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Original Article

Efficacy of remote respiratory rehabilitation in stable chronic obstructive pulmonary disease and factors affecting acute exacerbation

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Abstract: Objectives: To evaluate the effects of remote respiratory rehabilitation on patients with stable chronic obstructive pulmonary disease (COPD) and identify factors influencing acute exacerbation. Methods: This retrospective study included 60 stable COPD patients who visited the First Affiliated Hospital of Gannan Medical University between June 2020 and December 2021. Among them, 27 patients in the control group received routine health guidance, while 33 patients in the research group received WeChat app-based remote respiratory rehabilitation. The study comparatively analyzed pulmonary function (PF; forced vital capacity percentage [FVC%], forced expiratory volume in 1 second percentage [FEV1%], and FEV1/FVC), blood oxygen saturation (SaO_2), dyspnea index (Borg Dyspnea Scale), 6-minute walking distance (6MWD), number of hospitalizations, frequency of acute exacerbations, and health-related quality of life (measured using the Chronic Respiratory Disease Questionnaire [CRQ]). Additionally, univariate and multivariate analyses were conducted to identify factors contributing to acute exacerbation in stable COPD patients. Results: Significant improvement in FVC%, FEV1%, FEV1/FVC, SaO_2, 6MWD, and various CRQ scores were observed in the research group after treatment with higher values than the control group (all $P<0.05$). The Borg Dyspnea Scale scores were significantly lower in the research group than those of the control group ($P<0.05$). The research group had significantly fewer hospitalizations and acute exacerbations compared to the control group ($P<0.05$). Univariate analysis indicated that body mass index (BMI; $P=0.042$), smoking history ($P=0.011$), chronic respiratory failure ($P=0.010$), diabetes ($P=0.024$), hypertension ($P=0.008$), and treatment modality ($P=0.006$) were significantly associated with acute exacerbations in stable COPD patients. Multivariate analysis identified that hypertension ($P=0.032$) and treatment methods ($P=0.022$) were risk factors for acute exacerbation in stable COPD patients. Conclusions: Remote respiratory rehabilitation significantly benefits stable COPD patients by improving respiratory function, exercise endurance, and quality of life. Moreover, hypertension and conventional health guidance interventions are closely associated with an increased risk of acute exacerbation in stable COPD patients.

Keywords: Stable chronic obstructive pulmonary disease, remote respiratory rehabilitation, therapeutic effect, acute exacerbation, influencing factors

Introduction

Chronic obstructive pulmonary disease (COPD) is a chronic, progressive condition characterized by persistent respiratory symptoms and airflow limitation, that is not fully reversible. It typically has a long course and slow onset, significantly affecting patients' daily lives [1, 2]. The disease is associated with airway and/or alveolar abnormalities resulting from significant exposure to toxic particles or gases, leading to respiratory failure, coughing, expectoration, and other adverse symptoms [3, 4]. In contemporary society, the increasing aging population and environmental pollution have markedly elevated the risks of COPD-related morbidity, mortality, and disability [5]. Therefore, preventing recurrent episodes of COPD and mitigating the impact of related disabilities have become crucial research areas. Optimizing standardized treatment and long-term management for COPD patients is vital for slowing the

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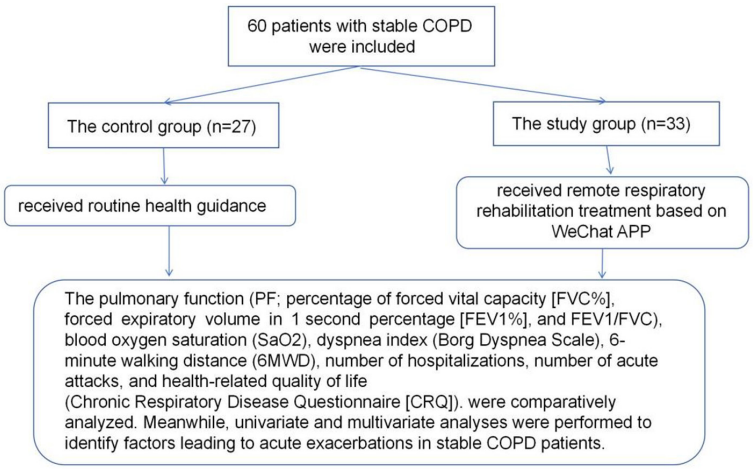

Figure 1. Flow chart. COPD, chronic obstructive pulmonary disease.

decline in pulmonary function (PF), enhancing lung function, and preventing disease progression [6, 7].

Remote respiratory rehabilitation is a key component in the treatment and long-term management of chronic diseases such as COPD [8]. This approach can significantly alleviate dyspnea symptoms, improve exercise capacity, and enhance quality of life [9]. With the advancement in mobile internet and smartphones, telemedicine technologies and platforms like the WeChat app have become mainstream tools for information exchange due to their low cost, high speed, and high acceptance [10]. These platforms are widely used in clinical treatment, rehabilitation, and nursing care [11, 12]. Telemedicine and WeChat app management allow rapid access to information regarding the clinical status and recovery confidence of patients with stable COPD, enabling timely and effective interventions by healthcare professionals to reduce acute exacerbations [13, 14]. For patients facing challenges in communication and transportation, telemedicine and WeChat apps can overcome geographical barriers, facilitating enhanced interaction between COPD patients and healthcare providers, other patients, and healthy individuals, thereby supporting the restoration of patients' social attributes [15]. Additionally, this management approach enables healthcare providers to deliver services without leaving their workplace, reducing travel time and minimizing the disruption to the daily lives of patients and their families, while promoting more efficient use of medical resources [16].

This study establishes a remote respiratory rehabilitation platform for patients with stable COPD using the WeChat app. It evaluates the effectiveness of remote respiratory rehabilitation for stable COPD patients, offering a novel technical approach for management and providing a robust foundation for clinicians to implement respiratory rehabilitation plans for these patients.

Materials and methods

General data

This retrospective study included 60 stable COPD patients who visited the First Affiliated Hospital of Gannan Medical University between June 2020 and December 2021. Of these, 27 patients in the control group received routine health guidance, while 33 patients in the research group received remote respiratory rehabilitation through a WeChat app-based platform. Ethical approval for the study was obtained from the Ethics Committee of the First Affiliated Hospital of Gannan Medical University. The study flowchart is presented in **Figure 1**.

Eligibility criteria

Inclusion criteria: (1) Patients met the diagnostic criteria for stable COPD [17], confirmed by physical signs, PF, imaging, and other examinations. (2) Patients were undergoing routine treatment in respiratory medicine. (3) Patients were in stable condition, and were able to continue maintenance treatment at home. (4) Patients were capable of participating in remote respiratory rehabilitation, demonstrated clinical symptoms such as shortness of breath, wheezing, coughing, prolonged exhalation compared to inhalation, and limb fatigue. (5) Patients had normal cognitive and communicative abilities, could understand and perform the required exercises, and had complete medical records.

Exclusion criteria: (1) Patients had mental illness, heart disease, acute exacerbations within 14 days, tuberculosis, pulmonary embolism, lung cancer, or other significant illnesses. (2)

Patients were unable to participate regularly in remote respiratory rehabilitation. (3) Patients had previous history of respiratory dysfunction or limb movement disorders, acquired immunodeficiency syndrome, or hepatitis B. (4) Patients were allergy to Tiotropium Bromide. (5) Patients had tumors or severe organ disease.

Treatment methods

WeChat App-based Remote Respiratory Rehabilitation Treatment: A WeChat app was developed, incorporating the following modules: patient diary, rehabilitation training, health education, question consultation, patient communication, data collection and analysis, and outpatient appointment.

Patient diary module: A table was created for patients to record daily activities, including diet, smoking, bowel movements, urination, vital signs before and after rehabilitation training, mental state, expectoration characteristics, chest tightness, dyspnea, limb edema, physical activity, medication, and oxygen therapy.

Rehabilitation training module: This module is divided into two parts. The first part involves recording and uploading images related to state adjustment techniques, such as relaxation therapy, breathing assistance, sputum elimination, breathing exercises (including pursed-lips and abdominal breathing), and thoracic range of motion exercises. The second part involves recording and uploading videos related to exercise therapy, including respiratory gymnastics, respiratory muscle training, and endurance training for the upper and lower limb muscles, focusing on flexibility, stretching, extension, and balance exercises. Upper limb training primarily includes rehabilitation gymnastics like shoulder flexion and abduction, elbow flexion and extension, and respiratory coordination.

Health education module: Guided by respiratory medicine specialists or rehabilitation therapists, this module provides information on COPD physiology and pathology, medication, nutritional intake, the significance of respiratory rehabilitation, and emergency management of exacerbations. The goal was to enhance patients' and their families' understanding and compliance with respiratory rehabilitation.

Question consultation module: This module allows patients to consult medical staff online at any time. Medical staff provided answers based on the patient's questions and condition.

Patient communication module: Through this module, patients can share disease-related knowledge and rehabilitation experiences with others on the platform.

Data collection and analysis module: Patients upload their rehabilitation training data to this module. Medical staff analyze the data, provide feedback on any issues, and ensure patients continue rehabilitation training as required.

Outpatient appointment module: Patients can use this module to schedule appointments with doctors. Medical staff can also use this module to remind patients to return to the hospital for regular check-ups.

Following the establishment of the WeChat app, the control group received routine health guidance upon discharge, including education on COPD, dietary advice, smoking and alcohol cessation, appropriate exercise, and respiratory function exercises. In contrast, the research group, in addition to routine health guidance, used the WeChat app-based remote respiratory rehabilitation platform to conduct rehabilitation training, regularly upload relevant information, communicate with medical staff online, and receive ongoing guidance.

Outcome measures

PF: The percentage of forced vital capacity (FVC%) and forced expiratory volume in 1 second percentage (FEV1%) were measured using a PF instrument (German GANSHORN Investment, model: PowerCube-Body).

Blood gas indexes: Blood oxygen saturation (SaO_2) was monitored before and after the intervention using a blood gas biochemical analyzer (Edan Medical Co., Ltd., 6944413-801875), strictly following the instrument's instructions.

Dyspnea index: The Borg Dyspnea Scale was used to assess patients' dyspnea and fatigue after walking. This scale ranges from 0 to 10, with higher scores indicating more severe dyspnea or fatigue.

Exercise endurance: Exercise endurance was evaluated using the 6-minute walking distance (6MWD). A 50-meter distance was marked on flat ground, and the maximum distance patients could walk back and forth within 6 minutes was recorded.

Rehabilitation indexes: The number of hospitalizations and acute exacerbations were observed and recorded.

Health-related quality of life: The Chronic Respiratory Disease Questionnaire (CRQ) [18] was used to assess patients' respiratory function before and after the intervention. The CRQ evaluates four dimensions: fatigue (4-20 points), dyspnea (5-20 points), disease control (4-20 points), and emotional function (7-35 points). The questionnaire comprises 20 items, each scored from 1 to 5. Lower scores indicated better respiratory function.

In this study, FVC%, FEV1%, FEV1/FVC, SaO_2, Borg Dyspnea Scale scores, and 6MWD were considered primary outcome measures, while the number of hospitalizations, acute exacerbations, and CRQ scores were secondary outcome measures.

Statistical analyses

Data were expressed as mean ± SEM. Intergroup comparisons were performed using independent sample t-tests, while intra-group comparisons used paired t-tests. Categorical data, presented as ratios (percentages), were compared between groups using χ^2 tests. Univariate and binary logistic regression analyses were conducted to identify risk factors for acute exacerbation. All analyses were performed using SPSS 20.0, with statistical significance set at $P<0.05$.

Results

Comparison of general information

No significant differences were found between the research and control groups regarding general characteristics such as age, sex, body mass index (BMI), disease duration, smoking/alcohol history, chronic respiratory failure, diabetes, and hypertension (all $P>0.05$; **Table 1**).

Comparison of PF and SaO_2

As shown in **Figure 2**, there were no significant differences in baseline FVC%, FEV1%, FEV1/FVC, and SaO_2 between the two groups (all $P>0.05$). However, post-treatment, these indicators showed significant improvement in both groups (all $P<0.05$), with greater increases observed in the research group (all $P<0.05$).

Comparison of Borg Dyspnea Scale scores and 6MWD

Figure 3 illustrates that both groups had similar pre-treatment Borg Dyspnea Scale scores and 6MWD results ($P>0.05$). After treatment, both groups experienced a reduction in Borg Dyspnea Scale scores and an increase in 6MWD results ($P<0.05$), with the research group showing significantly lower Borg Dyspnea Scale scores and higher 6MWD results than the control group ($P<0.05$).

Comparison of hospitalizations and acute attacks

Data indicated that the research group had significantly fewer hospitalizations and acute exacerbations compared to the control group (both $P<0.01$; **Figure 4**).

Comparison of quality of life

CRQ analysis showed no significant differences between groups in pre-treatment scores for dyspnea, fatigue, emotional function, or disease control (all $P>0.05$). Post-treatment, all CRQ dimensions showed significant improvement in both groups, with even lower scores observed in the research group (all $P<0.05$). See **Figure 5**.

Univariate and multivariate analyses of factors affecting acute exacerbation in stable COPD patients

Univariate analysis (**Table 2**) revealed that BMI, smoking history, chronic respiratory failure, diabetes, hypertension, and treatment modality were significantly associated with acute exacerbation in stable COPD patients (all $P<0.05$), whereas age, sex, disease duration, and alcohol history were not (all $P>0.05$).

Based on the univariate analysis, binary logistic regression identified hypertension and treat-

Table 1. Comparison of general information

General information	n	Control group (n=27)	Research group (n=33)	χ^2 value	*P* value
Age (years old)	60	52.30±6.98	53.52±7.49	0.6479	0.520
Sex				0.025	0.875
Male	34	15 (55.56)	19 (57.58)		
Female	26	12 (44.44)	14 (42.42)		
Body mass index (kg/m^2)	60	21.37±3.28	22.27±3.74	0.979	0.332
Disease course (years)	60	12.04±3.97	10.70±2.86	1.518	0.135
History of smoking				0.060	0.807
With	39	18 (66.67)	21 (63.64)		
Without	21	9 (33.33)	12 (36.36)		
History of alcoholism				0.606	0.436
With	30	15 (55.56)	15 (45.45)		
Without	30	12 (44.44)	18 (54.55)		
Complicated with chronic respiratory failure				0.848	0.357
With	25	13 (48.15)	12 (36.36)		
Without	35	14 (51.85)	21 (63.64)		
Diabetes				1.684	0.195
With	30	16 (59.26)	14 (42.42)		
Without	30	11 (40.74)	19 (57.58)		
Hypertension				0.243	0.622
With	31	13 (48.15)	18 (54.55)		
Without	29	14 (51.85)	15 (45.45)		

ment methods as significant risk factors for acute exacerbation in stable COPD patients. See **Tables 3** and **4**.

Discussion

For stable COPD patients, long-term hospitalization can hinder recovery, increase the economic burden on patients' families, and elevate the risk of infection [19]. Providing these patients with targeted rehabilitation interventions enhances their understanding of respiratory and rehabilitation training and offers effective guidance for respiratory exercises [20]. This approach not only facilitates effective home-based respiratory rehabilitation and improves quality of life for stable COPD patients but also improves their overall recovery.

In this study, we observed more significant improvements in PF and blood gas analysis indicators in the research group compared to the control group, suggesting that WeChat app-based remote respiratory rehabilitation effectively enhances PF and blood gas parameters in stable COPD patients. Furthermore, this intervention significantly relieved dyspnea and fatigue and improved exercise endurance. These findings can be attributed to the comprehensive rehabilitation and health education provided through the WeChat app, which offers stable COPD patients structured exercise and endurance training, fostering correct disease-related awareness. Consequently, patients engage in regular and active rehabilitation training, maximizing the benefits of remote respiratory rehabilitation and thereby enhancing lung function and blood gas indicators [21].

Şahın et al. [22] found that WeChat app-based remote respiratory rehabilitation for COVID-19 survivors reduced dyspnea, exertional dyspnea, and fatigue, aligning with our findings. According to Alwakeel et al. [23], this intervention consistently improved the 6MWD at 1, 3, 6, and 12 months post-intervention in COPD patients, further supporting our results.

Moreover, the research group had significantly fewer hospitalizations and acute exacerbations than the control group, indicating the efficacy of WeChat app-based remote respiratory rehabilitation in disease management for stable COPD patients. This outcome may be linked to

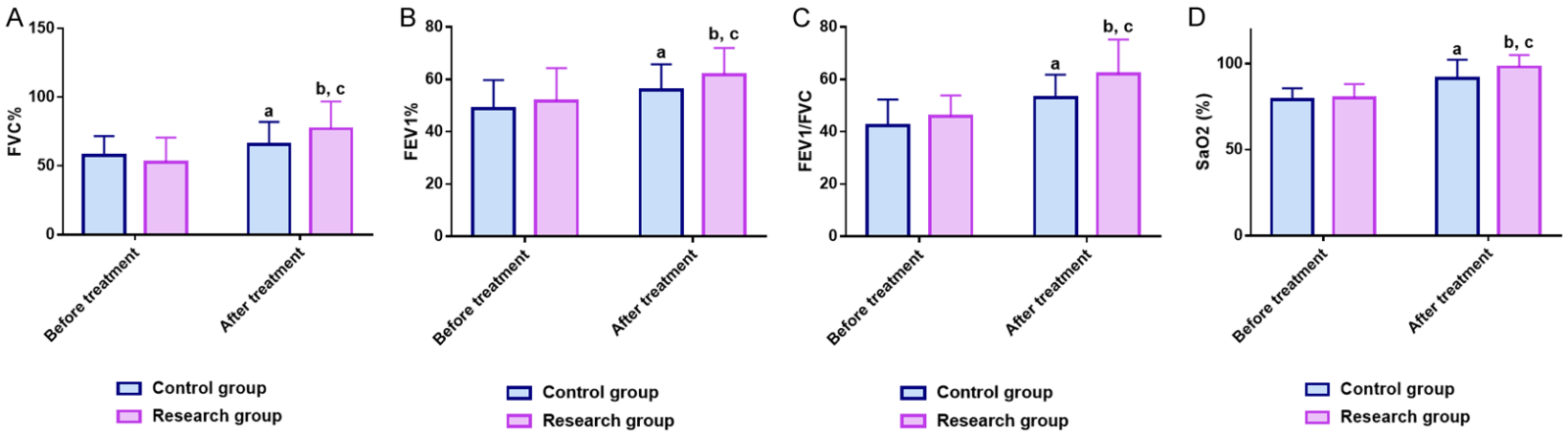

Figure 2. Comparison of pulmonary function and SaO_2 between the groups. A. Comparison of FVC% before and after treatment. B. Comparison of FEV1% before and after treatment. C. Comparison of FEV1/FVC before and after treatment. D. Comparison of SaO_2 before and after treatment. Note: [a]P<0.05 and [b]P<0.01 *vs.* before treatment; [c]P<0.05 *vs.* control. FVC, forced vital capacity; FEV1, forced expiratory volume in 1; SaO_2, blood oxygen saturation.

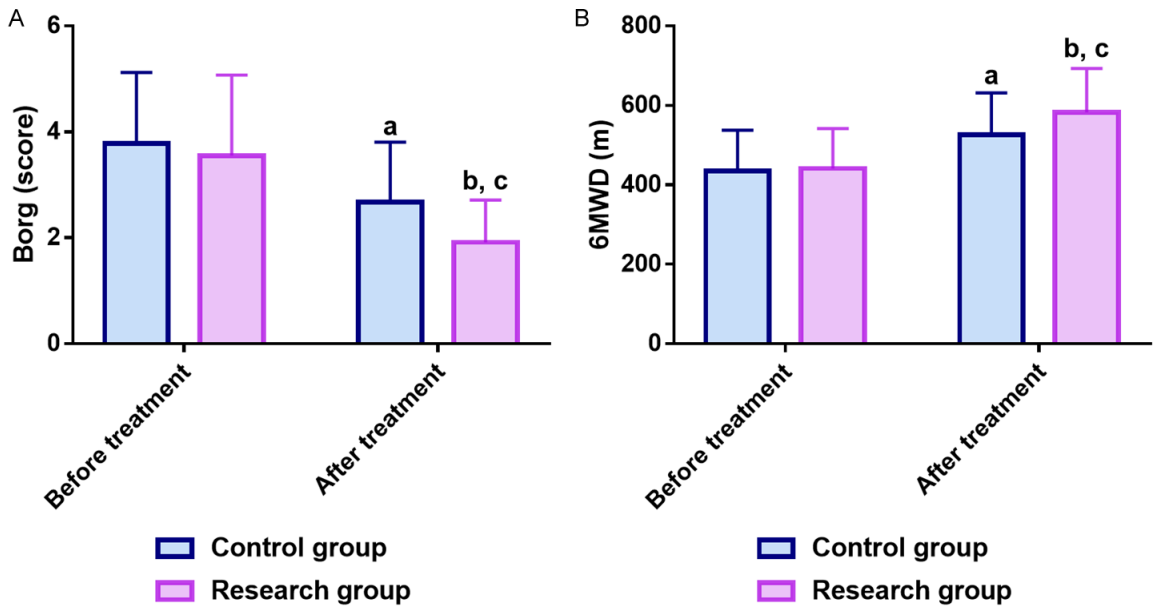

Figure 3. Comparative analysis of Borg Dyspnea Scale scores and 6MWD results. A. Comparison of Borg Dyspnea Scale scores before and after treatment. B. Comparison of 6MWD before and after treatment. Note: [a]P<0.05 and [b]P<0.01 *vs.* before treatment; [c]P<0.05 *vs.* Control. 6MWD, 6-minute walking distance.

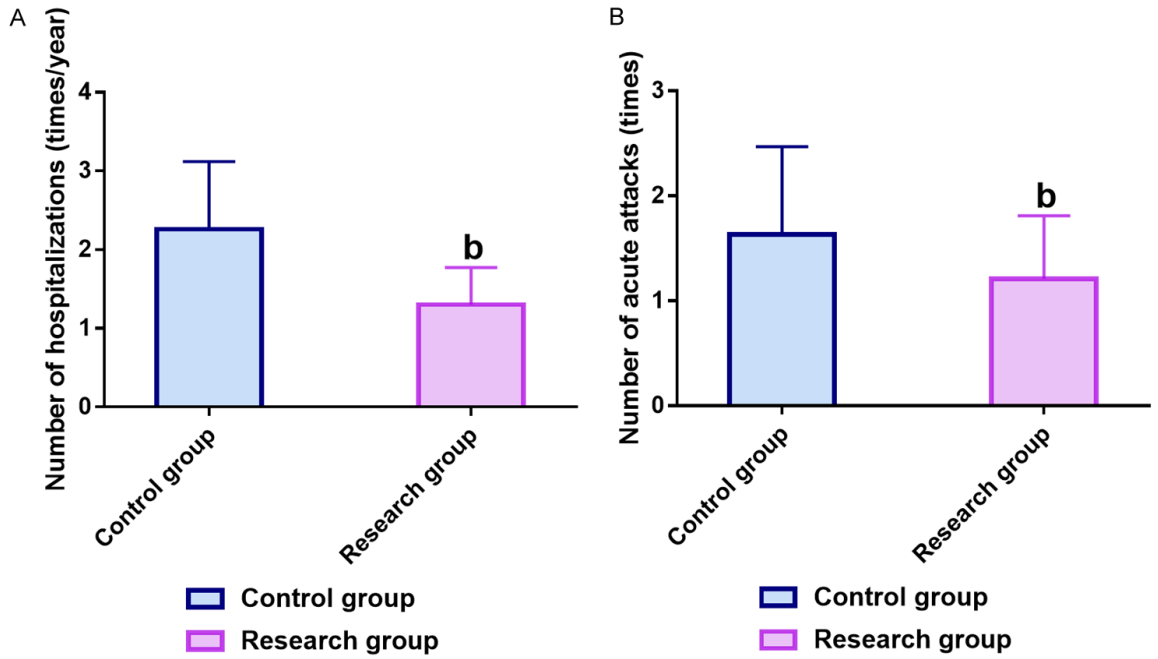

Figure 4. Comparison of the number of hospitalizations and acute attacks. A. Comparison of the number of hospitalizations patients. B. Comparison of the number of acute attacks. Note: [b]P<0.01 versus control.

services such as problem consultation, patient communication, and data collection and analysis provided through the app, which enhance patients' understanding of their condition. Engaging in consultations with healthcare providers and discussions with peers enabled patients to gain deeper insights into their disease, promoting proactive disease management and effective symptom control [24]. Zanaboni et al. [25] also reported that this type

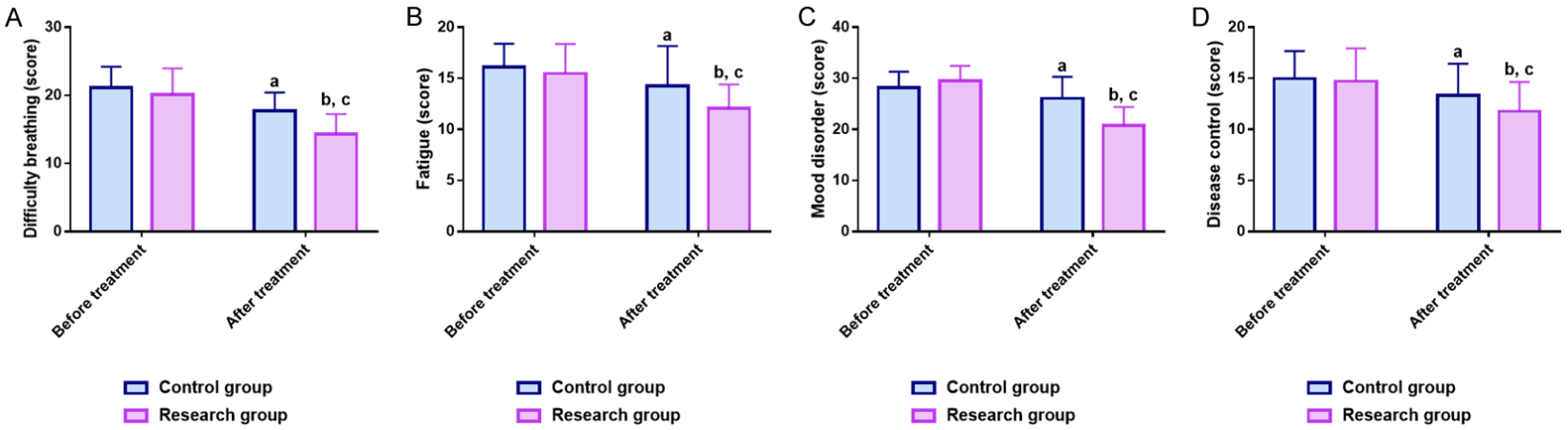

Figure 5. Comparison of quality of life before and after treatment. A. Comparison of difficulty breathing scores before and after treatment. B. Comparison of fatigue scores before and after treatment. C. Comparison of emotional disorder scores before and after treatment. D. Comparison of disease control scores before and after treatment. Note: [a]P<0.05 and [b]P<0.01 *vs.* before treatment; [c]P<0.05 *vs.* control.

Table 2. Univariate analysis of factors affecting acute exacerbations in stable COPD patients

Variables	n	Acute exacerbation (n=18)	Non-acute exacerbation (n=42)	χ^2 value	*P* value
Age (years old)				1.071	0.301
<55	36	9 (50.00)	27 (64.29)		
≥55	24	9 (50.00)	15 (35.71)		
Sex				1.564	0.211
Male	34	8 (44.44)	26 (61.90)		
Female	26	10 (55.56)	16 (38.10)		
Body mass index (kg/m^2)				4.156	0.042
<20	16	8 (44.44)	8 (19.05)		
≥20	44	10 (55.56)	34 (80.95)		
Disease course (years)				1.414	0.234
<12	33	12 (66.67)	21 (50.00)		
≥12	27	6 (33.33)	21 (50.00)		
History of smoking				6.450	0.011
With	39	16 (88.89)	23 (54.76)		
Without	21	2 (11.11)	19 (45.24)		
History of alcoholism				1.270	0.260
With	30	11 (61.11)	19 (45.24)		
Without	30	7 (38.89)	23 (54.76)		
Chronic respiratory failure				6.612	0.010
With	25	12 (66.67)	13 (30.95)		
Without	35	6 (33.33)	29 (69.05)		
Diabetes				5.079	0.024
With	30	13 (72.22)	17 (40.48)		
Without	30	5 (27.78)	25 (59.52)		
Hypertension				7.021	0.008
With	31	14 (77.78)	17 (40.48)		
Without	29	4 (22.22)	25 (59.52)		
Treatment method				7.699	0.006
Routine health guidance	27	13 (72.22)	14 (33.33)		
Remote respiratory rehabilitation therapy	33	5 (27.78)	28 (66.67)		

Note: COPD, chronic obstructive pulmonary disease.

Table 3. Variable assignment

Variable	Assignment
Body mass index (kg/m^2)	<20 = 0, ≥20 = 1
History of smoking	Without = 0, with = 1
Chronic respiratory failure	Without = 0, with = 1
Diabetes	Without = 0, with = 1
Hypertension	Without = 0, with = 1
Treatment method	Remote respiratory rehabilitation = 0, routine health guidance = 1

of remote rehabilitation significantly reduced readmission rate for COPD patients, consistent with our findings.

In terms of quality of life, the research group showed greater improvement in CRQ scores across dimensions of dyspnea, fatigue, emotional function, and disease control, indicating that WeChat app-based remote respiratory rehabilitation can effectively enhance the quality of life for stable COPD patients. This may be attributed to features such as patient consulta-

Table 4. Multivariate analysis of factors influencing acute exacerbation in stable COPD patients

Variable	β	SE	Wald	P	Exp(β)	95% CI
Body mass index (kg/m^2)	-1.216	0.855	2.024	0.155	0.296	0.056-1.583
History of smoking	2.012	1.050	3.672	0.055	7.479	0.955-58.564
Chronic respiratory failure	0.919	0.790	1.354	0.245	2.508	0.533-11.799
Diabetes	0.993	0.853	1.357	0.244	2.701	0.508-14.370
Hypertension	1.756	0.821	4.574	0.032	5.789	1.158-28.937
Treatment method	1.865	0.812	5.279	0.022	6.454	1.315-31.668

Note: COPD, chronic obstructive pulmonary disease.

tion, communication modules, and outpatient appointment scheduling offered by the remote rehabilitation platform. These services enable the creation of comprehensive disease records over time, allowing healthcare professionals to monitor patient conditions in real-time and adjust treatment as needed, thus maximizing long-term therapeutic outcomes and indirectly improving patients' quality of life [26]. Sanchez-Ramirez et al. [27] found similar results, showing positive effects on motor function and health-related quality of life from remote rehabilitation. Benzo et al. [28] also reported that these interventions not only promote health behavior changes in COPD patients but also positively affect their quality of life, daily physical activity, and sleep, supporting our findings.

Finally, univariate analysis identified low BMI, smoking history, chronic respiratory failure, diabetes, hypertension, and receiving only routine health guidance as factors closely related to acute exacerbations in stable COPD patients. Multivariate analysis further confirmed that hypertension and routine health guidance alone were risk factors for acute exacerbations in these patients. Chmiel et al. [29] also noted that WeChat app-based remote respiratory rehabilitation has predictive value for acute exacerbations in COPD patients.

Although our research yielded positive results, there are certain inherent limitations that should be acknowledged. First, inflammation-related factors were not included in our detection and analysis. Including these indicators in future studies would provide a more comprehensive understanding of the effect of WeChat app-based remote respiratory rehabilitation on inflammation in stable COPD patients. Second, this study did not analyze pulmonary rehabilitation compliance. Future prospective studies should incorporate relevant indicators to explore the clinical advantages of remote respiratory rehabilitation concerning lung rehabilitation compliance. These areas will be addressed and supplemented in future research.

In summary, WeChat app-based remote respiratory rehabilitation for stable COPD patients had a positive effect on improving PF and blood gas parameters. It significantly alleviated dyspnea and fatigue, enhanced motor function, effectively controled disease progression, promoted overall physical rehabilitation, and significantly improved the health-related quality of life for patients. Additionally, for patients with low BMI, a history of smoking, chronic respiratory failure, diabetes, and hypertension, enhanced health management is essential to prevent acute exacerbations. Therefore, it is recommended that stable COPD patients incorporate WeChat app-based remote respiratory rehabilitation into their routine health practice to strengthen disease management.

Disclosure of conflict of interest

None.

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