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Response of Pulmonary Functions to Inspiratory Muscles Training Versus Pneumatic Compression in COPD Patients

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Abstract

Background: Chronic obstructive pulmonary disease (COPD), which is a leading cause of mortality and morbidity worldwide, is the main cause of persistent obstruction of the airway leading to respiratory muscle weakness.

Aim of Study: Comparing the response of pulmonary functions to resisted inspiratory muscles training versus pneumatic compression in COPD patients.

Patients and Methods: Randomized prospective clinical study included 40 patients with moderate and sever COPD. They were recruited from outpatient clinic of chest disease, Benha University Hospital; patients were randomly assigned into two equal groups, group A received Inspiratory Muscle Training (30% of maximum inspiratory pressure) and group B received Pneumatic Compression with abdominal sleeve (30% of one-repetition maximum). All patients trained 3 times per week for 12 weeks. Respiratory function tests were compared before interventions and post 12 weeks.

Results: Comparison between groups post treatment revealed a significant increase in FEV 1, FVC, PEFR, FEF25-75% and 6MWT of group A compared with that of group B (p<0.05).

Conclusions: Inspiratory muscle training and pneumatic compression improve pulmonary functions and pneumatic compression can be considered as an effective component for pulmonary rehabilitation in COPD patients.

Key Words: *COPD – Pulmonary functions – Inspiratory muscle training – Pneumatic compression.*

Introduction

CHRONIC obstructive pulmonary disease (COPD), a degenerative, irreversible lung condition and its symptoms are Long-term shortness of breath, poor airflow, and a cough that produces sputum **[1]**. COPD isa growing serious health issue in Egypt, although data on its prevalence, morbidity, and death are still insufficient and must be estimated **[2]**. Due to its high occurrence, COPD is one of the leading causes of morbidity and mortality in the world. In terms of age-standardized death rates for both sexes, COPD has the third-highest rates in the world, with almost 3.2 million people dying from the disease in 2015 **[3]**.

Despite the fact that COPD has generally been regarded of as a disorder that primarily affects the lungs, its systemic implications are now more commonly understood, with a variety of symptoms affecting the other body systems **[4]**. It has also traditionally been thought of as a disease that only affects the elderly, while it can also affect those who are working age. The severity and frequency of exacerbations affect the prognosis of COPD patients, with annual death rates of 1 1% for those who require hospitalisation, 5-50% for those who require mechanical ventilation, and as high as 37% in the event of hospital treatment for exacerbation recurrence **[5]**.

Due to a variety of issues, including ventilation, gas exchange, cardiovascular illness, and abnormalities in peripheral muscles, people with COPD commonly present with limits in their ability to exercise. These individuals also experience inhalator muscle dysfunction, which is connected to dyspnea and a decreased ability to exercise **[6]**. Reducing the disease's progression, enhancing patient prognoses, lowering health care expenses, and lessening the disease's socioeconomic and worldwide burden have all been strategies that have been needed **[5]**.

The cornerstone complementary therapy for managing COPD and its complications is exercise. In COPD patients, exercise can help with functional

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ability, anxiety and depression, stress, fatigue, systemic inflammation, dyspnea, and hospitalisation rates. Additionally, exercise can improve a patient's capacity to manage chronic COPD [7]. Forpatients with varying degrees of disease severity, pulmonary rehabilitation is advised as an effective intervention in cardiorespiratory therapy, leading to gains in exercise capacity and decreases in dyspnea [8].

Various exercise rehabilitation techniques that stabilize COPD patients can easily perform at home, beginning with a variety of breathing techniques designed to enhance relaxation, strengthen respiratory muscles (such as diaphragmatic, pursed-lip, posture-connected breathing, and belt breathing exercises), and prevent the build-up of airway secretions and forced expiration [9].

Inspiratory muscle training (IMT) is a pulmonary rehabilitation technique that maximises lung capacity and subsequently enhances physical fitness. IMT enhances quality of life, dyspnea, and the strength of the inspiratory muscles. When IMT is used in pulmonary rehabilitation programmes for patients with weak inspiratory muscles, their strength and exercise capacity both increase [5]. Inspiratory muscle training is a typical method of developing respiratory muscles (IMT). It has been established that applying a load when the respiratory muscle is contracting is sufficient to increase its strength, resulting in a significant decrease in dyspnea. IMT has also shown to reduce the usage of healthcare services, which may have positive economic consequences, in a more recent experiment that examined the 1-year impact of IMT. IMT has also been demonstrated to enhance COPD patients' muscle power, endurance, and dyspnea sensation [10].

A study, [11] found a positive significant improvement in diaphragmatic excursion after using Intermittent Pneumatic Compression (IPC) in respiratory retraining of elderly patients with low back pain. Despite the evidence-based positive effect on pulmonary functions, inspiratory muscle trainer was not compared to the effect of newly-used IPC in the resisted training of inspiratory muscles of COPD patients. Pneumatic compression is newly device that patients use to give resistance to diaphragmatic muscle and strength it.

This study aimed to compare the response of pulmonary functions to resisted inspiratory muscles training versus pneumatic compression in COPD patients.

Patients and Methods

Subjects:

This study was conducted on fortyCOPD male patients (BMI<30) with moderate and sever COPD. All patients were in stage 2, and 3 COPD according to GOLD [1] classification; 50% FEV1 <80% predicted, and 30% FEV1 <50% predicted respectively. With age ranged from 45 to 55 years, patients were screened to be enrolled into this 12-week randomized controlled trial. They had been recruited from the outpatient clinic of chest disease, Benha University Hospital; to participate in this study through a period of 12 weeks (from January 2022 to December 2022). All patients received a complete explanation about procedures of the program of treatment and measurement devices. Patient were free without exacerbation for at least 12 weeks before the beginning of the study.

Exclusion criteria were: Psychiatric or cognitive impairment, Systemic chronic illness as diabetes mellites, hypertension,patient on supplemental oxygen therapy, patients with cardiac disease, renal, hepatic, and other pulmonary disorders, patients with previous chest trauma, Chest infection, neurological or neuromuscular disease, Patients who were not quit smoking during the study,recent cardiac surgery or anyabdominal surgery, patients with unstable hemodynamic condition.

This study was locally approved and reviewed by Committee Research of the Faculty of Physical Therapy, Cairo University, Egypt [NoP.T.REC/012/002975].

Material:

Pre and post evaluation tools: Electronic spirometer to measure pulmonary function test as: Forced expiratory volume in the first second (FEV 1), Forced vital capacity (FVC), FEV 1/FVC ratio, Peak expiratory flow rate (PEFR)and Forced expiratory flow at 25%-75% of maximal lung volume (FEF25-75%) [12]. The Modified Borg Dyspnea Scale (MBS) is 10-point scale that is used to assess the degree of dyspnea experienced by a patient during submaximal exercise in chronic lung disease. It is frequently employed during the six-minute walk test (6 MWT), MBS used the dyspnea in the following ways: (0-NOTHING AT ALL), (0.5 Just barely perceptible, (1 Very slight), (2 Slight), (3 Moderate), (4 Slightly severe), (5 Severe), (6, 7 Very severe), and (8, 9 Nearly maximal) (10 Maximum) [13]. The six-minute walk test (6 MWT) measures aerobic endurance and capacity through sub-maximal activity. The outcome by which to compare changes in performance capacity was the distance travelled during a period of 6 minutes. [14-16].

Training equipment: Threshold Inspiratory muscle trainer (IMT): (Respironics, Cedar Grove, NJ 07009-1201 USA). Intermittent pneumatic compression (PC): (model WHF-324 wonjinMulsanpower Q1000, made in Republic of Koreaon 2014).

Training procedures: Group A: 20 patients underwent training of the inspiratory muscles by (Threshold Inspiratory Muscle Trainer). Three times each week for 12 weeks, the subject underwent training in the form of six sets of five deep breaths against the trainer, with 1-2 minutes of rest in between sessions [17]. Depending on their rate of perceived exertion, the patient determined the maximum training load at which they could effectively perform 10 breaths at maximum resistance. A load equivalent to 30% of the patient's maximum inspiratory effort was used to begin the training. This unique load gradually increased as the inspiratory muscle got stronger [18]. At the conclusion of the three months, the training programmer had expanded by 5% to 10% per week, reaching 60% of themaximum inspiratory pressure (MIP) [17].

Group B: 20 patients underwent pneumatic compression devicewith abdominal sleeve on the top portion of the abdominal cavity beneath the xiphoid process. The patient used a pursed-lip breathing method to exhale after inhaling slowly through the nose such that the stomach slid out against the abdominal sleeve of the device. For 12 weeks, three times per week, the workout consisted of 10 sets with 4-5 breaths in each set and a rest period of 2-3 minutes.the exercise's resistance was applied to a small and delicate sheet of clothing. We adopted this measure of (1-RM) by pressure from the device and this measure was done separately for patients. The patient was instructed to make an inspiratory breath against the maximum resistance from a pneumatic device to test the maximum resistance that the patient was able to tolerate while performing forced inspiration.

- In the first 4th weeks of the training: 30% of (1-RM) was used.
- In the second 5th - 8th weeks of the training: 60% of (1-RM) was used.
- In the third 8th - 12th weeks of the training: 75% (1-RM) was used [11].

Statistical analysis:

Unpaired *t*-test was conducted for comparison of subject characteristics between groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to test the homogeneity between groups. Mixed MANOVA was conducted to investigate the effect of treatment on FEV1, FVC, FEV 1/FVC, PEFR, FEF25-75%, MBS, and 6MWT. Post-hoc tests using the Bonferroni correction were carried out for subsequent multiple comparison. The level of significance for all statistical tests was set at $p<0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

Results

Subject characteristics:

Table (1) showed the subject characteristics of the group A and B. There was no significant difference between groups in age, weight, height, BMI and RHR ($p>0.05$).

Table (1): Comparison of subject characteristics between the group A and B.

	Group A	Group B	MD	*t*-value	*p*-value
	Mean ± SD	Mean ± SD			
Age (years)	51.2±3.61	51.9±3.21	–0.7	–0.64	0.52
Weight (kg)	77.4±10.38	77.45±9.18	–0.05	–0.01	0.98
Height (cm)	167.75±8.22	168.05±7.17	–0.3	–0.12	0.9
BMI (kg/m^2)	27.44±2.69	27.33±1.70	0.11	0.14	0.88
RHR (beats/min)	86.2±9.13	83.6±7.71	2.6	0.97	0.33

SD : Standard deviation. BMI: Body mass index.
MD: Mean difference. RHR: Resting heart rate.
p-value: Probability value.

Effect of treatment on FEV1, FVC, FEV1/FVC, PEFR, FEF25-75%, MBS and 6MWT:

Mixed MANOVA revealed a significant interaction effect of treatment and time (F=23.39, p=0.001). There was a significant main effect time (F=166.14, p=0.001). There was no significant main effect of treatment (F=0.92, p=0.52).

Within group comparison:

There was a significant increase in FEV 1, FVC, PEFR, FEF25-75% andthere was a significant increase 6MWT post treatment in both groups compared with that pre-treatment (p>0.05). There was a significant decrease in MBS post treatment in both groups compared with that pre-treatment (p>0.05). (Table 2).

Between group comparison:

There was no significant difference between groups pre-treatment (p>0.05). Comparison between groups post treatment revealed a significant increase in FEV1, FVC, PEFR, FEF25-75% and a significant increase in 6MWT of group A compared with that of group B (p<0.05). There was a significant decrease in MBS of group A compared with that of group B (p<0.05). (Table 2).

Table (2): Mean FEV1, FVC, FEV1/FVC, PEFR, FEF25-75%, MBS and 6MWT pre and post treatment of group A and B.

	Pre-treatment	Post treatment	MD	% of change	p-value
	Mean ± SD	Mean ± SD			
FEV1 (L):					
Group A	1.26±0.25	1.56±0.21	–0.3	23.81	0.001
Group B	1.24±0.34	1.33±0.32	–0.09	7.26	0.001
MD	0.02	0.23			
	p=0.8	p=0.01			
FVC (L):					
Group A	2.19±0.37	2.71±0.38	–0.52	23.74	0.001
Group B	2.2±0.52	2.37±0.49	–0.17	7.73	0.001
MD	–0.01	0.34			
	p=0.94	p=0.02			
FEV1/FVC (%):					
Group A	57.85±5.25	58.41±7.24	–0.56	0.97	0.55
Group B	56.61±7.24	56.39±6.79	0.22	0.39	0.81
MD	1.24	2.02			
	p=0.53	p=0.36			
PEFR (L/min):					
Group A	2.18±0.65	2.96±0.73	–0.78	35.78	0.001
Group B	2.19±0.73	2.37±0.74	–0.18	8.22	0.02
MD	–0.01	0.59			
	p=0.94	p=0.01			
FEF 25-75%:					
Group A	18.8±5.57	24.86±4.88	–6.06	32.23	0.001
Group B	18.09±6.09	20.28±6.46	–2.19	12.11	0.001
MD	0.71	4.58			
	p=0.71	p=0.01			
MBS:					
Group A	7.6±1.46	3.8±1.05	3.8	50	0.001
Group B	7.95±1.47	4.95±1.31	3	37.74	0.001
MD	–0.35	–1.15			
	p=0.45	p=0.004			
6MWT (m):					
Group A	210.75±35.55	329.5±59.71	–118.75	56.35	0.001
Group B	224±41.34	278±57.59	–54	24.11	0.001
MD	–13.25	51.5			

SD : Standard Deviation.
MD: Mean Difference.
p-value: Probability value.
FEV1 : Forced expiratory volume in the first second.
FVC : Forced vital capacity.
PEFR : Peak expiratory flow rate.
FEF25-75%: Forced expiratory flow at 25 to75%.
MBS : Modified borg scale.
6MWT: Six-minute walk test.

Discussion

The aim of this study was to compare the response of pulmonary functions to resisted inspiratory muscles training versus pneumatic compression in COPD patients. It was observed that there was a significant improvement in both groups with more improvement in group A comparing with group B. The results of our study revealed a statistically significant improvement in FEV 1) 23.81 % and 7.26% for groups A and B, respectively (FVC) 23.74% and 7.73% for groups A and B, respectively (PEFR) 35.78% and 8.22% for groups A and B, respectively (FEF25-75%) 32.23% and 12.11% for groups A and B, respectively (and 6MWT) 56.35% and 24.11% for groups A and B, respectively (of group A compared with that of group B ($p<0.05$). There was a significant decrease in MBS) 50% and 37.74% for groups A and B, respectively (of group A compared with that of group B ($p<0.05$).

The results of this were supported by the findings of Figueiredo et al., [5] who found that isolated IMT is a successful therapy option for enhancing inspiratory muscle strength, functional capacity, and pulmonary function in COPD patients.

Buran Cirak et al., [19] showed that COPD patients who received IMT plus manual therapy had better outcomes in terms of functional capacity, respiratory muscle strength, pulmonary function, dyspnea, tiredness perception, and quality of life.

Beaumont et al., [20] agreed with this study results after their conclusion which confirmeffectiveness of inspiratory muscle training (IMT) on improves inhalor muscle strength, exercise capacity and quality of life and dyspnea (this conclusion extracted from conducted systemic review and metanalysis of studies investigated the effect of IMT on the mentioned parameters). Our result matched with Haytham et al., [18] whoconcluded that inspiratory muscle training device promotes diaphragmatic excursion in post-thoracotomy patients by strengthening the inspiratory muscles and enhancing breathing mechanics.

Rocha et al., [21] found a favorable correlation between FEV 1 and total lung volume and diaphragm motion in COPD patients. With regard to pulmonary function, diaphragm mobility is favorably connected. The modified Medical Research Council Dyspnea Scale (mMRC) scores and diaphragm mobility were found to be negatively correlated. When patients with COPD experience more dyspnea, their diaphragm mobility declines. Chen et al., [22].

This study will be the first report which argued PC device role to improve the pulmonary function in COPD patients. This device pneumatic compression (PC) was used by Mostafa et al., [11] to resist the diaphragm and assess the diaphragmatic excursion reaction. Forty people with chronic low back pain (twenty males and twenty females). Their ages ranged from 60 to 70 years, revealed that there was significant increase of Diaphragmatic excursion at post treatment in compare to pre-treatment in the group A (study group 10.05%) & group B (control group 0.98%) received traditional physical therapy in form of TENS and Ultrasound only.

Haytham et al., [18] and Mostafa et al., [11] both of them documented that response of diaphragmatic excursion to IMT and PC which supported our results, relieved that inspiratory muscle trainer more effective than pneumatic compression by percentage of improvement (59.52%) of IMT and (10.05%) of PC of diaphragmatic excursion. This significant improvement in diaphragmatic excursion in relating to improvement of pulmonary function which is supported by Jung & Kim [23] whose study demonstrated that there is a relationship between respiratory function and diaphragm thickness and diaphragm excursion, especially in the paretic side of the diaphragm.

Additionally, Shiraishi et al., [24] reported that Patients with chronic obstructive lung disease showed a correlation between diaphragmatic excursion and an increase in exercise tolerance following pulmonary rehabilitation. Also, Paulin et al., [25] who studied the influence of diaphragmatic mobility on exercise tolerance and dyspnea in patients with COPD.

Moreover, our study is supported by Rahmy & Esraa [26] who reported that, patients with interstitial pulmonary fibrosis may experience a difference between the effects of inspiratory muscle training and resistive diaphragmatic breathing on maximum inspiratory pressure. And their study supported ours, inspiratory muscle training was more successful and beneficial than diaphragmatic resisted breathing exercise.

However, Nambiraja & Sundaram [27] who examined the effects of inspiratory muscle training (IMT) and diaphragmatic breathing techniques (DBE) on improving functional capacity in people with chronic bronchitis. FVC and forced expiratory volume in the first second (FEV 1) significantly increased in the IMT and DBE groups (FEV 1). In comparison to the 6-minute walk, each group shown a considerable improvement.

But opposite to us, Derrickson et al., [28] examined the effects of inspiratory resistance muscle training using abdominal weights (AbWts) on a number of pulmonary function measurements in quadriplegic patients. There was no discernible difference between the treatment procedures after 7 weeks (p>0.05).

Conclusion:

There was a significant improvement inpulmonary functions by inspiratory muscle training and abdominal sleeve of pneumatic compression. Andpneumatic compression can be considered as an effective component for pulmonary rehabilitation in COPD patients.

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استجابة وظائف الرئة لتدريب عضلات الشهيق مقابل الضغط الهوائى فى مرضى الانسداد الرئوى المزمن

الخلفية : مرض الانسداد الرئوى المزمن (COPD)، وهو سبب رئيسى للوفيات والمضاعفات فى جميع أنحاء العالم، هو المسبب الرئيسى للانسداد المستمر فى مجرى الهواء مما يؤدى إلى ضعف عضلات الجهاز التنفسى.

الهدف من الدراسة : مقارنة استجابة وظائف الرئة لتدريب عضلات الشهيق المقاومة مقابل الضغط الهوائى فى مرضى الانسداد الرئوى المزمن.

المرضى والطرق : شملت دراسة التجارب السريرية العشوائية المرتقبة ٤٠ مريضاً يعانون من مرض الانسداد الرئوى المزمن المعتدل والشديد. تم اختيارهم من العيادة الخارجية لأمراض الصدر بمستشفى بنها الجامعى، تم تقسيم المرضى بشكل عشوائى إلى مجموعتين دراسيتين متساويتين فى العدد مجموعة أ تلقت علاج باستخدام جهاز مدرب عضلات الشهيق (٣٠٪ من أقصى ضغط الشهيق) والمجموعة ب تلقت جهاز الضغط هوائى بواسطة حزام على منطقة البطن (٣٠٪ من تكرار واحد كحد أقصى). تم تدريب جميع الحالات ٣ مرات فى الأسبوع لمدة ٣ أشهر. تمت مقارنة اختبارات وظائف الجهاز التنفسى قبل التدخلات وفى نهاية ١٢ أسبوعاً.

النتائج : أظهرت المقارنة بين المجموعات بعد العلاج زيادة معنوية فى FEV1 و FVC و PEFR 6MWT وFEF25-75% من المجموعة A مقارنة مع المجموعة B ($p<0.05$). كان هناك انخفاض معنوى فى MBS للمجموعة A مقارنة مع المجموعة B ($p<0.05$).

الاستنتاجات : يعمل جهازين تدريب العضلات الشهيق والضغط الهوائى على تحسين وظائف الرئة ويمكن اعتبار الضغط الهوائى مكوناً فعالاً لإعادة التأهيل الرئوى لمرضى مرض الانسداد الرئوى المزمن.