

# The Effects of Respiratory Training Combined with Limb Exercise on Pulmonary Function and Quality of Life in Patients with Bronchiectasis

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**Objective:** To investigate the effects of respiratory rehabilitation training combined with limb rehabilitation on sputum clearance and quality of life in patients with bronchiectasis.

**Methods:** A retrospective analysis of 86 patients with bronchiectasis was divided into an intervention group and an observation group, with 43 cases in each group. All patients were above 18 years of age with no history of relevant drug allergies. Patients in the observation group were treated with conventional drugs, and those in the intervention group were given respiratory rehabilitation training and limb rehabilitation on this basis. After three months of treatment, the indexes of sputum discharge, sputum traits, lung function, and the 6-minute walk distance (6MWD) were compared and quality of life and survival skills were assessed using the Barthel index and a quality-of-life comprehensive assessment questionnaire (GQOLI-74).

**Results:** The percentage of patients with mild Barthel index in the intervention group was higher than that in the observation group, and the difference between the groups was statistically significant ( $P < 0.05$ ). After treatment, the scores of life quality and the lung function in the intervention group were higher than those in the observation group (both  $P < 0.05$ ). After three months of treatment, the sputum volume and sputum viscosity scores of the two groups were higher than those before treatment ( $P < 0.05$ ).

**Conclusion:** Respiratory rehabilitation training with limb exercise rehabilitation can effectively improve the sputum clearance rate, lung function, and quality of life of patients with bronchiectasis and is thus worthy of clinical promotion and application.

**Keywords:** bronchiectasis, respiratory rehabilitation training, limb exercise rehabilitation, lung function, quality of life

## Introduction

The destruction of muscle and elastic fibres in the bronchial wall can lead to abnormal and persistent bronchial dilatation, which, in turn, may give rise to the occurrence of tracheal dilatation. Tracheal dilatation occurs primarily as a result of acute and chronic airway infections and bronchial obstruction and can also occur in patients with genetic, immunological, or anatomical defects.<sup>1-3</sup> Bronchiectasis and diseases such as chronic obstructive pulmonary disease promote one another, and bronchiectasis can simultaneously cause recurrent airway infections and increased sputum, thus aggravating airway obstruction.<sup>4-7</sup> Based on incomplete statistics, the incidence of bronchiectasis in China is approximately 53–566/100,000 – a trend that is increasing annually.<sup>8</sup> Effective sputum removal and anti-infective treatment, and maintenance of airway patency, have been routinely relied upon as important approaches for treating bronchiectasis.<sup>1</sup>

The effective clearance of airway secretions is an important part of the long-term treatment of patients with bronchiectasis. Although patients' adverse symptoms can be temporarily relieved after treatment with anti-infective, bronchodilator, and expectorant drugs,<sup>9-11</sup> their long-term motor function does not improve. In recent years, the treatment of chronic airway diseases such as bronchiectasis is no longer limited to simply the improvement of bronchial lesions and

airflow limitations but has shifted to improving patients' motor function and quality of life through a variety of rehabilitation exercises.<sup>12–14</sup> Respiratory rehabilitation training is one of the most important rehabilitation exercises in bronchiectasis treatment. This treatment can improve patients' lung function by helping them to change their existing breathing patterns, which primarily involves lip constriction breathing and breathing deeply from within the chest. A study by Liu et al<sup>15</sup> found that the use of effective respiratory muscle training for patients with chronic obstructive pulmonary disease (COPD) could improve their lung function and increase their blood oxygen saturation and endurance. Limb exercise training can also significantly improve the muscle strength and endurance of all muscle groups, improve the exercise capacity and respiratory muscle strength of patients, prevent premature airway trapping, and relieve respiratory distress.

However, the clinical efficacy of respiratory training with limb exercise rehabilitation in the treatment of bronchiectasis is not yet clear. This study investigates the effect of respiratory rehabilitation training with limb exercise rehabilitation on sputum clearance and quality of life in patients with bronchiectasis.

## Materials and Methods

### Study Subjects

The research group retrospectively investigated the electronic medical records of 86 patients with bronchiectasis and accompanying infections who were admitted to our hospital from March 2017 to June 2020, then randomly divided them into an observation group and an intervention group, with 43 cases in each group. The observation group was treated with conventional drugs, and the intervention group was given respiratory rehabilitation and limb exercise rehabilitation based on the observation group. The study was conducted following the Declaration of Helsinki of the World Medical Association and was approved by the hospital's ethics committee. All patients signed an informed consent form for inclusion in the study.

### Inclusion and Exclusion Criteria

The inclusion criteria of the current study were as follows: (1) patients had to meet the diagnostic criteria of the Expert Consensus on the Diagnosis and Treatment of Adult Bronchiectasis;<sup>6</sup> (2) they had to be able to complete follow-up and had to have good treatment compliance; (3) they had to have no history of relevant drug allergies; (4) they needed to be above 18 years of age; (5) they had to have signed the informed consent form.

Exclusion criteria: (1) combined asthma, tuberculosis, and lung tumour conditions; (2) major organ conditions such as heart, liver, and kidney diseases; (3) mental disorders, neurological diseases, etc., that may render patients unable to cooperate with exercise training; (4) incomplete patient information.

### Randomization and Blinding

Eligible patients were randomly assigned in a 1:1 ratio to each group using permuted, block-randomization to balance the number of patients allocated to each group. The permuted block randomization sequence was generated, using Package "randomize R" in R software version 3.6.1 and placed in individual sealed and opaque envelopes by the statistician. The investigator enrolled the patients and only then open envelopes to assign patients to the different groups. This method of allocation concealment could result in minimum selection and confounding biases.<sup>16</sup>

### Sample Size Calculations

In this study, we conducted sample size calculations based on detecting minimum clinically relevant differences (MCRDs) from expert opinion and previous research findings. Sample size calculations were based on detecting MCRDs with 80% power and a significance level of 5% and on the premise of using a two-sample paired means test. All sample size calculations were conducted in STATA V.<sup>17</sup> From the calculations, this study required the smallest sample size of 32 participants. Allowing for drop outs, we aimed to recruit 43 participants for each group.

## Six-Minute-Walk Distance (6MWD) Test

6MWT was performed in a flat, straight, surface rigid corridor inside the chamber. Before each 6MWT, patients were required to have a resting oxygen saturation of at least 83% as measured by pulse oximetry after 10 minutes of rest breathing room air or after breathing at the baseline O<sub>2</sub> flow rate. The patient was instructed to walk as far as possible and not jogging or running; If they needed to decelerate or stop to rest, they were allowed to do so and were encouraged to resume walking as soon as possible. Testing was stopped if the patient experienced chest pain, intolerable dyspnea, leg cramps, sweating, or saturation below 83%.<sup>18</sup>

## Treatment Methods

Both groups were given anti-infection and expectorant treatment to improve the symptoms of acute infection. The following drugs were routinely administered. A terbutaline sulfate solution for nebulisation (AstraZeneca, imported drug registration No. H20030642, 2 mL: 5 mg/tube) – one dose dissolved in 10 mL of 0.9% saline for nebulised inhalation three times daily. An ambroxol hydrochloride oral solution (Jiangsu Hengrui Pharmaceutical Co., Ltd., pharmaceutical product registration no. HC20040026; 100 mL, 0.3 g) – 10 mg, twice daily. Glucocorticoid drugs were added when necessary.

Based on these medications, the intervention group was given respiratory rehabilitation training and extremity exercise rehabilitation treatment. Respiratory training included deep breathing with chest expansion and lip contraction while walking or climbing stairs (among other things), which was performed under standardised demonstration conditions. The walking speed was controlled at 60–80 steps per minute for 15 minutes each time, and slow breathing with the mouth and lips was carried out once for every two steps when climbing stairs. This was conducted on the premise that each exercise should be tolerated by the individual, and attention should be paid to monitoring vital signs. Limb exercise training included endurance and strength training. The formerly employed cycle ergometer training (CPX/MAX/D, McGuffey, USA) for 20 minutes each time; the latter tested the single repetition maximum (one repetition maximum: 1RM) before training, and the training intensity was controlled at 70%–85% of 1RM. Eight repetitions for each muscle group action were completed in four sets. The training was conducted three times a week, with each session lasting 40 minutes. Both groups were treated for three months.

## Primary Observation Indexes

Researchers were blinded to patient grouping and evaluated patients before and after implementation of the intervention protocol. The main observation indexes included the patients' sputum volume, sputum properties, lung function-related indexes, and Barthel<sup>19</sup> and GQOLI-74<sup>20</sup> scores.

Patients rinsed twice with water and twice with hydrogen peroxide 10 min before induction of expectoration, according to the method of Pinto Plata et al.<sup>21</sup> After clearing nasal mucus, the patient was deeply coughed for sputum removal. Sputum volume for collection was required to be no less than 1 mL and to contain no saliva. A pipette was used to determine sputum volume. A dynamic rheological assessment of each collected sputum was performed using a rheometer (ar1500ex, Ta instruments, New Castle, Delaware). Interfacial tension was measured at the air–mucus interface by a strain gauge connected to the ring (Tensiomat Model 21, Fisher Scientific, Pittsburgh, Pennsylvania) to assess sputum viscosity.<sup>22</sup>

In this study, the Barthel index was used to evaluate the patients' daily living abilities after treatment. The index includes 10 items with a total score out of 100. A score  $\geq 60$  was considered “mild”, 59–41 was considered “moderate”, and  $\leq 40$  was considered “severe”. The post-intervention quality of life survey was conducted using the GQOLI-74 scale, which included four dimensions: physical life status, physical function, social function, and psychological function. All dimensions included five items, except for the first dimension, which included four. Five levels of scoring were applied to individual items, and these scores positively correlated with the effects. A pulmonary function tester was used to test the lung function indexes, eg the force expiratory volume in 1 second (FEV1), forced vital capacity (FVC), and FEV1/FVC. The amount of deep pulmonary sputum effectively coughed up by patients within 24 hours was recorded, and the sputum viscosity was assessed with reference to the relevant literature.<sup>7</sup>

## Statistical Analysis

The SPSS Statistics (v.20.0) software package was used for data processing in this study. The measurement data were expressed as mean  $\pm$  standard deviation ( $\bar{x} \pm s$ ). Count data were expressed as percentages (%). Normality tests were performed using the W-test. The W-test was used to compare the normal distribution data between the two groups; the non-parametric test was used for comparison between the groups regarding data that did not obey normal distribution patterning. A chi-square test was used for counting data;  $P < 0.05$  was considered a statistically significant difference.

## Results

### General Information

Between March 2017 and June 2020, 86 patients with bronchiectasis were identified and enrolled in the study, and they were randomly divided into observation and intervention groups ( $n = 23$  for each group). There was 23 male and 20 female in Intervention group compared with 22 male and 21 female in Observation group. The Age of intervention group and observation group was  $65.51 \pm 5.54$  vs  $65.70 \pm 5.55$  years, the disease duration was  $5.65 \pm 0.45$  vs  $5.75 \pm 0.39$  years, and the Barthel Index was  $35.41 \pm 3.20$  vs  $35.43 \pm 3.21$ . There was no statistically significant difference between the two groups in terms of gender, age, disease duration, and Barthel Index scores on admission ( $P > 0.05$ ) (Table 1).

### Comparison of Barthel Scores Between the Two Groups

The results of this study indicated a mild Barthel score for 90.70% (39/43) of patients in the intervention group; in the observation group, this value was 72.09% (31/43). Accordingly, the percentage of patients with a Barthel score below mild was significantly higher in the intervention group than in the observation group, with statistically significant differences ( $P < 0.05$ ).

### Comparison of the Quality-of-Life Scores in the Two Groups Before and After Treatment

The results showed that before treatment, there were no differences between the two groups in physical life status score, physical function score, social function score, and psychological function score ( $P > 0.05$ ). The post-treatment physical life status score, physical function score, social function score, and psychological function score of the patients in the intervention group were significantly higher than those in the observation group, and the differences were statistically significant ( $P < 0.001$ ). Intervention group and observation group, the post-treatment physical life status score, physical function score, social function score, and psychological function score of the patients were significantly higher than before treatment ( $P < 0.001$ ) (Table 2).

### Comparison of Pulmonary Function Indexes Between the Two Groups Before and After Treatment

The results showed that before treatment, there were no differences between the two groups in FEV1, FVC, and FEV1/FVC ( $P > 0.05$ ). After treatment, FEV1, FVC, and FEV1/FVC in the intervention group were significantly higher than those in the observation group, and all differences were statistically significant ( $P < 0.001$ ). Intervention group and observation group the post-treatment FEV1, FVC, and FEV1/FVC were significantly higher than before treatment ( $P < 0.001$ ) (Table 3).

**Table 1** Comparison of General Data Between the Two Groups

Group	Age (Years)	Gender (Male/Female)	Disease Duration (Years)	Barthel Index
Intervention group	$65.51 \pm 5.54$	23/20	$5.65 \pm 0.45$	$35.41 \pm 3.20$
Observation group	$65.70 \pm 5.55$	22/21	$5.75 \pm 0.39$	$35.43 \pm 3.21$
P	$>0.05$	$>0.05$	$>0.05$	$>0.05$

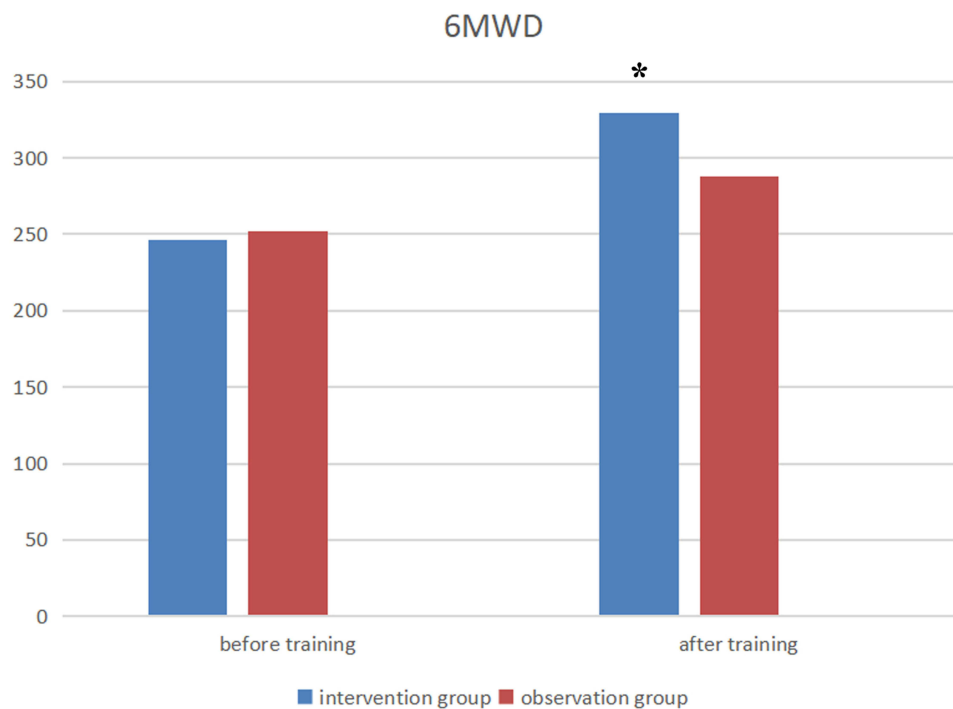
**Table 2** Comparison of Quality of Life Scores Between the Two Groups (Points)

Group	Physical Life Status (Score)		Physical Function (Score)		Social Function (Score)		Psychological Function (Score)	
	Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
Intervention group	21.15±3.22	28.59±3.41	30.23±3.00	38.37±3.36	30.86±3.11	38.28±3.42	32.45±3.12	38.44±3.25
Observation group	21.19±3.18	22.75±3.50	30.22±2.89	34.19±2.08	30.91±3.17	32.35±2.79	32.49±3.18	34.31±2.47
P value	0.899	<0.001	0.949	<0.001	0.893	<0.001	0.901	<0.001

**Table 3** Comparison of Pulmonary Function Indexes Between the Two Groups

Group	FEV1 (L)		FVC (L)		FEV1/FVC (%)	
	Before Treatment	After Treatment	Before Treatment	After Treatment	Before Treatment	After Treatment
Intervention group	1.24±0.33	1.81±0.45	1.34±0.25	1.82±0.36	0.58±0.15	0.78±0.15
Observation group	1.22±0.35	1.48±0.37	1.33±0.24	1.51±0.32	0.57±0.15	0.65±0.13
P value	0.682	<0.001	0.887	<0.001	0.435	<0.001

Figure 1 presented changes in 6MWD at baseline and after treatment for the intervention and observation groups. The results showed no significant differences in 6MWD experimental outcomes between the intervention and observation groups before treatment. While after receiving the respiratory rehabilitation training and extremity exercise rehabilitation



**Figure 1** Baseline 6-min walk distance (6MWD) and change after treatment in 6MWD in the intervention and observation groups before and after treatment. \*P < 0.05 compared with observation group after training.

**Table 4** Comparison of Sputum Excretion Between the Two Groups Before and After Treatment

Group	Sputum Volume (mL/d)		Sputum Viscosity (Score)	
	Before Treatment	After Treatment	Before Treatment	After Treatment
Intervention group	30.46±5.25	39.44±5.40	1.45±0.24	1.88±0.32
Observation group	30.40±5.22	34.41±5.28	1.44±0.21	1.69±0.20
P value	0.935	<0.001	0.785	<0.001

treatment, patients in the intervention group showed a significant increase in the distance traveled, in contrast to the observation group ( $P < 0.05$ ).

## Comparison of Sputum Excretion Between the Two Groups Before and After Treatment

The results of this study showed that there was no statistical difference between the two groups in terms of sputum volume (mL/d) and sputum viscosity (score). After treatment, the sputum volume and sputum viscosity scores of patients in the intervention group after three months of treatment were higher than in the observation group, and the differences were statistically significant ( $P < 0.001$ ). Intervention group and observation group the post-treatment sputum volume and sputum viscosity scores of patients were significantly higher than before treatment ( $P < 0.001$ ) (Table 4).

## Discussion

In this study, respiratory rehabilitation training combined with exercise training was used for patients with bronchiectasis. The results indicated that the lung-function score of the intervention group was significantly higher than that of the observation group, suggesting enhanced improvement. Furthermore, FEV<sub>1</sub>, FVC, FEV<sub>1</sub>/FVC, and 6WMD were all increased to different degrees. The current study results suggest that patients in the intervention group significantly improved their self-care ability and quality of life after respiratory and limb exercise training. In this study, the duration of treatment was increased to three months, and Barthel scores were more significantly increased, indicating that the patients' self-living ability had been significantly improved.

## Respiratory Rehabilitation Training and Limb Exercise Training Can Improve the Limb Training Efficiency and Promote the Recovery of Respiratory Function

Results from evidence-based medical research published in recent years have shown that pulmonary rehabilitation (PR) can significantly improve exercise capacity and health-related quality of life in patients with bronchiectasis, adding to the growing evidence to support the routine provision of PR to patients with bronchiectasis and exertional dyspnoea.<sup>23,24</sup> Previous study also suggested that respiratory muscle stretching associated with aerobic training could reduce respiratory muscle activity during exercise and improves lung volumes and capacities in patients with moderate-to-severe COPD.<sup>25</sup> Similarly, we also observed that respiratory rehabilitation training and limb rehabilitation significantly improved the scores of patients' quality of life indicators.

## The Mechanism of Lung Function Improvement

Respiratory muscle training promotes the growth of diaphragm type I muscle fibres by imposing a reasonable respiratory load. In this way, the patient's respiratory muscle endurance and fatigue resistance is improved, and ultimately, the strength of the patient's main inspiratory muscle and auxiliary inspiratory muscle is also enhanced, while the sympathetic tone is strengthened and vagal tone reduced through respiratory feedback training, thus promoting the autonomic function regulation of breathing and ultimately improving the patient's lung function-related indexes. Many patients with bronchiectasis have sputum accumulation, which affects respiratory function. Effective respiratory and exercise training can enhance the clearance efficiency of respiratory muscles and liquefy and loosen airway secretions, thus making them easier to cough up. This study found that the sputum clearance rate and 24-hour clearance in the intervention group were significantly higher than those in the observation group. However, these indications are reliant on effective anti-infection treatment.<sup>26</sup>

## Limitations

Our data have several common limitations relevant to most prospective analyses. First, because of the study's retrospective nature, treatment options were not randomised. Second, the specific protocols of respiratory training and limb exercise training, particularly the frequency and time, remain open for discussion. However, regardless of the training programme, subjective feelings of fatigue, activity ability, and the clinical manifestations of patients should be considered important reference indexes.

## Conclusions

Respiratory rehabilitation training with limb exercise rehabilitation can effectively increase the sputum clearance rate, improve lung function, and enhance the survival quality in patients with bronchiectasis, and it exhibits broad clinical application prospects.

## Research and Publication Ethics

This study was conducted in accordance with the Declaration of Helsinki and approved by the ethics committee of Huainan Eastern Hospital Group and Nanxiang Hospital of the Jiading District, Shanghai. All patients signed an informed consent form for inclusion in the study.

## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas. Xiaoyun Fan designed the study. Rongping Ni was responsible for collecting all the epidemiological and clinical data, writing the paper. Yingru Xing made the illustrations and Weiwei Ren helped analyze the data. All authors took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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## Disclosure

All of the authors had no any personal, financial, commercial or academic conflicts of interest separately for this work.

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