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Original Article

Conspicuous effect on treatment of mild-to-moderate COPD by combining deep-breathing exercise with oxygen inhalation

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Abstract: Chronic obstructive pulmonary disease (COPD) can lead to respiratory failure, but current pharmacological treatments focus on symptom relief or slowing disease progression. Here, the effectiveness of an alternative therapy combining deep-breathing exercises and oxygen inhalation therapy was assessed in mild-to-moderate COPD patients. Forty-two male mild-to-moderate COPD patients were randomly divided into a deep-breathing training group, an oxygen inhalation group, and a combination group (n=14 in each). In the deep-breathing training group, the patients were treated only by the deep-breathing exercise; in the oxygen inhalation group, the patients were treated only by oxygen inhalation; in the combination group, the patients were treated by combining the deep-breathing exercises with oxygen inhalation. Before treatment, there were no statistical differences in the general characteristics or lung function indexes between the three groups of patients ($P > 0.05$). However, after treatment, patients in the combination group had significantly better lung function indexes than they did before treatment, and their improvement was also superior to that of patients from the deep-breathing training group and the oxygen inhalation group ($P < 0.01$ and $P < 0.05$, respectively). Thus, a treatment method combining deep-breathing exercise with oxygen inhalation offers more significant lung function improvement in COPD patients than either the deep-breathing exercise or oxygen inhalation alone. This approach should be further explored for use in the clinic.

Keywords: Deep-breathing exercise, oxygen inhalation, chronic obstructive pulmonary disease, treatment effect

Introduction

Chronic obstructive pulmonary disease (COPD) includes the following conditions affecting the lungs: chronic bronchitis, bronchial asthma, pulmonary emphysema, and pulmonary heart disease. These conditions cause different-level bronchial congestion and respiratory disturbances. COPD is preventable; the patient's condition is related to enhanced chronic inflammation of the breathing pathway and the lung tissue, both of which are affected by tobacco smoke, smog, harmful gases, or dangerous air particles [1]. Treatment for COPD typically is through avoidance of the irritants or by pharmaceuticals. However, pharmaceutical treatment has limited effects, generally reducing symptoms in the short-term [2, 3]. In recent years, COPD patients have been treated by functional exercise, oxygen inhalation, and other physical means; these methods have obtained general approval [4, 5]. However, there are few clinical trials attempting to treat COPD by combining deep-breathing exercises with oxygen inhalation. In current study, mild-to-moderate COPD patients were randomly divided into three treatment groups to assess the effectiveness of combination deep-breathing exercises and oxygen inhalation treatment on lung function improvement compared to either treatment alone.

Participants and methods

Research participants

Because there are fewer females affected with COPD and the training load intensity differs by sex for the deep-breathing exercise, patient selection was restricted to male patients to reduce experimental data interference caused

Table 1. Characteristics of included patients ($\overline{x}$±s)

Category	Case number	Height (cm)	Weight (kg)	Age (years)	Medical history (months)				Illness degree	
					Below 3	3-6	6-12	above 12	Mild	Moderate
Training group	14	169.30±2.17	65.91±3.54	52.64±5.09	2	5	5	2	8	6
Oxygen inhalation group	14	170.11±2.34	66.32±3.49	51.83±4.92	1	6	6	1	7	7
Combination group	14	169.78±2.50	66.87±3.72	53.07±5.11	2	6	4	2	8	6

by sex-related factors. The study therefore comprised 42 male COPD patients (ages 45-60 years) who were diagnosed based on symptoms, physical signs, lung function tests, chest X-ray, and blood gas analysis; all patients met the COPD standards formulated in the Diagnosis and treatment draft of chronic obstructive pulmonary disease issued by the Respiratory Branch of the Chinese Medicine Academy in 2002. Patient conditions were either mild or moderate. Criteria for patient selection included the following: (1) varying degrees of aggravated dyspnea, increased sputum volume or purulent sputum, which appeared 1 week prior; (2) hypoxemia (PaO_2 < 60 mmHg), hypercapnia (50 mmHg < $PaCO_2$ < 80 mmHg) and acidosis (7.30 ≤ pH < 7.35). Patients were excluded by the following criteria: (1) presence of bronchial asthma (simply referred to as asthma), allergic rhinitis, hereditary allergies, or an elevated eosinophil (EOS) count (≥ 400 mL in men, ≥ 320 mL in women); (2) frequent need for oxygen inhalation during the daytime; (3) history of upper respiratory tract infection in the 6 preceding weeks or during the 2-week screening; (4) presence of other serious disorders besides COPD; (8) history of myocardial infarction in the preceding year; (6) history of heart failure in the preceding 3 years, or any arrhythmia that indicated treatment with drugs; (7) active tuberculosis; (8) history of cancer in previous 5 years; (9) life-threatening obstructive pulmonary disease; (10) a history of pulmonary cystic fibrosis or bronchiectasis; (11) history of pneumonectomy; (12) suffering from prostatic hyperplasia or vesical neck constriction with marked symptoms; (13) narrow-angle glaucoma, as well as allergies to any inhaled ingredient of anticholinergic agents, lactose, or Quantitative aerosol (MDI); (14) cromolyn sodium or nedocromil sodium was being used; (15) antihistamine therapy was being used; (16) the dosage of oral glucocorticoids needed to be changed, or oral glucocorticoids were steadily used but their dosage exceeded the one equivalent to 10 mg/d, the dosage of prednisone; (17) pregnant women, breastfeeding women or women of childbearing age, who did not used effective contraceptive measures; (18) history of alcohol abuse or drug dependence, or currently abusing alcohol or addictive drugs; (19) abnormal results of routine blood tests, blood biochemical tests, or routine urine tests; (20) the ratio of alanine transarninase/aspartate aminotransferase (ALT/AST) was more than twice the normal upper limit, the hemobilirubin level was more 1.5 times the normal upper limit, or the blood creatinine level was more 1.2 times the normal upper limit; (21) patients who participated in other clinical studies within 1 month before screening, or patients who were still within 6 half-lives of previous investigational drugs when they participated in this study. Patients were evenly divided (1:1:1) into the exercise training group, the oxygen inhalation group, and the combination group. SPSS 13.0 was used to produce random digit tables, the tables were placed into the envelopes, and the envelopes were sealed. Participants were selected by the order of their visits, and they were randomly assigned to the above groups according to the serial number of the envelopes. General characteristics for patients in the three groups are shown in **Table 1**. There were no statistical differences in general characteristics between groups (P > 0.05).

Experimental apparatus

The lung function test was performed by a SENSOR MEDICS-2200 lung function apparatus (USA) and an RMS-II respiratory muscle function microcomputer tester (China). Blood gas analysis was performed by a full-automatic PHOX blood-gas analyzer (NOVA, USA). Basic information was measured by a scale and a height indicator. A 2.5-5 kg sandbag was applied to respiratory muscle training so as to increase abdominal pressure and respiratory muscle load.

Treating method

For the deep-breathing training group, the patient specifically exercised respiratory muscle strength through deep-breathing exercises under medical guidance. First, for the pressurized deep-breathing exercise, the participant lies flat, keeps the body straight and relaxes muscles. A 3-kg sandbag is placed flat on the midsection adjacent to the chest, the patient is allowed to uniformly and slowly take a deep breath, then the patient raises the sandbag as far as possible on the chest to the highest position during inhalation, and lowers the sandbag as far as possible during expiration. The participant rests for 2 min after exercising for 2-3 min. Next, the participant performs a natural breathing exercise: the participant stands up, naturally relaxes, and normally breathes for about 30 s to adapt. Third, the obstruction deep-breathing exercise is performed. The participant stands up, keeps the body straight, relaxes the muscles, tries to take a deep breath, fastens the blowing nozzle (the blowing nozzle of the lung function apparatus is used as the raw material, and the air leakage hole of the blowing nozzle is lessened to obtain the air leakage hole area of 4-5 mm^2) of the specially manufactured lung function apparatus to the mouth, inhales by mouth at the fastest speed and the maximum lung volume and naturally exhales. Each exercise is performed 10-20 times. The natural breathing exercise is repeated, then the obstruction deep-breathing exercise is repeated, but this time the participant take a deep breath in the maximum lung volume, fastens the blowing nozzle to the mouth, exhales by mouth at the fastest speed and naturally inhales, performing this 10-20 times. The natural breathing exercise is performed again. Then, for the body turning and chest-beating exercise, the participant stands up, naturally drops the arms, relaxes the muscles, breathes naturally, then beats the chest and the back by turning the body to move the arms. This is continued for 2-5 min in each exercise. The first 6 exercises are performed sequentially and repeated, but the chest-beating exercise is used as the auxiliary relaxing exercise after the other exercises are finished. The patient is exercised once for about 30 min each day, over 8 weeks of training therapy.

For the oxygen inhalation group, under medical guidance, the patient continuously inhales oxygen through a nasal catheter at low flow, with the oxygen inhalation flow of 1-2 L/min and a concentration of 20-29%. The patient inhales oxygen about 2 hours each time, 3 times per day, for 8 weeks.

For the combination group, under medical guidance, the patient is treated by combining the deep-breathing exercises and oxygen inhalation. The oxygen inhalation content and duration reflect those of the oxygen inhalation group. During an oxygen inhalation interval, the deep-breathing training method, duration, and load mimicked those from the deep-breathing training group. The patient inhales oxygen about 6 hours in each day, with one deep-breathing exercise, for 8 weeks of combined treatment.

Detection of treatment effect

Before treatment and after the 8-week treatment regimen, relevant lung function indexes were detected by the lung function apparatus, the respiratory muscle function tester, and the blood-gas analyzer. The main detection components were as follows: Maximum Inspiratory Pressure (MIP); Maximum Expiratory Pressure (MEP); Slow Vital Capacity (SVC); Forced Vital Capacity (FVC); Forced Expiratory Volume In One Second (FEV_1); decubitus arterial blood oxygen partial pressure (PaO_2) and carbon dioxide partial pressure ($PaCO_2$).

Statistical analysis

The data were processed by SPSS 13.0 software and represented by ($\bar{x}$±s). Data in the groups were compared before and after treatment, and the improvement effect of the data among the groups was compared after treatment. The multiple groups were compared by variance analysis. Two groups were compared by Dunnett's t-test. When P was less than 0.05, the difference was considered statistically significant. After variance analysis, when the difference among geometric means from each group were statistically significant, the total geometric means from several groups were different or incompletely identical, if the total different geometric means from two groups were further comprehended, the multiple means performed paired comparison, called multiple comparisons, the paper adopted the Dunnett's t-test, which was applied to comparison

Table 2. Physiologic parameters of included patients before treatment ($\overline{x}\pm s$)

Category	Case number	MIP (Pa)	MEP (Pa)	SVC (L)	FVC (L)	FEV1 (L)	PaO_2 (kPa)	$PaCO_2$ (kPa)
Training group	14	6.34±1.23	8.24±1.47	3.05±0.80	2.66±0.62	3.13±1.05	8.81±0.76	6.15±0.77
Oxygen inhalation group	14	6.28±1.36	8.37±1.35	3.11±0.74	2.70±0.67	3.16±0.79	8.76±0.72	6.21±0.83
Combination group	14	6.31±1.32	8.28±1.39	3.07±0.79	2.72±0.65	3.15±1.02	8.85±0.73	6.13±0.74

between the two groups from multiple comparison groups and one experimental group.

Results

Before treatment, general characteristics (**Table 1**) and lung function indexes (**Table 2**) were statistically similar between groups ($P > 0.05$). After the 8-week treatment, there were statistically significant differences in lung function within each group when compared to the baseline lung function (**Table 2**; $P < 0.05$); however, in the oxygen inhalation group, PaO_2 and $PaCO_2$ indexes were the only ones that significantly improved after treatment ($P < 0.05$). Importantly, when comparing across treatment paradigms, following the 8-week intervention, the lung function improvement in the combination group was statistically superior to the improvements observed in both the exercise training group and the oxygen inhalation group (**Table 3**; $P < 0.05$).

Discussion

COPD is caused or aggravated by atmospheric pollution, occupational dust, chemical substances, viral or bacterial infection, and long-time tobacco smoking. Due to airway obstruction, the adaptability of the patient's lung and thorax is reduced, and the lung is excessively inflated so that the diaphragm muscle is pressed and lowered, thereby reducing diaphragm contractility and resulting in atrophy of the diaphragm, airway collapse, and blockage. Alveolar air then cannot be effectively eliminated, thereby affecting the normal gas exchange [6, 7], and resulting in difficulty breathing and reduced activity tolerance. Indeed, reduced lung capacity may be predominantly due to undeveloped respiratory muscle and weak respiratory muscle tolerance [8, 9]; for example, the diaphragm muscle is regarded as the main respiratory muscle of the body, plays a main role in normal aeration and lung functions and bears the aeration demand of 60%-75%. The pulmonary ventilation volume is increased by 250-300 mL [10] when the diaphragm muscle is increased by 1 cm. Thus, a functional disorder of the diaphragm muscle is regarded as an important reason for acute or chronic respiratory exhaustion and one of the basic pathological changes of the COPD. As for skeletal muscles in general, research shows that the respiratory muscle function can be improved by performing exercises. For example, Chen et al. [11] show that the respiratory muscle strength of the patient can be improved by respiratory training via abdominal pressurization, increasing lung function. Larson et al. [12] discovered that the obstruction load takes the respiratory muscle exercise by 30% of the peak airway pressure; the respiratory muscle strength, endurance time, and walking distance are increased; while 15% of the peak airway pressure is not changed. Thus, respiratory muscle strength and endurance can be improved by using special breathing exercises with a certain load. This supports a rationale for improving lung function through respiratory muscle training.

According to clinical practice, a load breathing training method should be designed so that, during respiration, the load pressure of the chest is increased by increasing abdomen pressure and air resistance. This specifically improves coordination of diaphragm muscles, abdominal muscles, and intercostal muscles, thereby enhancing the respiratory muscle strength, amplifying the thorax movement range, and magnifying the diaphragm muscle distance moved to effectively expand the airway, reduce resistance, and improve breathing quality. By the load breathing training method, lung tissue elasticity reduction caused by activity limitation and respiratory muscle atrophy can be restricted; the respiratory muscle strength is enhanced; the pulmonary ventilation volume and the pulmonary alveoli expansion rate are improved; the lung tissue elasticity, the small airway smoothness, and the thorax

Table 3. Relevant indexes from included patients before and after treatment ($\overline{x}\pm s$)

Category		Case number	MIP (Pa)	MEP (Pa)	SVC (L)	FVC (L)	FEV1 (L)	PaO_2 (kPa)	$PaCO_2$ (kPa)
Training group	Before	14	6.34±1.23	8.24±1.47	3.05±0.80	2.66±0.62	3.13±1.05	8.81±0.76	6.15±0.77
	After	14	7.00±1.33[c]	9.07±1.49[c]	3.62±0.85[c]	3.38±0.71[c]	3.55±1.12[c]	9.36±0.83[c]	5.56±0.69[c]
Oxygen inhalation group	Before	14	6.28±1.36	8.37±1.35	3.11±0.74	2.70±0.64	3.16±0.79	8.76±0.72	6.21±0.83
	After	14	6.34±1.39	8.41±1.39	3.12±0.73	2.72±0.66	3.19±0.77	9.74±0.81[c]	5.32±0.79[c]
Combination group	Before	14	6.31±1.32	8.28±1.39	3.11±0.74	2.72±0.65	3.15±1.02	8.85±0.73	6.13±0.74
	After	14	7.49±1.38[a,b,c]	9.81±1.60[a,b,c]	3.91±0.77[a,b,c]	3.69±0.66[a,b,c]	3.87±1.04[a,b,c]	9.82±0.77[a,c]	5.30±0.68[a,c]

Compared with the training group, [a]$P < 0.05$; t compared with the oxygen inhalation group, [b]$P < 0.05$; compared before and after treatment, [c]$P < 0.05$ and [c]$P < 0.01$.

activity can be maintained. Further, the thickening and aging process of the pulmonary alveoli is prolonged due to physical inactivity; here, during training, the respiratory resistance is increased by the blowing nozzle specifically produced and transmitted to the bronchus to keep a certain tension. Through the breathing method, the airway resistance can be increased to prevent the small peripheral airway from being in advance collapse and blockage, enabling full gas exchange inside the lung. Thus, the lung capacity and the maximal breathing capacity are improved, the residual volume is reduced, and the anaerobic condition is corrected. Importantly, this approach may have significance for improving the respiratory function of older individuals [13-15]. Here, 8 weeks of training with deep-breathing exercises alone or in combination with oxygen inhalation did produce significant improvements in lung function, which conforms to the relevant research.

Respiratory dysfunction causes COPD patients to experience long-term, chronic hypoxia, due to insufficient oxygen intake, which results in a lot of damage to the body. However, oxygen inhalation therapy can improve the oxygen pressure of pulmonary alveoli and arteries, increase the oxygen delivery capacity of the tissue, stabilize and reduce the pulmonary artery pressure, reduce viscosity of red blood cells and the blood, and ease breathing [16]. Further, long-term oxygen therapy can delay the progression of COPD, thereby improving quality of life and survival [17]. Brill et al. [18] indicated that lung function indexes and PaO_2 of patients receiving oxygen inhalation therapy are improved by inhaling oxygen for more than 15 hours each day, demonstrating the benefit of this treatment for COPD patients. In the current study, 8 weeks of treatment with oxygen inhalation for 6 hours daily resulted in significant improvements in PaO and $PaCO_2$. However, other detection indexes were not changed after treatment. This shows that only the blood oxygen concentration can be improved, and the lung function does not improve, following oxygen inhalation therapy. This result may be related to the daily oxygen inhalation duration and an insufficient number of continuous days of treatment.

Importantly, the combination of deep-breathing exercises and oxygen inhalation led to greater lung function improvement than either treatment alone. COPD leads to narrow airways, damaged pulmonary capillary beds, and reduced vascular bed area, which typically result in hypoxia. When the patient undertakes an endurance load exercise such as the deep-breathing exercise, the diaphragm muscles and other tissues need more oxygen. Adding oxygen inhalation when the respiratory muscle has been exercised enables the body to acquire enough blood oxygen, thereby retarding the fatigue of the respiratory muscle and maintaining its intense vitality during the exercise. In addition, the patient's increased blood oxygen can enable the patient to feel more comfortable physically and mentally, improving the efficiency of the deep-breathing exercise. Thus, COPD patients can experience improved lung function through combined deep-breathing exercises and oxygen inhalation therapy. This combination approach should be further explored in the clinic.

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Disclosure of conflict of interest

None.

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