

Original Article

Peak expiratory flow- and 6-minute walk test-based individualized management in elderly patients with chronic obstructive pulmonary disease: a retrospective analysis of cardiopulmonary function

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Received August 26, 2026; Accepted September 30, 2026; Epub October 15, 2026; Published October 30, 2026

Abstract: Objective: To evaluate the association of peak expiratory flow (PEF) and 6-minute walk test (6MWT)-based management with disease severity and cardiopulmonary function in elderly patients with chronic obstructive pulmonary disease (COPD). Methods: This retrospective study included 128 elderly patients with stable COPD treated between December 2022 and August 2024. Patients received routine nursing (control, n = 64) or routine nursing plus individualized PEF/6MWT-based management (observation, n = 64). Symptoms, pulmonary function, arterial blood gas values, cardiac function, exercise capacity, inflammatory markers, and quality of life were assessed at baseline and after 12 weeks. Results: After intervention, the COPD Assessment Test (CAT), modified Medical Research Council (mMRC) score, arterial partial pressure of carbon dioxide (PaCO₂), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), pulmonary artery systolic pressure (PASP), percentage of total 6MWT time with peripheral oxygen saturation (SpO₂) below 88%, 90%, and 92% (T88, T90, and T92, respectively), maximum heart rate, Borg score, neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and monocyte-to-lymphocyte ratio (MLR) decreased significantly compared to baseline values ($P < 0.05$) and were lower in the observation group than in the control group ($P < 0.05$). In contrast, peak expiratory flow (PEF), forced expiratory volume in 1 second (FEV₁), FEV₁/forced vital capacity (FEV₁/FVC), arterial partial pressure of oxygen (PaO₂), SpO₂, left ventricular ejection fraction (LVEF), 6MWD, minimum SpO₂ during exercise, and quality-of-life scores increased significantly after the intervention ($P < 0.05$) and were higher in the observation group than in the control group ($P < 0.05$). Conclusion: In elderly patients with stable COPD, PEF- and 6MWT-based management was associated with improvements in clinical symptoms, cardiopulmonary function, exercise capacity, inflammatory status, and quality of life.

Keywords: Peak expiratory flow, 6-minute walk test, elderly patients, individualized management, chronic obstructive pulmonary disease, pulmonary rehabilitation

Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by persistent airflow limitation [1], mainly caused by smoking, air pollution, and dust exposure [2]. Its manifestations include dyspnea, cough, sputum production, and reduced exercise tolerance. The prevalence of COPD increases with age, posing a substantial global burden [3]. Current treatment strategies include long-acting bronchodilators, inhaled

corticosteroids, combination therapy, oxygen therapy, pulmonary rehabilitation, and nutritional support [4]. Although these approaches can alleviate symptoms and delay the decline in pulmonary function, the lack of personalized methods for dynamic evaluation of cardiopulmonary function during routine management makes it difficult to accurately guide rehabilitation [5]. In addition, elderly patients often have limited cardiopulmonary reserve and multiple comorbidities, which may reduce the effective-

ness of drug treatment alone [6]. Therefore, developing a simple, quantitative, and comprehensive assessment tool to guide rehabilitation management is of great importance.

Peak expiratory flow (PEF) can reflect airway patency in real time, while the 6-minute walk test (6MWT) can comprehensively evaluate exercise endurance and cardiopulmonary reserve [7, 8]. The combination of these two indicators may facilitate the assessment of airway obstruction and the dynamic monitoring of cardiopulmonary function, thus addressing the limitations of relying on a single evaluation. Accordingly, this retrospective study aimed to evaluate a personalized management model that combines PEF with 6MWT values. In addition to routine nursing care, elderly patients with stable COPD received individualized comprehensive interventions. The effectiveness of this model in improving disease severity, cardiopulmonary function, and quality of life was assessed to provide evidence for clinical rehabilitation management.

Patients and methods

General information

In this retrospective study, 128 patients with stable COPD treated at Suqian Hospital of Traditional Chinese Medicine between December 2022 and August 2024 were included. Patients were categorized into a routine-care control group ($n = 64$) and an observation group ($n = 64$), which received individualized management based on the PEF and 6MWT.

This study was approved by the Ethics Committee of Suqian Hospital of Traditional Chinese Medicine (Approval No. Suqian TCM Lun [2021] 012; Approval date: November 20, 2022). The requirement for informed consent was waived because of the retrospective study design. All patient data were anonymized before analysis. Baseline and 12-week data on symptoms, pulmonary function, arterial blood gas values, echocardiographic findings, 6MWT results, inflammatory markers, and quality of life were collected.

Inclusion criteria

(1) Patients met the diagnostic criteria for stable COPD according to the revised 2021 guideline [9], including typical symptoms, relevant

risk factors, and a post-bronchodilator forced expiratory volume in 1 second/forced vital capacity (FEV_1/FVC) < 0.70 ; (2) Age ≥ 65 years; (3) Medical records confirmed no acute exacerbation within 4 weeks before the initial assessment and a stable medication regimen and dosage for at least 4 weeks before the initial assessment; (4) Patients had complete clinical and follow-up data, including pulmonary function tests, arterial blood gas analysis, echocardiography, 6MWT, and questionnaire surveys, at both baseline and 12-week follow-up.

Exclusion criteria

(1) Severe cardiovascular and cerebrovascular diseases; (2) Severe respiratory diseases; (3) Musculoskeletal or neurological diseases affecting exercise tests; (4) Severe hepatic or renal insufficiency, malignant tumors, or psychiatric disorders that could preclude adequate cooperation; (5) Incomplete clinical data or missing key records for the required assessment.

Sample size calculation: Before case screening, the required sample size was estimated based on the primary outcome, the 6-minute walking distance (6MWD). Assuming a minimum clinically important difference (MCID) of 30 m, a standard deviation of 45 m, a two-sided α of 0.05, and 90% statistical power, 48 patients were required in each group. Assuming a 20% exclusion rate due to incomplete data or missing key records, 60 patients per group were needed. Accordingly, at least 120 potentially eligible patients were planned for screening. After applying the inclusion and exclusion criteria, 128 patients (64 per group) were ultimately included.

Study design and background treatment: This was a retrospective, non-randomized study. Data were extracted from the hospital's electronic medical record system. All patients continued their background treatment during the 12-week observation period. Maintenance treatment included inhalation of 18 μ g tiotropium bromide through a HandiHaler inhaler (Boehringer Ingelheim, Germany) once daily, and salmeterol/fluticasone propionate 50/500 μ g through a Diskus inhaler (GlaxoSmithKline, UK) twice daily, alone or in combination. These treatment strategies were consistent with the recommendations of the Global Initiative for

Chronic Obstructive Pulmonary Disease (GOLD). Specifically, 86 patients received tiotropium bromide alone, 32 received tiotropium bromide combined with salmeterol/fluticasone propionate, and 10 received budesonide/formoterol (320/9 µg twice daily; AstraZeneca, Sweden). According to the medical records, medication regimen and dosages had remained stable for at least 4 weeks before the initial assessment and throughout the documented treatment period, unless treatment was modified because of an acute exacerbation.

Control group: The control group received routine nursing care, including health education, respiratory training, dietary guidance, medication-compliance consultation, and general advice on low-intensity physical activity. No structured exercise prescription was provided.

Observation group: The observation group received routine care plus a 12-week personalized plan based on PEF and 6MWT values. Patients performed PEF self-monitoring twice daily and recorded the values (once in the morning and once in the evening). A decrease of $\geq 20\%$ from the personal best value triggered a clinical reassessment. A personalized walking plan was formulated according to the baseline 6MWT results. The target heart rate was set at 60%-80% of the maximum heart rate, with each session lasting 20-30 minutes and conducted 5 times per week, including three supervised hospital-based sessions and 2 home-based sessions. If peripheral oxygen saturation (SpO_2) fell below 90% during exercise, supplemental oxygen was provided to maintain SpO_2 at $\geq 90\%$. Exercise intensity was adjusted according to the Borg scale, with a target score of 3-5. The exercise prescription was reviewed and adjusted every 2 weeks according to the PEF trends and the patient's Borg scale score response.

Follow-up evaluation: All outcome data at 12 weeks after intervention of the management program were extracted from the same electronic medical record system and assessed using the same evaluation procedures as those used at baseline.

Data collection and outcome measures

(1) Symptom assessment: The COPD Assessment Test (CAT) [10] contains 8 items, with total scores ranging from 0 to 40, and was

used to assess symptom burden. The modified Medical Research Council (mMRC) scale [11] grades dyspnea into 0 to 4 levels, with higher scores indicating more severe dyspnea. CAT and mMRC scores were extracted from the medical records at baseline and 12 weeks.

(2) Pulmonary function test: A portable spirometer (FGC-A+, China) was used to measure forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and PEF. The FEV_1 /FVC ratio was calculated. All measurements were performed after inhalation of a bronchodilator (400 µg salbutamol). Pulmonary function data were obtained from the corresponding test reports recorded in the medical records at both time points.

(3) Arterial blood gas analysis and SpO_2 monitoring: Arterial blood samples were collected at rest while patients breathed room air. A blood gas analyzer (ABL80 FLEX, Radiometer, Denmark) was used to measure arterial partial pressure of oxygen (PaO_2) and carbon dioxide ($PaCO_2$). SpO_2 was simultaneously recorded using a pulse oximeter. These values were extracted from the laboratory information system at both time points.

(4) 6MWT: The 6MWT was performed according to a standardized protocol [12]. SpO_2 and heart rate were continuously monitored using a portable pulse oximeter with data-storage function. The following values were recorded: 6MWD, minimum SpO_2 during exercise, maximum heart rate, and Borg scale score immediately after the test. In addition, the cumulative durations of SpO_2 below 88%, 90%, and 92% were automatically calculated by the pulse oximeter software and expressed as percentages of the total 6MWT time (T88, T90, and T92, respectively). Patients with contraindications to exercise testing, such as unstable angina pectoris, uncontrolled arrhythmia, or an inability to walk independently, were excluded from the 6MWT. All 6MWT data were extracted from rehabilitation evaluation records at baseline and at the 12-week follow-up.

(5) Echocardiography: Transthoracic echocardiography was performed by a certified echocardiographer using a standardized ultrasound system. Patients were examined in the left lateral decubitus position, in the morning. All measurements were averaged over three con-

Table 1. Baseline characteristics of the study participants (mean $\pm$ SD)

Indicator	Control Group (n = 64)	Observation Group (n = 64)	t/ χ^2	P
Sex (Male/Female), n	36/28	34/30	0.126	0.722
Age (years)	73.28 $\pm$ 3.31	73.41 $\pm$ 3.29	-0.224	0.823
Disease duration (years)	3.48 $\pm$ 0.35	3.56 $\pm$ 0.34	-1.306	0.194
GOLD stage (2/3), n	38/26	36/28	0.127	0.722
Smoking				
Yes	42	40	0.136	0.713
No	22	24		

Notes: GOLD, Global Initiative for Chronic Obstructive Lung Disease; SD, standard deviation.

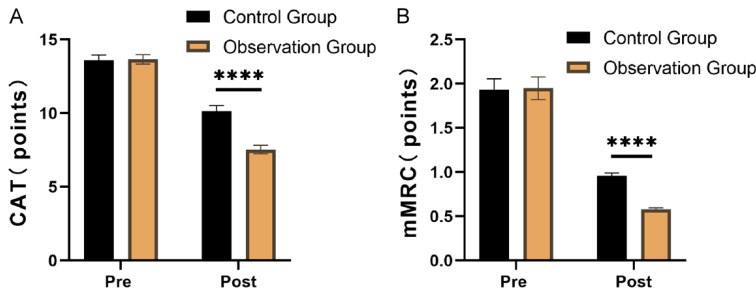


Figure 1. Comparison of CAT and mMRC scores between the two groups before and 12 weeks after intervention. (A) CAT score, (B) mMRC score. Notes: **** $P < 0.0001$. CAT, COPD Assessment Test; COPD, chronic obstructive pulmonary disease; mMRC, modified Medical Research Council dyspnea scale.

secutive cardiac cycles, including left ventricular ejection fraction (LVEF) (calculated using the Simpson method), left ventricular end-diastolic diameter (LVEDD), left ventricular end-systolic diameter (LVESD), and pulmonary artery systolic pressure (PASP) derived from tricuspid regurgitation velocity. Echocardiographic reports from both time points were retrieved from the electronic imaging archive.

(6) Inflammation parameters: The neutrophil-to-lymphocyte ratio (NLR), platelet-to-lymphocyte ratio (PLR), and monocyte-to-lymphocyte ratio (MLR) were calculated from routine blood counts (5 mL fasting venous sample) and analyzed using an automated analyzer. Data were retrieved from laboratory records at baseline and at 12 weeks.

(7) Quality-of-life assessment: Quality of life (QoL) was assessed at baseline and at week 12 using the World Health Organization Quality of Life-BREF (WHOQOL-BREF) [13]. The questionnaire comprises 26 items covering 4 domains. Domain scores were transformed to a 0-100 scale, with higher scores indicating better quality of life.

Statistical methods

Statistical analyses were performed using SPSS 25.0 (IBM, Armonk, NY). Continuous variables were presented as mean $\pm$ standard deviation (SD), and categorical variables as n (%). Baseline characteristics were compared using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. GOLD stage (2 vs. 3) was treated as a categorical variable. Within-

group changes from baseline to 12 weeks were assessed using paired-samples t-tests. Between-group comparisons of post-intervention values were performed using independent-samples t-tests. For the primary outcome (6MWD), multivariable linear regression was performed with group allocation as the independent variable, adjusting for age, sex, smoking status, GOLD stage, and baseline 6MWD. Sensitivity analyses were performed using two approaches: (1) change in 6MWD from baseline as the dependent variable, and (2) exclusion of patients with GOLD stage 3. Secondary outcomes were analyzed as exploratory endpoints using the same between-group and within-group comparison methods. A two-sided $P < 0.05$ was considered significant.

Results

Baseline characteristics

As shown in **Table 1**, baseline characteristics did not differ significantly between the two groups in age, sex, disease duration, GOLD stage, or smoking history ($P > 0.05$), indicating they were comparable.

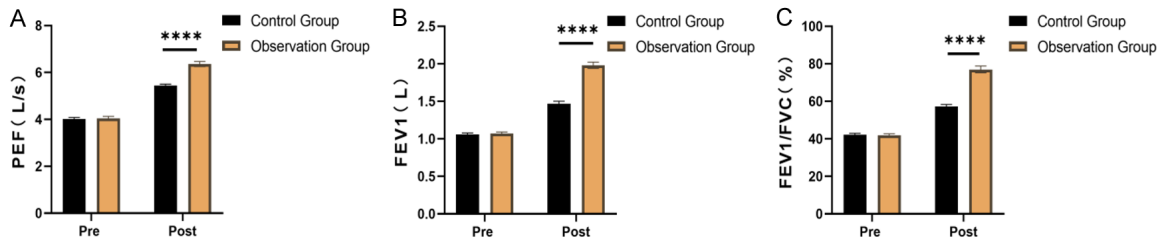


Figure 2. Comparison of pulmonary function values between the two groups before and 12 weeks after intervention. (A) PEF, (B) FEV₁, (C) FEV₁/FVC. Notes: **** $P < 0.0001$. PEF, peak expiratory flow; FEV₁, forced expiratory volume in one second; FVC, forced vital capacity.

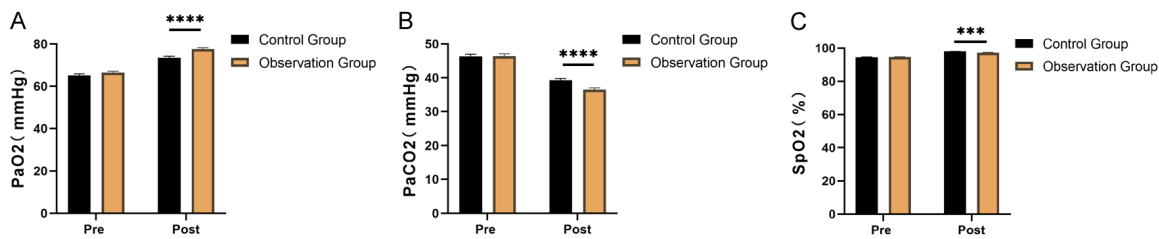


Figure 3. Comparison of blood oxygen levels between the two groups before and 12 weeks after intervention. (A) PaO₂, (B) PaCO₂, (C) SpO₂. Notes: *** $P < 0.001$, **** $P < 0.0001$. PaO₂, partial pressure of arterial oxygen; PaCO₂, partial pressure of arterial carbon dioxide; SpO₂, peripheral oxygen saturation.

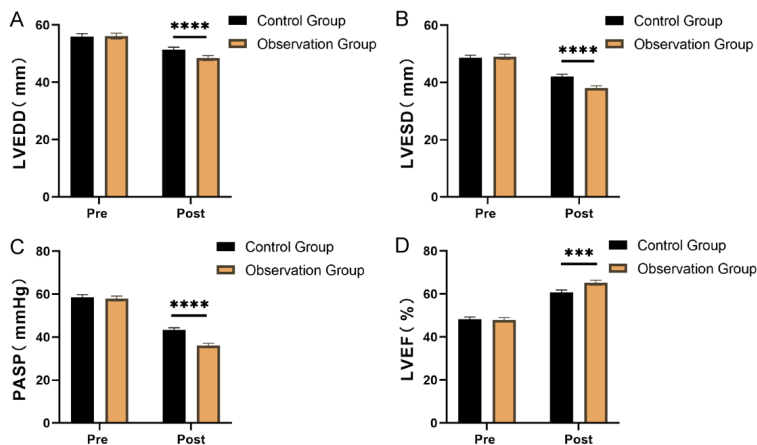


Figure 4. Comparison of cardiac function values between the two groups before and 12 weeks after intervention. (A) LVEDD, (B) LVESD, (C) PASP, (D) LVEF. Notes: **** $P < 0.0001$, *** $P < 0.001$. LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; PASP, pulmonary artery systolic pressure; LVEF, left ventricular ejection fraction.

CAT and mMRC scores

Baseline CAT and mMRC scores were comparable between the two groups ($P > 0.05$). Both scores decreased significantly from baseline in both groups ($P < 0.05$), and the observation group had significantly lower scores than the control group at 12 weeks after intervention ($P < 0.05$) (Figure 1).

Pulmonary function

Baseline PEF, FEV₁, and FEV₁/FVC values were comparable between groups ($P > 0.05$). After intervention, all three values increased significantly from baseline in both groups ($P < 0.05$), and the observation group showed significantly higher values than the control group ($P < 0.05$) (Figure 2).

Arterial blood gas and SpO₂

Baseline PaO₂, PaCO₂, and SpO₂ values were comparable between groups ($P > 0.05$). After intervention, PaO₂ and SpO₂ increased significantly, whereas PaCO₂ decreased significantly in both groups ($P < 0.05$), with greater improvement in the observation group ($P < 0.05$) (Figure 3).

Baseline PEF, FEV₁, and FEV₁/FVC values were comparable between groups ($P > 0.05$). After intervention, all three values increased significantly from baseline in both groups ($P < 0.05$), and the observation group showed significantly higher values than the control group ($P < 0.05$) (Figure 2).

Cardiac function

Baseline LVEDD, LVESD, PASP, and LVEF values were comparable between the two groups ($P > 0.05$). Both groups showed significant decreases

Table 2. Comparison of 6MWT values between the two groups (mean $\pm$ SD)

Indicator	Time point	Control Group (n = 64)	Observation Group (n = 64)	t	P
6MWD (m)	Pre	365.44 $\pm$ 45.30	363.25 $\pm$ 44.28	0.277	0.783
	Post	419.34 $\pm$ 39.57*	456.81 $\pm$ 42.34*	5.173	< 0.001
Minimum SpO ₂ during Exercise (%)	Pre	92.66 $\pm$ 3.22	92.18 $\pm$ 3.15	0.853	0.396
	Post	94.56 $\pm$ 2.87*	96.82 $\pm$ 2.31*	4.908	< 0.001
T88 (%)	Pre	1.68 $\pm$ 0.35	1.72 $\pm$ 0.38	0.619	0.537
	Post	0.85 $\pm$ 0.22*	0.38 $\pm$ 0.21*	12.363	< 0.001
T90 (%)	Pre	1.94 $\pm$ 0.67	1.98 $\pm$ 0.71	0.328	0.745
	Post	0.92 $\pm$ 0.35*	0.42 $\pm$ 0.18*	10.163	< 0.001
T92 (%)	Pre	4.56 $\pm$ 1.14	4.68 $\pm$ 1.21	0.578	0.565
	Post	2.15 $\pm$ 0.89*	1.02 $\pm$ 0.56*	8.597	< 0.001
Maximum Heart Rate (beats per minute, bpm)	Pre	115.66 $\pm$ 12.45	116.23 $\pm$ 12.58	0.258	0.797
	Post	108.45 $\pm$ 10.32*	101.27 $\pm$ 9.86*	4.024	< 0.001
Borg scale score (points)	Pre	3.51 $\pm$ 1.27	3.46 $\pm$ 1.32	0.218	0.828
	Post	2.18 $\pm$ 0.95*	1.35 $\pm$ 0.72*	5.570	< 0.001

Note: * P < 0.05 vs. baseline. 6MWD, six-minute walk distance; SpO₂, peripheral oxygen saturation; T88, T90, and T92: percentage of total 6MWT time during which SpO₂ was below 88%, 90%, and 92%, respectively.

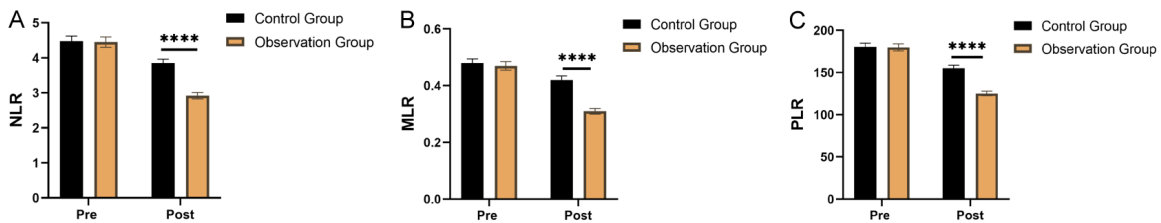


Figure 5. Comparison of inflammatory values between the two groups before and 12 weeks after intervention. (A) NLR, (B) MLR, (C) PLR. Notes: **** P < 0.0001. NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; MLR, monocyte-to-lymphocyte ratio.

es in LVEDD, LVESD, and PASP and a significant increase in LVEF from baseline (P < 0.05), with greater improvements observed in the observation group (P < 0.05) (**Figure 4**).

6MWT values

Baseline 6MWT values were comparable between the two groups (P > 0.05). After the intervention, both groups showed significant improvements from baseline (P < 0.05). Compared to the control group, the observation group had a greater increase in 6MWD and minimum SpO₂ and greater reductions in the percentages of 6MWT time with SpO₂ below 88%, 90%, and 92% (T88, T90, and T92, respectively), maximum heart rate, and Borg score (P < 0.05) (**Table 2**).

Inflammatory indicators

Baseline NLR, PLR, and MLR values were comparable between the two groups (P > 0.05). After intervention, all three indicators decreased significantly in both groups (P < 0.05), with greater reductions observed in the observation group (P < 0.05) (**Figure 5**).

Quality of life

Baseline WHOQOL-BREF domain scores were comparable between the two groups (P > 0.05). After intervention, scores in all four domains increased significantly in both groups (P < 0.05), with greater improvements observed in the observation group across all four domains (P < 0.05) (**Figure 6**).

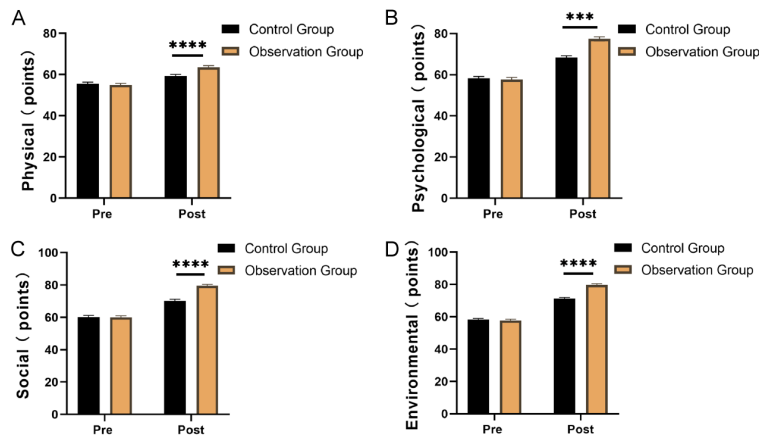


Figure 6. Comparison of quality of life between the two groups before and 12 weeks after intervention. (A) physical health, (B) psychological health, (C) social relationships, (D) environment. Notes: *** $P < 0.001$, **** $P < 0.0001$. WHOQOL-BREF, World Health Organization Quality of Life Brief Version.

Multivariable regression and sensitivity analyses for 6MWD

In a multivariable linear regression model adjusted for age, sex, smoking history, GOLD stage, and baseline 6MWD, the between-group difference in 6MWD remained significant ($\beta = 32.15$, 95% CI 18.42-45.88, $P < 0.001$; **Table 3**). Sensitivity analyses yielded consistent results (**Table 4**).

Discussion

This retrospective analysis evaluated a two-dimensional management approach integrating PEF and 6MWT values to guide individualized care in elderly patients with stable COPD. The results suggested that this approach was associated with significant improvements in symptoms, pulmonary function, arterial blood gas values, cardiac function, exercise endurance, inflammatory status, and quality of life. The between-group differences remained evident during 12-week follow-up, indicating that this simple and quantifiable strategy may help assess the rehabilitation of elderly patients with COPD.

The main value of this analysis was the demonstration of the feasibility of combining airway function monitoring with dynamic assessment of cardiopulmonary exercise tolerance in the management of COPD in elderly patients.

The observation group showed significantly greater reductions in CAT and mMRC scores

than the control group, and this advantage persisted after 12 weeks, indicating that the method may help establish long-term behavioral improvement. The observation group also showed greater improvements in PEF, FEV_1 , and FEV_1/FVC . Notably, PEF improvement has been associated with airway secretion clearance and exacerbation risk in previous studies [14, 15]. PaO_2 , SpO_2 , and minimum SpO_2 during exercise significantly increased, whereas $PaCO_2$ decreased, suggesting improved oxygenation and ventilatory status.

Exercise endurance and cardiac function improved significantly. In the observation group, 6MWD increased by 93.56 m, far exceeding the prespecified minimal clinically important difference (MCID) of 30 m. Echocardiography revealed significantly increased LVEF and decreased PASP. The reduction in PASP may reflect improved cardiopulmonary hemodynamics, although the present study did not directly measure pulmonary vascular resistance. This change may be related to the combined effects of regular exercise training and reduced exposure to hypoxemia [16]. The improvement in left ventricular function may be related to reduced peripheral vascular resistance, improved myocardial oxygen supply-demand balance, and attenuation of systemic inflammation [17]. These combined cardiopulmonary benefits may be particularly critical for elderly patients with COPD, who frequently have limited respiratory reserve and coexisting cardiovascular disease.

NLR, PLR, and MLR decreased significantly in the observation group, as did T88, T90, and T92. Reduced percentage of total 6MWT time with exercise-related desaturation may be associated with lower intermittent hypoxemic exposure and reduced activation of hypoxia-related inflammatory pathways, including NF- κ B signaling and pro-inflammatory cytokine release [18]. Previous studies have reported associations between elevated NLR or PLR and inferior pulmonary function or increased mortality in COPD patients [19, 20]. Therefore, the

Table 3. Multivariable linear regression for 6MWD after adjustment

Outcome	Model	β (95% CI)	P
6MWD (m)	Adjusted for age, sex, smoking, GOLD stage, baseline 6MWD	32.15 (18.42, 45.88)	< 0.001

Note: β : regression coefficient for group allocation (observation vs. control). A positive β indicates greater 6MWD in the observation group. 95% CI: 95% confidence interval; 6MWD: 6-minute walking distance; GOLD: Global Initiative for Chronic Obstructive Lung Disease.

Table 4. Sensitivity analyses for 6MWD

Analysis	β (95% CI)	P
Main model: age, sex, smoking, GOLD stage, baseline 6MWD	32.15 (18.42, 45.88)	< 0.001
Change from baseline as dependent variable	30.87 (17.20, 44.54)	< 0.001
Excluding GOLD stage 3	28.94 (14.02, 43.86)	< 0.001

Note: β : regression coefficient for group allocation (observation vs. control). A positive β indicates greater 6MWD in the observation group. 95% CI: 95% confidence interval; 6MWD: 6-minute walking distance; GOLD: Global Initiative for Chronic Obstructive Lung Disease.

observed reductions in these indices may indicate an improvement in systemic inflammatory status. Moreover, the comprehensive improvement across all four WHOQOL-BREF domains further suggests that the observed functional improvements may have translated into better perceived daily functioning and well-being.

Compared to conventional pulmonary rehabilitation studies [21-23], the core innovation of this study was in the use of personalized physiologic measurements to guide management. The target heart-rate range, oxygen supplementation, and exercise intensity were adjusted according to each patient's oxygenation status, heart-rate response, and Borg score. This personalized strategy may have contributed to the observed improvements in multiple outcomes.

The combination of the two-dimensional evaluation system and personalized exercise prescription provided a framework for implementing the management strategy and may explain the observed associations. As a home-based self-monitoring indicator of airway function, PEF can capture daily fluctuations in expiratory airflow and provide an early warning of deterioration. However, it cannot assess cardiopulmonary compensatory capacity during exercise, which is a key determinant of daily functioning in elderly patients with COPD. In contrast, 6MWT values, including minimum SpO₂ during exercise, the percentage of total 6MWT time with oxygen desaturation, heart-rate response, and Borg score, provide an integrated

assessment of exercise tolerance, oxygenation, and subjective exertional load [24, 25]. The combination of these two methods enables simultaneous assessment of airway function and functional reserve under exercise stress, thereby complementing traditional single-values monitoring.

Based on this two-dimensional evaluation, the present management strategy moved beyond a traditional fixed-intensity exercise regimen. Data obtained from the 6MWT were used to individualize the target heart-rate range and oxygen supplementation, while exercise intensity was adjusted according to the Borg score. While ensuring safety, this individualized prescription may promote several physiologic adaptations, including enhanced respiratory muscle strength and endurance, improved skeletal-muscle mitochondrial biosynthesis and oxidase activity, reduced sympathetic activation, and improved vascular endothelial function and microcirculation perfusion [26, 27]. Together, these adaptations may have contributed to the significant improvement in 6MWD and selected cardiac-function values.

Exercise-induced oxygen desaturation is very common in patients with COPD. Repeated hypoxia and reoxygenation may activate nuclear factor kappa B (NF- κ B), promote the release of interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF- α), and stimulate neutrophil and monocyte activation [28, 29]. By adjusting oxygen supplementation and exercise intensity according to individual responses, the interven-

tion significantly reduced T88, T90, and T92, thus minimizing repeated “hypoxia shock” and reducing the ratios of NLR, PLR, and MLR. Reduced systemic inflammation may help stabilize airway inflammation, improve endothelial function, and limit myocardial stress. The “hypoxia-inflammatory-organ function” chain may represent a possible pathophysiologic pathway associated with multi-system benefits [30, 31]. In addition, patients recorded PEF daily and self-assessed dyspnea and perceived exertion after exercise. This participatory management approach may have improved disease awareness, encouraged active self-management, and facilitated the integration of rehabilitation behavior into daily habits. Self-efficacy is considered an important determinant of long-term management of chronic diseases [32]. The continuous and significant improvement in CAT and mMRC scores during the 12-week follow-up in this analysis confirmed the actual effect of this behavioral mechanism.

This study has several limitations. First, its retrospective, single-center design and relatively small sample size limited the generalizability of the findings. Second, the lack of randomization and retrospective nature of group allocation may have introduced selection bias; therefore, the observed associations should not be interpreted as evidence of causality. Third, the 12-week follow-up focused primarily on surrogate outcomes. Clinical endpoints, including acute exacerbations, hospitalizations, and emergency visits, were not evaluated; therefore, the long-term benefits and safety of the intervention remain uncertain. Fourth, right-heart structure and function were not comprehensively evaluated, although right-heart involvement may occur early in COPD patients. Echocardiographic assessment was limited to LVEF, LVEDD, LVESD, and PASP. Future studies should include comprehensive right-heart assessment, such as tricuspid annular plane systolic excursion (TAPSE), right ventricular (RV) diameter, and RV fractional area change. In addition, assessment of inflammatory mechanisms was limited to peripheral blood biomarkers, without direct evaluation of tissue-level or molecular pathways. Future prospective randomized controlled trials (RCTs) with larger sample sizes, longer follow-up, and multicenter designs are needed to verify our findings. Wearable monitoring devices could also improve

the continuity, accuracy, and applicability of individualized exercise management.

Conclusion

The management model based on PEF and 6MWT values provided a practical means of assessing airway function and cardiopulmonary function in elderly patients with stable COPD. The model was associated with improvements in symptoms, cardiopulmonary function, exercise capacity, and quality of life over 12 weeks. The approach may be feasible in primary health care institutions and provides new options for the rehabilitation management of elderly patients with COPD, although its implementation and longer-term benefits require further evaluation.

Acknowledgements

This work was supported by the National Major S&T Special Project for Major Disease Prevention and Treatment (Grant 2023ZD0506300).

Disclosure of conflict of interest

None.

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