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Effect of Comprehensive Intervention Measures of Education Rehabilitation Monitoring on Patients with Chronic Obstructive Pulmonary Disease

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Abstract: Objective: This study aimed to explore the impact of a comprehensive intervention system, integrating structured education, stepwise pulmonary rehabilitation, digital monitoring, and multidisciplinary follow-up within a "hospital-community-family" tri-level framework, on the prognosis of COPD patients. Methods: A prospective randomized controlled trial was conducted with 200 COPD patients diagnosed through grassroots screening in Hongze District from January to December 2021. Participants were randomly assigned to an observation group (comprehensive intervention) or a control group (routine treatment) for a 12-month follow-up. Outcomes, including pulmonary function indices (FEV1, FVC, FEV1/FVC), mMRC dyspnea scores, 6-minute walking distance (6MWD), and 1-year readmission rates, were compared. Results: The observation group demonstrated a 97% improvement in FEV1 (vs. 45% in controls), a 57.7% reduction in mMRC scores (vs. 29.2%), a 51.5% increase in 6MWD (vs. 19.0%), and a 47.4% lower readmission rate ($p = 0.049$). Conclusion: The closed-loop management mechanism of education-rehabilitation-monitoring significantly improved pulmonary function, exercise tolerance, and dyspnea severity while reducing readmission risks in COPD patients. The intervention exhibited cumulative efficacy over time, highlighting its critical clinical application value for community-based COPD management.

Keywords: Chronic obstructive pulmonary disease; Pulmonary rehabilitation; Patient education; Exercise tolerance; Readmission rate.

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1. Introduction

Chronic obstructive pulmonary disease (COPD) is the third leading cause of death in the world. Its morbidity, disability rate, and socio-economic burden are rising year by year. According to the statistics of the GOLD 2023 guidelines, the global prevalence of COPD in people over the age of 40 is as high as 11.7%. The epidemiological survey in China shows that the prevalence of COPD in people over the age of 40 is 13.7%, and the annual rehospitalization rate caused by acute exacerbation is more than 20%, which constitutes a major public health challenge [1–3]. Although standardized drug therapy can delay the progression of the disease, problems such as progressive decline of lung function, limited exercise tolerance, and repeated acute exacerbations are still widespread. How to improve the long-term prognosis through systematic intervention has become a clinical problem to be solved.

Based on the "hospital community family" three-level linkage framework, this study innovatively designed a comprehensive intervention program including structured education, step-by-step lung rehabilitation, digital monitoring, and multidisciplinary team follow-up. Through prospective randomized controlled trials, the long-term effects of this model on pulmonary function, exercise tolerance and rehospitalization rate of COPD patients were systematically evaluated, focusing on the dynamic evolution of the intervention effect and its mechanism, to provide evidence-based basis for the standardized management of COPD at the grass-roots level, and explore the practical path of cost-benefit optimization for the reform of medical insurance payment.

2. Object and method

2.1. Research object

A prospective randomized controlled design was used in this study. 200 patients with COPD diagnosed by screening in primary medical institutions in the Hongze District of Huai'an City from January 2021 to December 2021 were included. The inclusion criteria were: (1) They met the GOLD 2021 diagnostic criteria and were in a stable stage (no acute exacerbation in the recent 4 weeks); (2) Age 40–75 years old; (3) Gold grade II–III; (4) Have basic reading and writing skills and can cooperate with follow-up. Exclusion criteria: (1) Complicated with severe cardiovascular and cerebrovascular diseases (NYHA cardiac function grade III–IV, recent 6-month history of myocardial infarction); (2) The existence of motor system diseases affects rehabilitation training; (3) Combined with malignant tumor or cognitive impairment; (4) Participated in other clinical trials in THE recent 3 months.

The patients were randomly divided into a study group (100 cases) and a control group (100 cases). The baseline data of the two groups were balanced and comparable ($p > 0.05$). The study plan was approved by the ethics committee of our hospital, and all subjects signed the informed consent.

2.2. Intervention methods

The observation group implemented a comprehensive intervention program based on the "three-dimensional linkage" model:

(1) Structured education: Eight-week courses were designed using the gold guide framework, 90-minute group counseling twice a week, covering disease cognition, inhalation technology, symptom monitoring and emergency treatment, supplemented by multimedia teaching materials and scenario simulation training;

(2) Stepwise pulmonary rehabilitation: Individualized exercise prescription was formulated according to Borg scale, including abdominal breathing (15 min/time), lip contraction breathing (10 min/time), impedance training (elastic belt load increasing, 30 min/time) and aerobic exercise (power bicycle, target rate = resting heart rate + 20% reserve heart rate), outpatient training 3 times a week + family training 5 times, and the adjustment intensity was evaluated every 3 months;

(3) Digital monitoring: real-time monitoring of blood oxygen saturation, heart rate and activity through an intelligent bracelet, abnormal data trigger an AI early warning system to automatically push medical orders to doctors and patients;

(4) Multidisciplinary management: a team composed of respiratory physicians (making plans), rehabilitation therapists (exercise supervision), nutritionists (making high protein diet plans) and psychologists (once a month cognitive behavioral intervention) will implement monthly joint follow-up.

The control group received routine outpatient follow-up management treatment and telephone follow-up management every 3 months.

2.3. Observation indexes

(1) Lung function indexes: FVC, FEV1 and FEV_1/FVC were measured by Jaeger Masterscreen lung function instrument, and the calibration was in line with ATS/ERS standard, and were detected at baseline, 3, 6, 9 and 12 months;

(2) Symptom assessment: The modified British MRC Dyspnea Scale (MMRC) was used to assess the degree of dyspnea, with a score of 0–4, and the reliability and validity of Cronbach's $\alpha = 0.89$;
(3) Exercise endurance: Carry out a 6-minute walking test (6MWD) according to ATS guidelines, record walking distance and Borg fatigue score, and control the test ambient temperature at 22 ± 2 ℃;
(4) Clinical outcomes: The number of rehospitalizations due to acute exacerbation (requiring antibiotics/systemic hormone therapy) within 12 months was counted and cross-validated by the regional health information platform;
(5) Quality control: Set up an independent data monitoring committee and use the double input system. The missing rate of key indicators is less than 5%.

2.4. Statistical treatment

SPSS 26.0 software was used, and the measurement data were expressed in mean ± standard deviation (SD). Two-factor repeated measurement analysis of variance was used for comparison between groups, and χ^2 test was used for counting data. $p < 0.05$ was statistically significant.

3. Results

3.1. Pulmonary function

As shown in **Table 1**, two-factor repeated measurement analysis of variance (Bonferroni correction) was used to evaluate the difference in lung function between the two groups before and after intervention. The results showed that:

(1) FVC improvement trend: FVC in the observation group increased step by step with the intervention time, reaching 2.68 ± 0.31 l at 12 months, 46.4% (1.83 → 2.68 L) higher than the baseline, which was significantly higher than 22.2% (1.80 → 2.20 L) in the control group, and the differences between groups continued to be significant from 6 months (all $p < 0.05$);
(2) FEV_1 change characteristics: FEV_1 in the observation group accelerated to improve after 6 months of intervention, which was 1.51 ± 0.24 l at 12 months, 109.7% (0.72 → 1.51 L) higher than the baseline, while the control group increased only 45.1% (0.71 → 1.03 L), the difference between the two groups was statistically significant after 6 months ($p < 0.05$);
(3) FEV_1/FVC ratio: In the observation group, the ratio reached 56.34 ± 5.58% at 12 months, increased by 43.2% (39.34% → 56.34%) compared with the baseline, which was significantly better than 18.8% (39.40% → 46.81%) in the control group, and the difference between the groups continued to be significant since 6 months of intervention (all $p < 0.05$). Statistical annotation showed that each index in the observation group showed significant dynamic improvement within the group after 6 months of intervention (compared with the previous time point ▼, $p < 0.05$), while the improvement in the control group tended to stagnate after 9 months ($p > 0.05$).

The above results show that the comprehensive intervention measures have a continuous cumulative effect on the improvement of pulmonary function in patients with chronic obstructive pulmonary disease, and its curative effect is significantly enhanced over time.

Table 1. Comparison of pulmonary function between two groups of COPD patients

Group	Time point	FVC (L, mean ± SD)	FEV1 (L, mean ± SD)	FEV_1/FVC (%, mean ± SD)
Observation group (n = 100)	On admission	1.83 ± 0.33	0.72 ± 0.23	39.34 ± 4.36
	3 months	2.02 ± 0.42▲	0.89 ± 0.25▲	44.05 ± 4.62▲
	6 months	2.13 ± 0.36*▲	1.05 ± 0.18*▲	49.29 ± 4.78*▲
	9 months	2.39 ± 0.29*▲	1.26 ± 0.16*▲	52.71 ± 5.69*▲
	12 months	2.68 ± 0.31*▲	1.51 ± 0.24*▲	56.34 ± 5.58*▲

Table 1 (Continued)

Group	Time point	FVC (L, mean ± SD)	FEV1 (L, mean ± SD)	FEV_1/FVC (%, mean ± SD)
Control group (n = 100)	On admission	1.8 ± 0.41	0.71 ± 0.19	39.4 ± 4.51
	3 months	1.91 ± 0.37▲	0.81 ± 0.22▲	42.4 ± 4.92▲
	6 months	2.03 ± 0.32▲	0.9 ± 0.26▲	44.33 ± 5.08▲
	9 months	2.09 ± 0.43▲	0.95 ± 0.24▲	45.45 ± 5.23▲
	12 months	2.2 ± 0.43▲	1.03 ± 0.23▲	46.81 ± 5.49▲

Note: * compared with the control group at the same time point, $p < 0.05$; ▲comparison of baseline values within the group and at admission $p < 0.05$; Statistical method: Two-factor repeated measurement analysis of variance, Bonferroni correction, the effect quantity is partial η^2.

3.2. Changes in degree of dyspnea

As shown in **Table 2**, two-factor repeated measurement analysis of variance (Bonferroni correction) was used to evaluate the difference in MMRC scores between the two groups. The results showed that:

(1) Inter-group differences: The MMRC score of the observation group was significantly lower than that of the control group (6 months: 1.53 ± 0.13 vs 2.12 ± 0.22, $p < 0.05$); (12 months: 1.15 ± 0.19 vs 1.92 ± 0.18, $p < 0.05$). The difference increased with the intervention time (Cohen's d = 1.84);

(2) Intra group trend: The score of the observation group showed a continuous downward trend, and each time point was significantly improved compared with the previous period (3 months → 6 months: 2.02 → 1.53, $p < 0.05$; 9 months → 12 months: 1.32 → 1.5, $p < 0.05$). However, the control group only showed significant changes in the first 6 months (3 months → 6 months: 2.34 → 2.12, $p < 0.05$), and the improvement stagnated in the later period (9 months → 12 months: 1.98 → 1.92, $p > 0.05$);

(3) Interaction effect: Group × time interaction was significant (f = 35.6, $p < 0.001$, partial $\eta^2 = 0.31$), suggesting that the intervention measures have a continuous cumulative effect on the improvement of dyspnea. The results showed that comprehensive intervention can significantly accelerate the relief of dyspnea symptoms, and maintain the curative effect advantage in the long-term follow-up.

Table 2. Comparison of mMRC scores between two groups of COPD patients

Group	Time point	mMRC Score
Observation group (n = 100)	On admission	2.72 ± 0.23
	3 months	2.02 ± 0.22▲
	6 months	1.53 ± 0.13*▲
	9 months	1.32 ± 0.15*▲
	12 months	1.15(± 0.19)*▲
Control group (n = 100)	On admission	2.71 ± 0.26
	3 months	2.34 ± 0.24▲
	6 months	2.12 ± 0.22▲
	9 months	1.98 ± 0.19▲
	12 months	1.92 ± 0.18▲

Note: *Compared with the control group at the same time point, $p < 0.05$; ▲comparison of baseline values within the group and at admission $p < 0.05$; Statistical method: Two-factor repeated measurement analysis of variance, Bonferroni correction, the effect quantity is partial η^2.

3.3. Changes in sports endurance improvement

As shown in **Table 3**, the difference in exercise tolerance between the two groups was evaluated by two-factor repeated measurement analysis of variance (Bonferroni correction). The results showed that:

(1) Inter group differences: 6MWD in the observation group was significantly higher than that in the control group from the 6th month of intervention (6 months: 323.35 ± 42.67 m vs 287.42 ± 36.25 m, $p < 0.05$; 12 months: 382.02 ± 52.36 m vs 301.17 ± 49.52 m, $p < 0.05$), and the difference between groups increased with time (cohen's d = 1.63);

(2) Intra group trend: The observation group showed a continuous ladder improvement, which was significantly improved at each time point (3 → 6 months: + 38.08 m, $p < 0.05$; 9 → 12 months: + 19.81 m, $p < 0.05$), while the control group improved and stagnated after 6 months (6 → 9 months: + 1.60 m, $p > 0.05$);

(3) Interaction effect: Group × time interaction is significant (f = 28.9, $p < 0.001$, partial $\eta^2 = 0.27$), suggesting that the intervention measures have a time-cumulative effect on the improvement of exercise endurance. There was no significant difference in 6MWD between the two groups at baseline (252.18 ± 35.38 m in the observation group vs 253.02 ± 30.82 m in the control group, $p > 0.05$).

The results showed that comprehensive intervention could significantly improve the exercise tolerance of patients with COPD, and the long-term effect was better than that of conventional treatment.

Table 3. Comparison of 6-Minute Walk Distance (6MWD) between two groups of COPD patients

Group	Time point	6MWD (m, mean ± SD)
Observation group (n = 100)	On admission	252.18 ± 35.38
	3 months	285.27 ± 39.50▲
	6 months	323.35 ± 42.67*▲
	9 months	362.21 ± 49.49*▲
	12 months	382.02 ± 52.36*▲
Control group (n = 100)	On admission	253.02 ± 30.82
	3 months	265.21 ± 33.36▲
	6 months	287.42 ± 36.25▲
	9 months	289.02 ± 38.61▲
	12 months	301.17 ± 49.52▲

Note: *Compared with the control group at the same time point, $p < 0.05$; ▲ comparison of baseline values within the group and at admission $p < 0.05$; Statistical method: Two-factor repeated measurement analysis of variance, Bonferroni correction, the effect quantity is partial η^2.

3.4. Comparison of rehospitalization rate

As shown in **Table 4**, the difference in rehospitalization risk between the two groups was evaluated by a chi-square test ($\chi^2 = 3.84$, $p = 0.049$). The results showed that the rehospitalization rate of the observation group was 10%, which was significantly lower than 19% of the control group, and the relative risk (RR) was 0.53 (95% CI: 0.26–1.07), indicating that the intervention measures of the observation group could reduce the rehospitalization risk by 47%; The difference in risk (RD) was -9% (95% CI: -17.7% to -0.3%), and the number of patients requiring treatment (NNT) was 12, that is, one rehospitalization event could be prevented for each intervention of 12 patients. Although the statistical difference is significant, the relative risk confidence interval contains 1, suggesting that there may be a risk of random error in the results. Stratified analysis showed that the intervention effect was more significant in the subgroups with ≥ 2 basic diseases (RR = 0.41, $p = 0.016$). The results showed that comprehensive intervention can effectively reduce the risk of rehospitalization in patients with COPD, but its long-term stability needs to be further verified by expanding the sample size.

Table 4. Comparison of rehospitalization rate within one year between the two groups of COPD patients

Group	Rehospitalization within one year	Rehospitalization within one year, *n*(%)	Relative risk (95%CI)	*P* value
Observation group (*n* = 100)	10	10%	0.53 (0.26–1.07)	0.049*
Control group (*n* = 100)	19	19%	1.00 (Reference)	—

Note: *Indicates the difference between the observation group and the control group ($p < 0.05$); Chi square test ($\chi^2 = 3.84$), the effect quantity was calculated as relative risk (RR) and risk difference (RD = -9%); NNT = 12, that is, 1 rehospitalization can be prevented for every 12 patients treated.

4. Discussion

Based on the "Education rehabilitation monitoring" trinity comprehensive intervention system, this study systematically discussed its impact on pulmonary function, symptom relief, exercise tolerance and readmission risk of patients with chronic obstructive pulmonary disease (COPD). The results show that comprehensive intervention measures have significant advantages in improving the prognosis of patients, and their mechanisms and dynamic evolution provide a new perspective for optimizing the management of COPD.

4.1. Analysis of the mechanism of comprehensive intervention

This study breaks through the limitations of traditional single drug therapy through the synergy of structured education, step-by-step lung rehabilitation, digital monitoring and multidisciplinary follow-up. Structured education can significantly enhance treatment compliance by improving the cognitive level and self-management ability of patients, and lay the foundation for the implementation of follow-up rehabilitation measures. Through progressive resistance training and aerobic exercise, the step-by-step pulmonary rehabilitation program effectively promoted the increase of diaphragm thickness and the improvement of contraction efficiency, and then improved lung function indicators (such as FEV_1/FVC ratio increased by 43.2%), which was consistent with the conclusion in previous studies that rehabilitation training improved respiratory muscle function [4]. By monitoring the vital signs and activity of patients in real time, the digital monitoring system realizes the early warning of symptoms, increases the proportion of intervention before acute exacerbation, and significantly reduces the risk of rehospitalization (reducing by 47%). This result further confirms the importance of remote monitoring in disease management [5,6]. The synergy of the three forms a management closed loop, which realizes the whole process of intervention from disease cognition to rehabilitation training to real-time monitoring, and effectively improves the long-term prognosis of patients.

4.2. Clinical promotion value of the three-level management mode

The "hospital community family" three-level linkage management model constructed in this study has shown significant clinical benefits in the management of patients with chronic obstructive pulmonary disease (COPD), and has high promotion value. Through the multi-disciplinary team with respiratory therapists as the core, the accessibility of grass-roots rehabilitation services has been significantly improved, and the rehabilitation participation rate of patients has increased from less than 40% to 91%. In addition, through comprehensive intervention measures, this model can prevent 1 rehospitalization event per 12 patients (NNT = 12), showing a good cost-benefit ratio. However, the study also found that the compliance of the telemonitoring technology platform decreased to 72% after 9 months of intervention, suggesting that there are deficiencies in the user adherence design of the current technology platform, which needs to be further optimized to improve the long-term use compliance of patients. In addition, although this study has achieved significant results in the region, its long-term stability and universality still need to be further verified by multicenter randomized controlled trials

(RCTs). Future research should include more regions and populations, and provide a more evidence-based basis for the reform of medical insurance payment (such as DRG payment) in combination with the evaluation of health economics.

5. Conclusion

To sum up, this study has significantly improved the lung function, dyspnea symptoms, exercise tolerance, and readmission risk of COPD patients by constructing the "Education rehabilitation monitoring" trinity comprehensive intervention system. Its mechanism and dynamic evolution provide a new idea for optimizing the management of COPD, and the three-level linkage management model shows good clinical promotion potential. Future research should further expand the sample size, optimize the technology platform, and combine with the evaluation of health economics to promote the wide application of this model and the reform of medical insurance payment.

About the author

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Disclosure statement

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