the PF index in patients in the treatment group. The study sample was from a single center with limited regional representation, and the generalizability of the results needs to be further verified by multicenter, large-sample studies. Second, patients' exercise adherence during the study period relied on the WeChat platform clocking and subjective reporting, with some risk of bias. Third, although CT images were used to quantitatively analyze lung structural changes, objective indicators of lung function, such as 2FEV1, were not systematically included, limiting the comprehensive assessment of functional improvement. Finally, the study period of 12 weeks was not long enough to assess the long-term sustained effects of the MT intervention.

Future research will be expanded in the following areas: First, the sample size will be increased, and the follow-up period will be extended to confirm the long-term effects of multimodal rehabilitation interventions on elderly patients with stable COPD and different disease courses and classifications. Second, wearable devices and mobile health platforms will be combined to provide personalized, dynamic adjustments to exercise prescriptions, as well as to monitor changes in daily activity levels and compliance. Third, multimodal physiological indicators, such as end-tidal carbon dioxide partial pressure monitoring and lung function classification, will be introduced. These indicators will be used to conduct multidimensional correlation analyses with imaging parameters in order to explore predictive models for rehabilitation effects. In addition, more advanced imaging quantification techniques and machine learning algorithms will be employed to enable automated assessments and early warnings of changes in lung structure and function. Research needs to consider cross-regional studies with multiple centers to validate the feasibility and generalizable value of intervention models under different healthcare resource conditions.

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This study was performed in accordance with the 1964 Declaration of Helsinki and later amendments, and was approved by the Ethics Committee of The Fifth Affiliated Hospital of Zhengzhou University (approval no. 2024-KY-1540-009).

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

The authors wrote, reviewed, and edited the content as needed, and they have not utilised artificial intelligence (AI) tools. The authors take full responsibility for the content of the publication.

References:

[1] Stolz, D., Mkorombindo, T., Schumann, D.M., Agusti, A., Ash, S.Y., Bafadhel, M., Bai, C., Chalmers, J.D., Criner, G.J., Dharmage, S.C., Franssen, F.M.E., Frey, U., Han, M., Hansel, N.N., Hawkins, N.M., Kalhan, R., Konigshoff, M., Ko, F.W., Parekh, T.M., Powell, P., Rutten-van Mölken, M., Simpson, J., Sin, D.D., Song, Y., Suki, B., Troosters, T., Washko, G.R., Welte, T., Dransfield, M.T., Towards the Elimination of Chronic Obstructive Pulmonary Disease: A Lancet Commission, *The Lancet*, Vol.400, No.10356, 2022, pp. 921-972. https://doi.org/10.1016/s0140-6736(22)01273-9.

[2] MacLeod, M., Papi, A., Contoli, M., Beghé, B., Celli, B.R., Wedzicha, J.A., Fabbri, L.M., Chronic Obstructive Pulmonary Disease Exacerbation Fundamentals: Diagnosis, Treatment, Prevention and Disease Impact, *Respirology*, Vol.26, No.6, 2021, pp. 532-551. https://doi.org/10.1111/resp.14041.

[3] Gredic, M., Blanco, I., Kovacs, G., Helyes, Z., Ferdinandy, P., Olschewski, H., Barberà, J.A.,

Weissmann, N., Pulmonary Hypertension in Chronic Obstructive Pulmonary Disease, *British Journal of Pharmacology*, Vol.178, No.1, 2021, pp. 132-151. https://doi.org/10.1111/bph.14979.

[4] Chetambath, R., Pulmonary rehabilitation in Chronic Respiratory Diseases, *Journal of Advanced Lung Health*, Vol.2, No.1, 2022, pp. 5-12. https://doi.org/10.4103/jalh.jalh_9_21.

[5] Zhang, H., Hu, D., Xu, Y., Wu, L., Lou, L., Effect of Pulmonary Rehabilitation in Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-analysis of Randomized Controlled Trials, *Annals of Medicine*, Vol.54, No.1, 2022, pp. 262-273. https://doi.org/10.1080/07853890.2021.1999494.

[6] Yang, Y., Wei, L., Wang, S., Ke, L., Zhao, H., Mao, J., Li, J., Mao, Z., The Effects of Pursed Lip Breathing Combined with Diaphragmatic Breathing on Pulmonary Function and Exercise Capacity in Patients with COPD: A Systematic Review and Meta-analysis, *Physiotherapy Theory and Practice*, Vol.38, No.7, 2022, pp. 847-857. https://doi.org/10.1080/09593985.2020.1805834.

[7] McKendry, J., Coletta, G., Nunes, E.A., Lim, C., Phillips, S.M., Mitigating Disuse- induced Skeletal Muscle Atrophy in Ageing: Resistance Exercise as a Critical Countermeasure, *Experimental Physiology*, Vol.109, No.10, 2024, pp. 1650-1662. https://doi.org/10.1113/ep091937.

[8] Santos, L.E., de Sá Ferreira, A., Vilella, R.C., Lunkes, L.C., The Importance of Physical Therapy in the Evaluation of Fall Prevention Programs in Older Adults: A Scoping Review, *Topics in Geriatric Rehabilitation*, Vol.40, No.1, 2024, pp. 83-92. http://dx.doi.org/10.1097/TGR.0000000000000426.

[9] Bhana, R.H., Magan, A.B., Lung Mechanics: A Review of Solid Mechanical Elasticity in Lung Parenchyma, *Journal of Elasticity*, Vol.153, No.1, 2023, pp. 53-117. https://doi.org/10.1007/s10659-022-09973-6.

[10] Zigmond, A.S., Snaith, R.P., The Hospital Anxiety and Depression Scale, *Acta Psychiatrica Scandinavica*, 1983, Vol.67, No.6, pp. 361-370. https://doi.org/10.1111/j.1600-0447.1983.tb09716.x.

[11] Resnick, B., Jenkins, L.S., Testing the Reliability and Validity of the Self-efficacy for Exercise Scale, *Nursing Research*, Vol.49, No.3, 2000, pp. 154-159. https://doi.org/10.1097/00006199-200005000-00007.

[12] Sechrist, K.R., Walker, S.N., Pender, N.J., Development and Psychometric Evaluation of the Exercise Benefits/Barriers Scale, *Research in Nursing & Health*, Vol.10, No.6, 1987, pp. 357-365. https://doi.org/10.1002/nur.4770100603.

[13] Jones, P.W., Harding, G., Berry, P., Wiklund, I., Chen, W.H., Leidy, N.K., Development and First Validation of the COPD Assessment Test, *European Respiratory Journal*, Vol.34, No.3, 2009, pp. 648-654. https://doi.org/10.1183/09031936.00102509.

[14] Chaudhary, M.F., Hoffman, E.A., Guo, J., Comellas, A.P., Newell, J.D., Nagpal, P., Reinhardt, J.M., Predicting Severe Chronic Obstructive Pulmonary Disease Exacerbations Using Quantitative CT: A Retrospective Model Development and External Validation Study, *The Lancet Digital Health*, Vol.5, No.2, 2023, pp. 83-92.

[15] Delbressine, J.M., Vaes, A.W., Goërtz, Y.M., Sillen, M.J., Kawagoshi, A., Meijer, K., Janssen, D.J.A., Spruit, M.A., Effects of Exercise-based Interventions on Fall Risk and Balance in Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review, *Journal of Cardiopulmonary Rehabilitation and Prevention*, Vol.40, No.3, 2020, pp. 152-163. https://doi.org/10.1097/hcr.0000000000000513

[16] Ward, T.J., Plumptre, C.D., Fraser-Pye, A.V., Dolmage, T.E., Jones, A.V., Trethewey, R., Latimer, L., Singh, S.J., Lindley, M.R., Steiner, M.C., Evans, R.A., Understanding the Effectiveness of Different Exercise Training Programme Designs on V̇O2peak in COPD: A Component Network Meta-analysis, *Thorax*, Vol.78, No.10, 2023, pp. 1035-1038. https://doi.org/10.1136/thorax-2023-220071.

[17] Martí, J.D., McWilliams, D., Gimeno-Santos, E., Physical Therapy and Rehabilitation in Chronic Obstructive Pulmonary Disease Patients Admitted to the Intensive Care Unit. *Seminars in Respiratory and Critical Care Medicine*, Vol.41, No.6, 2020, pp. 886-898. https://doi.org/10.1055/s-0040-1709139.

[18] Spielmanns, M., Gloeckl, R., Jarosch, I., Leitl, D., Schneeberger, T., Boeselt, T., Huber, S., Kaur-Bollinger, P., Ulm, B., Mueller, C., Bjoerklund, J., Spielmanns, S., Windisch, W., Pekacka-Egli, A.M., Koczulla, A.R., Using a Smartphone Application Maintains Physical

Activity Following Pulmonary Rehabilitation in Patients with COPD: A Randomised Controlled Trial, *Thorax*, Vol.78, No.5, 2023, pp. 442-450. https://doi.org/10.1136/thoraxjnl-2021-218338.

[19] Cao, A., Feng, F., Zhang, L., Zhou, X., Baduanjin Exercise for Chronic Obstructive Pulmonary Disease: An Updated Systematic Review and Meta-analysis, *Clinical Rehabilitation*, Vol.34, No.8, 2020, pp. 1004-1013. https://doi.org/10.1177/0269215520926635.

[20] Paneroni, M., Vitacca, M., Venturelli, M., Simonelli, C., Bertacchini, L., Scalvini, S., Schena, F., Ambrosino, N., The Impact of Exercise Training on Fatigue in Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-analysis, *Pulmonology*, Vol.26, No.5, 2020, pp. 304-313. https://doi.org/10.1016/j.pulmoe.2020.02.004.

[21] Mendes Xavier, D., Lanza Galvão, E., Aliane Fonseca, A., de Souza, G.M., Pereira Lima, V., Effects of Home-based Pulmonary Rehabilitation on Dyspnea, Exercise Capacity, Quality of Life and Impact of the Disease in COPD Patients: A Systematic Review, *COPD: Journal of Chronic Obstructive Pulmonary Disease*, Vol.19, No.1, 2022, pp. 18-46. https://doi.org/10.1080/15412555.2021.2020234.

[22] Frei, A., Radtke, T., Dalla Lana, K., Brun, P., Sigrist, T., Spielmanns, M., Beyer, S., Riegler, T.F., Büsching, G., Spielmanns, S., Kunz, R., Cerini, T., Braun, J., Tomonaga, Y., Serra-Burriel, M., Polhemus, A., Puhan, M.A., Effectiveness of a Long-term Home-based Exercise Training Program in Patients with COPD after Pulmonary Rehabilitation: A Multicenter Randomized Controlled Trial, *Chest*, Vol.162, No.6, 2022, pp. 1277-1286. https://doi.org/10.1016/j.chest.2022.07.026.

[23] Casaburi, R., Merrill, D., Leidy, N.K., Locantore, N., Dolmage, T., Garcia-Aymerich, J., Goldstein, R., Harding, G., Maltais, F., O'Donnell, D., Porszasz, J., Puente-Maestu, L., Rennard, S., Rossiter, H.B., Sciurba, F., Spruit, M.A., Tal-Singer, R., Tetzlaff, K., Van't Hul, A., Yu, R., Hamilton, A., Validation of Constant Work Rate Cycling Endurance Time for Use in Chronic Obstructive Pulmonary Disease Clinical Trials, *Annals of the American Thoracic Society*, Vol.21, No.5, 2024, pp. 727-739. https://doi.org/10.1513/annalsats.202305-480oc.

[24] Au, D.H., Gleason, E., Hunter-Merrill, R., Barón, A.E., Collins, M., Ronneberg, C., Lv, N., Rise, P., Wai, T.H., Plumley, R., Wisniewski, S.R., Sciurba, F.C., Kim, D.Y., Simonelli, P., Krishnan, J.A., Wendt, C.H., Feemster, L.C., Criner, G.J., Maddipati, V., Mohan, A., Ma, J., Lifestyle Intervention and Excess Weight in Chronic Obstructive Pulmonary Disease (COPD): INSIGHT COPD Randomized Clinical Trial, *Annals of the American Thoracic Society*, Vol.20, No.12, 2023, pp. 1743-1751. https://doi.org/10.1513/annalsats.202305-458oc.

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APPENDIX

Summary of core scales and scoring standards

Scale name	Dimensions/Items	Score range	Scoring interpretation	Example items	Reliability/Validity
HADS	7 items for anxiety, 7 items for depression	0-21 (per subscale)	0-7 normal; 8-10 borderline; ≥11 abnormal	"I feel tense or 'wound up"	Cronbach's α=0.82-0.90; validated in COPD populations
CAT	8 items	0-40	0-10 mild; 11-20 moderate; 21–30 severe; 31-40 very severe	"I have difficulty walking up hills"	Cronbach's α=0.88; strong correlation with SGRQ
EBBS	43 items (29 benefits, 14 barriers)	43-172	Higher scores indicate greater perceived benefits and fewer perceived barriers.	"Exercise improves my mental health"	Cronbach's α=0.89; widely used in elderly populations
SEE	9 items	0-90	Higher scores indicate greater self-efficacy for exercise	"I am confident I can exercise even when tired"	Cronbach's α=0.92; validated in older adults

Table 1. General information about patients

Category		Test group (n=49)	Control group (n=50)	*p*
Age	/	69.74±5.63	68.88±5.75	0.981
Gender	Male	41 (83.67%)	42 (84.00%)	1.000
	Female	8 (16.33%)	8 (16.00%)	
Residence	Urban	18 (36.73%)	16 (32.00%)	0.776
	Rural	31 (63.27%)	34 (68.00%)	
Education level	Primary and below	39 (79.59%)	37 (74.00%)	0.737
	Secondary	7 (14.29%)	8 (16.00%)	
	Higher education	3 (6.12%)	5 (10.00%)	
Smoking status	Never smoked	9 (18.37%)	7 (14.00%)	0.837
	Still smoking	21 (42.86%)	23 (46.00%)	
	Has quit smoking	19 (38.78%)	20 (40.00%)	
Weekly exercise frequency	Less than 3 times	25 (51.02%)	24 (48.00%)	0.939
	3-5 times	19 (38.78%)	20 (40.00%)	
	More than 5 times	5 (10.20%)	6 (12.00%)	
Each exercise duration	Less than 20 minutes	33 (67.35%)	31 (62.00%)	0.853
	20-40 minutes	12 (24.49%)	14 (28.00%)	
	More than 40 minutes	4 (8.16%)	5 (10.00%)	
Pulmonary function grading	Grade II	25 (51.02%)	26 (53.00%)	0.953
	Grade III	14 (28.57%)	15 (30.00%)	
	Grade IV	10 (20.41%)	9 (18.00%)	

Source: created by the authors

Table 2. 6MWT results and effect size analysis of the two groups (unit: m)

Time point	Test group	Control group	p	Cohen's d	95% CI
Pre-test	275.80±65.17	274.82±70.08	0.94	0.01	[-0.37,0.39]
Test 6 weeks	308.95±76.34	279.92±72.71	0.021*	0.39	[0.06,0.72]
Test 12 weeks	348.12±65.44	288.33±74.59	<0.001**	0.86	[0.51,1.21]

Note: * indicates $p<0.05$. ** indicates $p<0.01$.

Source: created by the authors

Table 3. Analysis of mMRC scores and effect sizes between the two groups

Time point	Test group	Control group	*p*	Cohen's d	95% CI
Pre-test	2.64±0.14	2.63±0.16	0.88	0.02	[-0.36,0.40]
Test 6 weeks	2.01±0.14	2.09±0.13	0.024*	0.28	[0.05,0.60]
Test 12 weeks	1.32±0.12	1.86±0.13	<0.001**	-4.34	[-5.16,-3.52]

Note: * indicates $p<0.05$. ** indicates $p<0.01$.

Source: created by the authors

Table 4. HADS scores and effect size analysis between the two groups

Scale	Time point	Test group	Control group	*p*	Cohen's d	95% CI
HADS-A	Pre-test	10.23±3.14	10.40±3.06	0.81	-0.05	[-0.42,0.33]
	Test 6 weeks	8.50±2.20	9.98±3.03	0.013*	-0.55	[-0.88,-0.21]
	Test 12 weeks	6.99±2.01	9.12±3.17	0.004**	-0.56	[-0.90,-0.22]
HADS-D	Pre-test	9.11±3.87	9.23±3.75	0.89	-0.03	[-0.41,0.35]
	Test 6 weeks	7.60±4.07	9.39±3.97	0.019*	-0.44	[-0.78,-0.10]
	Test 12 weeks	6.33±2.90	8.28±3.41	0.008**	-0.51	[-0.85,-0.17]

Note: * indicates $p<0.05$. ** indicates $p<0.01$.

Source: created by the authors

Table 5. Comparison of exercise self-efficacy, perceived exercise behaviour, and quality of life scores between the two groups of patients before and after multimodal intervention

Index	Time point	Test group	Control group	*p*	Cohen's d	95% CI
SSE	Pre-test	3.93±2.14	3.92±2.16	0.982	0.00	[-0.37,0.37]
	Test 6 weeks	5.55±2.16	4.56±2.13	0.024*	0.46	[0.12,0.79]
	Test 12 weeks	7.44±1.68	5.40±1.99	<0.001**	1.10	[0.74,1.46]
EBBS	Pre-test	71.82±13.17	70.57±14.20	0.651	0.09	[-0.28,0.46]
	Test 6 weeks	77.98±11.20	72.13±13.02	0.019*	0.48	[0.14,0.81]
	Test 12 weeks	83.35±9.98	73.60±12.70	<0.001**	0.85	[0.49,1.21]
CAT	Pre-test	22.15±5.97	22.88±5.34	0.523	-0.13	[-0.50,0.25]
	Test 6 weeks	18.50±6.25	22.37±5.66	0.002*	-0.65	[-1.00,-0.31]
	Test 12 weeks	15.43±5.07	20.65±5.32	<0.001**	-0.99	[-1.35,0-.63]

Note: * indicates $p<0.05$. ** indicates $p<0.01$.

Source: created by the authors.

Table 6. Comparison of CAT scale scores in the Control group and the ctest group

Category		Pre-test	Test 6 weeks	Test 12 weeks
Cough	Test group	(1.00,2.00)	(1.00,2.00)	(1.00,2.00)
	Control group	(1.00,2.00)	(1.00,2.00)	(1.00,2.00)
	p	0.18	0.94	0.65
Phlegm	Test group	(1.00,2.00)	(1.00,2.00)	(1.00,2.00)
	Control group	(1.00,3.00)	(1.00,3.00)	(1.00,2.25)
	p	0.35	0.62	0.54
Going out ability	Test group	(2.00,5.00)	(2.00,4.50)	(2.00,4.00)
	Control group	(2.00,5.00)	(2.00,5.00)	(2.00,4.25)
	p	0.49	0.40	0.26
Sleep	Test group	(1.00,3.00)	(1.00,4.00)	(1.00,4.00)
	Control group	(1.75,3.00)	(1.00,3.00)	(1.00,3.00)
	p	0.64	0.42	0.44
Energy	Test group	(2.00,3.00)	(2.00,3.00)	(1.00,2.00)
	Control group	(2.00,3.00)	(2.00,3.00)	(2.00,3.00)
	p	0.66	0.97	0.00*
Chest tightness	Test group	(4.00,5.00)	(1.00,2.00)	(0.00,2.00)
	Control group	(4.00,5.00)	(3.00,4.00)	(3.00,3.25)
	p	0.91	0.00*	0.00*
Activity ability	Test group	(3.00,5.00)	(2.00,3.00)	(1.00,2.00)
	Control group	(3.00,5.00)	(3.00,4.00)	(2.00,4.00)
	p	0.13	0.00*	0.00*
Daily life ability	Test group	(2.00,5.00)	(2.00,4.00)	(2.00,3.00)
	Control group	(3.00,5.00)	(3.00,5.00)	(2.00,4.00)
	p	0.07	0.01*	0.00*

Note: * indicates $p<0.05$.

Source: created by the authors

Table 7. Comparison of imaging examination results between the experimental group and the control group

Index	Time point	Test group	Control group	p	Cohen's d	95% CI
Lung volume (L)	Pre-test	4.20±0.03	4.19±0.02	0.12	0.38	[0.05,0.70]
	Test 12 weeks	4.56±0.12	4.03±0.05	<0.001**	2.91	[2.28,3.54]
Emphysema severity (%)	Pre-test	3.48±0.22	3.49±0.25	0.84	-0.04	[-0.41,0.34]
	Test 12 weeks	2.48±0.10	2.93±0.13	0.002*	-3.87	[-4.64,-3.10]
Airway thickening (mm)	Pre-test	2.20±0.57	2.25±0.46	0.68	-0.09	[-0.46,0.29]
	Test 12 weeks	1.76±0.08	2.13±0.32	<0.001**	-1.59	[-1.96,-1.22]

Note: * indicates $p<0.05$. ** indicates $p<0.01$.

Source: created by the authors

Table 8. Comparison of different COPD rehabilitation studies

Study	Year	Intervention type	Sample characteristics	Evaluation indicators	Imaging application	Adherence management	Main findings
Reference [19]	2020	Baduanjin aerobic training	COPD patients (middle-aged and elderly)	6MWT, lung function, CAT	None	Offline follow-up	Improved exercise endurance and quality of life
Reference [22]	2022	Home-based exercise training	COPD patients (mixed middle-aged and elderly)	6MWT, mMRC	None	Mobile app monitoring	Improved endurance and reduced dyspnea
Reference [24]	2023	Lifestyle intervention	COPD patients (middle-aged and elderly)	Body weight, CAT, quality of life	None	Telephone follow-up	Reduced body weight and improved quality of life
This study	2025	Multimodal rehabilitation (aerobic+strength+balance+stretching)	Elderly patients with stable COPD	6MWT, mMRC, HADS, SEE, EBBS, CAT	HRCT quantitative analysis (emphysema severity, airway wall thickness)	WeChat-based check-in and psychological support	Significantly improved endurance, dyspnea, emotional status, quality of life, and imaging parameters

Source: created by the authors

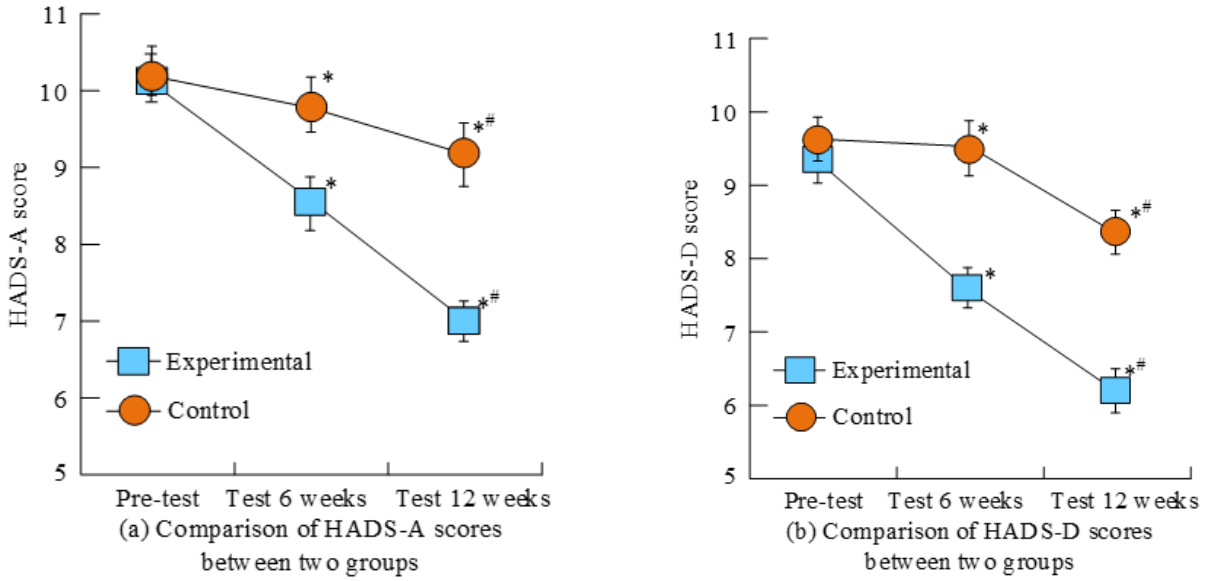

Fig. 2: Comparison of HADS scores between the two groups

Note: * indicates comparisons with pre-test and # indicates comparisons with 6 weeks of the test, both $p < 0.05$.

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