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Effectiveness of Home-Based Respiratory Muscle Training in Patients with COPD and with Different Symptoms: A Case Series

*Chang HY[1,2], Kuo HP[3,4,5], Chen MC[4,5], Chou PC[3,4,5], Chou CL[4,5] and Ho SC[1,5,6]**

[1]Department of Respiratory Therapy, Taipei Medical University, Taipei, Taiwan

[2]Department of Respiratory Therapy, Chang Gung Memorial Hospital, Taoyuan, Taiwan

[3]Department of Internal Medicine, Division of Pulmonary Medicine, Taipei Medical University, Taipei, Taiwan

[4]Department of Internal Medicine, Division of Thoracic Medicine, Taipei Medical University Hospital, Taiwan

[5]Pulmonary Medicine Research Center, Taipei Medical University, Taipei, Taiwan

[6]Department of Internal Medicine, Shuang Ho Hospital, Taipei Medical University, New Taipei City, Taiwan

Abstract

Additional Respiratory Muscle Training (RMT) appears to benefit patients with Chronic Obstructive Pulmonary Disease (COPD). However, the suitability of RMT for patients with different characteristics and different severity of COPD is unknown. We investigated the effectiveness of home-based RMT in three patients with COPD with different characteristics, including symptoms of respiratory diseases, dynamic hyperinflation, and respiratory muscle weakness, and who presented with varying degrees of COPD severity from COPD Global Initiative for Chronic Obstructive Lung Disease (GOLD) grades II to IV. The three patients underwent home-based RMT therapy. They all continued to take existing medication and performed RMT exercises for 8 weeks with a target respiratory muscle training load of 50% of each participant's maximum respiratory muscle strength. Data on dyspnea sensation, Quality of Life (QoL), respiratory muscle strength, pulmonary function, 6-Min Walk Distance (6MWD), and diaphragm excursion were collected. The patient with symptoms of respiratory diseases improved the most as indicated by a decrease in dyspnea sensation during activity and an improvement in diaphragm excursion at rest. The patient with dynamic hyperinflation had an increase in the changed of inspiratory capacity and the 6MWD. The patient with respiratory muscle weakness had an improved QoL. Further studies should be performed with larger sample sizes.

Keywords: Respiratory muscle training; Symptoms of respiratory diseases; Dynamic hyperventilation; Respiratory muscle weakness; Diaphragm sonography; COPD

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Correspondence:
Shu-Chuan Ho, Department of Respiratory Therapy, College of Medicine, Taipei Medical University, 250 Wuxing Street, Taipei 11031, Taiwan, Tel: +886-2-27361661; Fax: +886-2-27391143;
E-mail: shu-chuan@tmu.edu.tw

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Introduction

COPD has an estimated prevalence rate of 6.1% in the general population in Taiwan [1]. Rochester showed that generalized muscle weakness in patients with COPD contributes to low inspiratory muscle strength next to hyperinflation [2]. Furthermore, Maximum Inspiratory Pressure (MIP) is known to be impaired by hyperinflation due to shortening of the inspiratory muscles [3]. Total Lung Capacity (TLC) is calculated according to lung volume–related physiology as the sum of End-Expiratory Lung Volume (EELV) and Inspiratory Capacity (IC) [4]. Thus, when air trapping during physical activity, EELV increases, IC decreases, and TLC remains constant. This phenomenon is known as dynamic hyperventilation.

We can surmise that hyperventilation leads to diaphragm limitation during exercise. A Min et al. found that the degree of diaphragmatic excursion during deep breathing was lower in patients with COPD and correlated significantly with disease severity [5].

Alba et al. demonstrated that inspiratory muscles training induces adaptive changes in the structure of the external intercostal muscles [6]. Improvement in inspiratory muscle performance is associated with an increase in 6MWD and the sensation of dyspnea [7]. Furthermore, Chun et al. [8] reported significant improvements after pulmonary rehabilitation in diaphragmatic motion during full inspiration and expiration in both lungs, indicated by fluoroscopy imaging findings [8].

Therefore, this case series investigated the effects of RMT in patients with COPD who exhibit classic respiratory symptoms, dynamic hyperinflation, or respiratory muscle weakness. We investigated the effectiveness of RMT in patients with COPD of varying severity who present with various symptoms.

Materials and Methods

Study design and subjects

The study protocol was approved by the ethics committee of the Taipei Medical University Joint Institutional Review Board, Taiwan (Study Code: N201808069). Data collection were performed from October 2018 to June 2019 at Taipei Medical University Hospital Pulmonary Rehabilitation Center, Taipei, Taiwan. A signed consent form has been obtained from all of the patients. The inclusion criteria were the participants who were categorized from moderate (GOLD II) to very severe (GOLD IV) COPD, age from 40 to 90 years old with stable condition. The GOLD strategy for COPD categorization was located in group B. The exclusion criteria were neuromuscular disease, diaphragm paralysis, dementia and COPDAE past 3 months.

Patient 1 exhibited respiratory disease symptoms. Patient 2 exhibited dynamic hyperventilation. Patient 3 had respiratory muscle weakness. Participants were permitted to continue taking existing medication. We collected the following information: Health history, dyspnea sensation, Quality of Life (QoL), respiratory muscle strength, pulmonary function, 6MWT, and diaphragm excursion.

Respiratory muscle training with a Dofin breathing trainer

RMT involving both inspiratory and expiratory muscles was performed. The target training load was set individually at 50% of each participant's MIP and MEP. After 4 weeks, participants returned to the pulmonary rehabilitation center for a respiratory muscle strength evaluation. Updated MIP and MEP values were used to adjust each participant's target training load. Participants then performed RMT involving 30 breaths per day with a pause of 30s to 60s after every five breaths. The experiment lasted for 8 weeks.

Outcome evaluation

Exercise pulmonary function test: Dynamic hyperinflation used to be indicated by a change in IC (ΔIC, in liters) of less than or equal to −0.10 L at the peak of exercise [9]; however, it is more recently indicated by a tidal volume at peak exercise (VT peak) /TLC of less than 0.4 [10]. Pulmonary function test was assessed using a spirometer (Vitalograph model 6800). Participants performed a 6MWT to measure their exercise endurance index.

Respiratory muscle strength test: The MIP Lower Limit of Normal (LLN) was 62 – (0.15 × age), and the MEP LLN was 117 – (0.83 × age) cmH_2O in men [11]. In our analysis, patients with MIP <60 cmH_2O were considered to have inspiratory muscle weakness [12]. MIP and MEP were measured with GaleMedGas Pressure Gauge, while participants were in a sitting position.

Quality of life evaluation: QoL was measured using the CAT formulated by from GlaxoSmithKline. A Short Form 12-item (SF-12) survey was used to measure functional health and wellbeing from each participant's perspective.

Diaphragm excursion measurement: Diaphragm excursion was measured using ultrasound imaging (Hitachi Noblus) of resting deep breath by one thoracic medical physician. The measurement reference lines were the bilateral scapular lines and bilateral posterior axillary lines. We measured the distance moved according to the grid lines on the screen of the ultrasound imaging machine.

Results

Patient 1 was a 78-year-old man presenting with symptoms of a respiratory disease and moderately severe COPD with predicted FEV1 of 54% and an mMRC score of 2. The 6MWD at baseline was 147 m, and that after RMT intervention was 244 m. At baseline, the Borg scale at rest was 5 and that after the 6MWT was 7; after the RMT intervention, the Borg scale at rest was 2 and that after the 6MWT was 3, indicating an improvement in the sensation of dyspnea.

QoL also improved considerably. Scores from the SF-12 survey increased from 40% to 63%; specifically, the scores increased from 21% to 50% in the physical component and 52% to 71% in the mental component. The CAT score decreased from 20 to 14 points.

MIP increased from 80 cmH_2O to 104 cmH_2O, and MEP increased from 100 cmH_2O to 120 cmH_2O. Diaphragm excursion also increased from 4 cm to 7 cm.

Patient 2 was a 77-year-old man who presented with dynamic hyperventilation and severe COPD with predicted FEV1 of 35% and an mMRC score of 1. The exercise pulmonary function test revealed a ΔIC of −0.12 L after the 6MWT. At baseline, his 6MWD was 263 m, and post-RMT, his 6MWD was 433 m. Also, it is worth noting that the ΔIC was from -0.12 improved to 0.09.

The QoL and CAT scores also improved. Scores from the SF-12 survey increased from 74% to 80%, including 71% to 81% for the

Table 1: Patient baseline characteristics.

Case	1	2	3
Characteristic	Symptoms of respiratory disease	Dynamic hyperinflation	Respiratory muscle weakness
Age/Gender	78/Male	77/Male	75/Male
BMI (kg/m²)	30.5	17.9	15.8
COPD Group	B	B	B
FEV1/FVC%	63	44	35
FEV1%	54	35	11
FVC%	64	61	24
mMRC	2	1	4
6-min Walk Test			
6MWT distance (pred%)	147 (40%)	263 (51%)	89 (18%)
ΔIC (L)	0.04	-0.12	0.24
Lowest SpO_2%	83	89	70
Borg	5→7	1→2	1→2
Quality of Life			
SF-12 (%)	40	74	51
CAT Score	20	13	21
Respiratory Muscle Strength			
MIP (cmH_2O)	80	54	12
MEP (cmH_2O)	100	80	48
Diaphragm Excursion (cm)	4	4	1.5

Abbreviations: BMI: Body Mass Index; COPD: Chronic Obstructive Pulmonary Disease; FEV1: Forced Expiratory Volume in One Second; FVC: Forced Vital Capacity; 6MWT: 6-Min Walk Test; IC: Inspiratory Capacity; SF-12: Short Form 12-Item Health Survey; CAT: COPD Assessment Test; MIP: Max Inspiratory Pressure; MEP: Max Expiratory Pressure

Table 2: Respiratory muscle training effectiveness.

Case	1		2		3	
Characteristic	Symptoms of respiratory disease		Dynamic hyperinflation		Respiratory muscle weakness	
	B	2M	B	2M	B	2M
6-min Walk Test						
6MWT distance (pred%)	147 (40%)	244 (66%)	263 (51%)	433 (84%)	89 (18%)	111 (23%)
∆6MWT distance (m)	-	+97	-	+170	-	+22
∆IC (L)	0.04	-0.06	-0.12	0.09	0.24	-0.44
Borg	5→7	2→3	1→2	0→2	1→2	1→4
Quality of Life						
SF-12 (%)	40	63	74	80	51	77
Physical (%)	21	50	79	79	50	64
Mental (%)	52	71	71	81	52	86
CAT Score	20	14	13	10	21	19
Respiratory Muscle Strength						
MIP (cmH_2O)	80	104	54	73	12	22
∆MIP	-	24	-	19	-	10
MEP (cmH_2O)	100	120	80	91	48	54
∆MEP	-	20	-	11	-	6
Diaphragm Excursion (cm)						
Right post-axillary line	4	7	4	4	1.5	2

Abbreviations: B: Baseline; 2M: Post-2-Month RMT Intervention

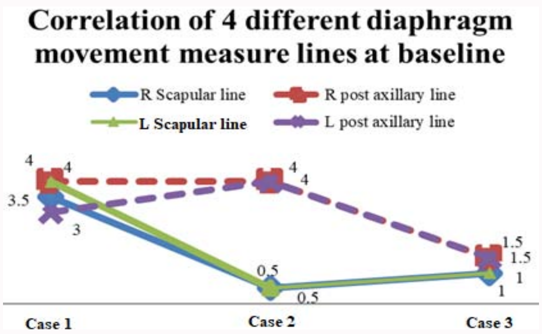

Figure 1: Bilateral scapular lines and post-axillary lines of the three cases for comparison.

mental component. The CAT score decreased from 13 to 10 points.

MIP increased from 54 cmH_2O to 73 cmH_2O, and MEP increased from 80 cmH_2O to 91 cm H_2O. The resting deep breath diaphragm excursion was unchanged at 4 cm.

Patient 3 was a 75-year-old man who presented with respiratory muscle weakness and very severe COPD with predicted FEV1 of 11% and an mMRC score of 4. The 6MWD at baseline and that following RMT intervention were 89 and 111 m, respectively. QoL improved considerably. Scores from the SF-12 survey increased from 51% to 77%; The CAT score decreased from 21 to 19 points.

His respiratory muscle strength improved slightly. At baseline, his MIP was 12 cmH_2O, and MEP was 48 cmH_2O. Post-RMT intervention, the MIP was 22 cmH_2O and MEP was 54 cmH_2O. The diaphragm excursion did not change significantly. The distance in the right post-axillary line was 1.5 cm at baseline and 2 cm post-RMT intervention (Table 1, 2).

We measured diaphragm movement using four lines, which were the scapular line and the post-axillary line on both the right and left sides. The distribution was related. The post-axillary line was slightly longer than the scapular line (Figure 1).

Discussion

The aim of this case series was to identify characteristics that are associated with favorable outcomes from RMT intervention. Increased breathing difficulty is indicated by a high inspiratory pressure to MIP ratio, which is related to perceived dyspnea sensation [13]. Chuang et al. [14] revealed that RMT increases MIP, improves 6MWT, reduces sensations of dyspnea, and improves QoL, allowing patients to more easily perform daily activities in patients with moderate to very severe COPD [14].

We found that in patient 1, when symptoms subsided, the QoL improved. Previous research has shown that MIP has a significant negative correlation with diaphragm excursion [15]. His diaphragm excursion increased from 4 cm to 7 cm accompany by increase MIP also noted.

Patient 2 presented MIP, MEP and 6MWD increased after the RMT intervention. A previous study showed that higher inspiratory muscle strength leads to improved exercise capacity and reduces dynamic hyperinflation and breathlessness during exercise [16]. We now have a better understanding of the mechanisms that lead to improved exercise capacity through RMT. QoL also improved with increased exercise tolerance. No change was observed in the diaphragm excursion in patient 2, different results might be observed if the diaphragm is measured in an active state.

Patient 3 presented with very severe COPD and with respiratory muscle weakness. Decreased MEP is common in patients with advanced COPD [2]. His 6MWD increased by only 22 m. But the minimum clinically important difference of the 6MWD suggests approximately 32 m [17]. The increase in diaphragm excursion only

0.5 cm was below the threshold of clinical measurement accuracy. Despite the poor clinical results, this patient's QoL improved much. The benefits of RMT for patients with very severe COPD remains unknown. Patient 3 did not show significant improvement probably because the training period was too short or because complementary modalities were required. In any case, RMT resulted in maintained muscle strength and increased exercise capacity, thereby improving QoL.

In conclusion, RMT has varying degrees of benefit for patients with COPD. Prolonged RMT or RMT in combination with additional training may provide better results.

Conclusion

Additional RMT increased MIP, MEP, CAT scores and QoL. The participant with symptoms of respiratory diseases had the greatest improvement in diaphragm excursion. The participant with dynamic hyperinflation had an increased ΔIC, which subsequently improved exercise capacity. The participant with respiratory muscle weakness, which is usually associated with very severe COPD, exhibited improvement in QoL.

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