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Original Article

Influences of pulmonary rehabilitation on COPD patients

Pulmonology

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) has several systemic manifestations that impacts its severity, exercise capacity, and progression. Pulmonary rehabilitation (PR) program helps to decrease symptoms and improve exercise capacity.

Objective: To assess the effect of pulmonary rehabilitation on exercise capacity, skeletal and diaphragmatic muscles in stable COPD patients.

Methodology: A prospective interventional study was conducted on 60 patients with stable COPD. All of them were assessed by the following at baseline and 12 weeks after PR program; spirometric-indices, arterial blood gases, ultrasonographic assessment of diaphragm thickness fraction (DTF%) and tidal breathing diaphragm excursion (TDE), assessment of diaphragm and quadriceps muscle shear wave elastography (SWE), measurement of right ventricular systolic pressure (RVSP) gradient by echocardiography, and evaluation of functional health status by; COPD assessment (CAT) test, modified medical research council (mMRC) scale and six minutes' walk test (6MWT).

Results: In COPD patients, the spirometry-indices were significantly improved after PR compared to baseline value ($p<0.001$). The oxygen saturation (SaO_2%), and arterial partial of oxygen (PaO_2) were significantly improved as both were increased, while the arterial partial of carbon dioxide ($PaCO_2$) and pH were significantly decreased after PR compared to the baseline value ($p< 0.05$). The DTF %, and TDE were significantly increased after PR compared to baseline ($p<0.05$). The diaphragm SWE, quadriceps SWE, and RVSP were significantly improved after PR compared to the baseline values, all decreased ($p<0.05$). The exercise tolerance parameters, CAT score and mMRC scale were significantly decreased ($p<0.001$), while the 6MWT distance, and pre and post 6MWT SpO_2 were significantly increased ($p<0.001$) after PR compared to the baseline values.

Conclusion: PR confers benefits to COPD patients that manifest in diverse ways as improvement of ventilatory function, arterial blood gases, exercise capacity, and diaphragm functions, with decrease of diaphragm and quadriceps muscle stiffness and pulmonary artery pressure.

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Keywords: COPD; pulmonary rehabilitation; diaphragmatic breathing; mMRC scale; pursed lip breathing.

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is an overwhelming disease and at present is the 3rd leading cause of death worldwide. It is also the 7th leading cause of disability-adjusted life years. In its earliest stages, the patients frequently limit their physical activities to accommodate for dyspnea. With COPD progression, physical activities and exercise capacity continue to decrease with development of vicious cycle of deconditioning, dyspnea, and more decrease in physical activities [1]. Despite improvements of pharmacological treatments of COPD, a huge number of patients remain symptomatic and suffer from frequent exacerbations and hospitalizations. Dyspnea developed at rest and/or during daily-living activities in COPD patients can lead to more sedentary lifestyle, a progressive declining in exercise capacity, with subsequent home isolation [2].

For many years, smoking cessation and pharmacological treatment are the mainstay of COPD treatment, but currently forceful exercise programs like pulmonary rehabilitation (PR) have been considered a fundamental part in managing COPD patients [3]. PR is considered the most effective non-pharmacological treatment for improving exercise capacity in COPD patients and has become a regular care for these patients [4]. PR and drug therapy are not competitive but rather, they must have a synergistic effect to result in better successful outcome [3].

Chronic airflow limitation increased respiratory muscles load, make the diaphragm flat, and decreasing its capacity to generate tension. Numerous other mechanisms can alter functions of respiratory muscles in COPD patients, e.g. ageing, oxidative stress, malnutrition, activation of proteases, and associated comorbidities; however, changes in thoracic wall geometry and diaphragm place are the most documented mechanisms leading to diaphragmatic dysfunction [5]. Therefore, assessing diaphragmatic function in patients with COPD has been the focus of many studies [6]. Ultrasonographic (US) assessment of diaphragm thickness at zone of apposition (ZOA) at the end of maximum inspiration is considered a good marker of quantifying hyperinflation. Moreover, the diaphragmatic excursion (DE) was correlated with degree of airway obstruction. Therefore, changes in diaphragmatic thickness or excursion after PR programs may be good markers of how successful the PR [7]. Shear wave US elastography (SWE) is an innovative US technology that offer a direct and real-time measurements of the mechanical characteristics of tissues and information muscle quality. SWE identify the stiffness of the tissue by measuring the elasticity index based on the grade of distortion under the application of an external force [8].

Respiratory and skeletal muscle dysfunction in COPD patients lead to increased dyspnea index score [modified medical research council (mMRC) scale], decrease exercise tolerance and capacity, and reduced activities. Early recognition and intervention to improve skeletal muscle function is essential for improving prognosis and quality of life of COPD patients [3]. The COPD assessment test (CAT) is a questionnaire primarily used to assess the health status of COPD patients. It includes several domains e.g. symptoms, physical activities capacity, psychological, sleep status, social impacts, and others. It is widely reflecting the quality of life of COPD patients and provide a simple method to assess and follow symptoms [9]. The 6-minutes' walk test (6MWT) evaluate global and combined responses of different body systems to exercise e.g. pulmonary and cardiovascular systems, blood and neuromuscular system., and peripheral and systemic circulation. It is a valued index for assessing functional capacity in COPD patient as the 6MWT distance is a useful indicator of COPD severity and predictor of survival [10].

Pulmonary hypertension (PH) is a frequent and significant finding in COPD. It leads to with poor clinical courses with more recurrent exacerbation events, shorter survival, and larger need of health resources [11].

This study aimed to assess the influences of PR program on exercise capacity, skeletal and diaphragmatic muscles in stable COPD patients.

SUBJECT AND METHODS

An interventional study was performed chest diseases department, Al-Zahraa University hospital, Cairo, from September 2022 to May 2024.

Study participants: A total of 60 out of 197 patients with stable COPD were selected from chest outpatient's clinic where they regularly followed-up. They were diagnosed several years ago on the bases of typical symptoms and signs of COPD, and post-bronchodilator $FEV_1/FCV<70\%$ and an increase of $FEV_1<12\%$ and/ or < 200 mL 15 minutes after 4 puffs 400 µg of inhaled salbutamol [12].

Exclusion criteria: COPD patients with the following diseases were not included into the study; major organ failure (e.g. renal failure, liver cell failure, heart failure), uncontrolled diabetes or hypertension, unstable angina or recent myocardial infarction in the last 6 months, and neuromuscular or orthopaedic diseases, patient on long-term oxygen therapy, patients received systemic steroid in the last 4 weeks, and patient having previous pulmonary or cardiac surgery.

Ethical consideration

The study protocol was approved by faculty of medicine for girls, Cairo, Al-Azhar University, Egypt institutional review board committee (No. 1421) and a written informed approval was taken from each patient prior to participation into the study. All data were nameless and coded to ensure confidentiality of patients.

Methods

The patients age, sex, body mass index (BMI) was reported. Liver and renal function tests, fasting blood glucose, complete blood count, and ECG were done to confirm that the studied COPD patients have no exclusion criteria. The assessment of functional health status of the COPD patients was done using the CAT score, mMRC dyspnea scale, and the 6MWT. The CAT score is an 8-item questionnaire and ranges from 0-40. Higher scores signify a more severe influence of COPD on a patient's life. It was translated into Arabic language, and it was reliable and validated for use in Arabic nations [13]. The mMRC scale is a self-assessment scoring system used to evaluate impairment caused by shortness of breath during daily activities, it was ranged from 0-4, with 0 means less breathlessness and 4 means marked breathlessness [14]. The 6MWT is an authorised test, of submaximal intensity, used to objectively assess functional exercise capacity across many pathologies. The 6MWT was conducted according to ATS guidelines [15].
Measurements of arterial blood gases (ABG) was performed after resting in room air for 15 minutes, it was

done using (Rapid Lab 248 blood gases analyser, Siemens Medical Solutions, Malvern, PA, US). The following parameters were recorded; O_2 saturation % (SaO_2%), arterial partial pressure of oxygen (PaO_2) mmHg, and arterial partial pressure of carbon dioxide ($PaCO_2$) mmHg, bicarbonate (HCO_3) mmol/L and power of hydrogen (pH).

Spirometry was done in accordance with the standards of the ERS/ATS [16] using (Smart PFT trolley S, Germany). The following parameters were measured; forced vital capacity % predicted (FVC%), forced expiratory volume in first second % predicted (FEV_1%), FEV_1/FVC ratio, and forced expiratory flow 25-75 % predicted (FEF 25-75 %). The best of three technically accepted performance was selected.
Ultrasound assessment of diaphragm thickness and excursion were done by using Sonoscape SSI6000 (Medical Systems, Shenzhen, China). The tidal diaphragm excursion (TDE) was measured by using a low frequency transducer (3.5-5 MHz). It was assessed by both motion-mode (M-mode) and brightness-mode (B-mode) US. The DE was measured during tidal breathing (TDE). It was examined through right anterior subcostal window. Through this window, the diaphragm visualized as a thick, deeply located, hyperechoic, and curved structure that separates thoracic and abdominal cavities [17]. The probe was positioned between the midclavicular and the anterior-axillary lines, below the right costal margin, and directed cephalic, posteriorly, and medially [7]. The amplitude of the DE was measured by placing callipers at the bottom and top of the diaphragmatic inspiratory slope. To quantify DE in an objective manner, at least three images were evaluated, and the mean of the three measurements were reported [17] (figure 1).

A. Right anterior subcostal window for measurement of diaphragm excursion: The probe was placed between the mid-clavicular and the anterior axillary lines, below the costal margin, and directed cephalad, medially, and dorsally.

B. Ultrasonographic image of diaphragm tidal breathing excursion: The amplitude of the DE was by placing calipers at the bottom and top of the diaphragmatic inspiratory slope.

Figure (1): Ultrasonographic measurements of diaphragm thickness and excursion

For measurement of diaphragm thickness the high frequency linear probe (9.5-15 MHz) was placed mid-way between the anterior and mid-axillary line, between 7th and 9th intercostal space in the ZOA [17]. On B-mode diaphragm visualized as an echogenic linear structure between highly reflective peritoneal and pleural membranes. The thickness was measured as the distance from the middle of the diaphragmatic pleura to the middle of the peritoneal membrane [18]. It was measured by placing callipers on reflective lines at end expiration i.e. residual volume and after deep inspiration i.e. total lung capacity (figure 2). The diaphragm thickness fraction (DTF%) was calculated using the following equation:

$$"\frac{\text{(Thickness at total lung capacity – (Thickness at residual volume)}}{\text{(Thickness at residual volume)}} \text{X100"}$$

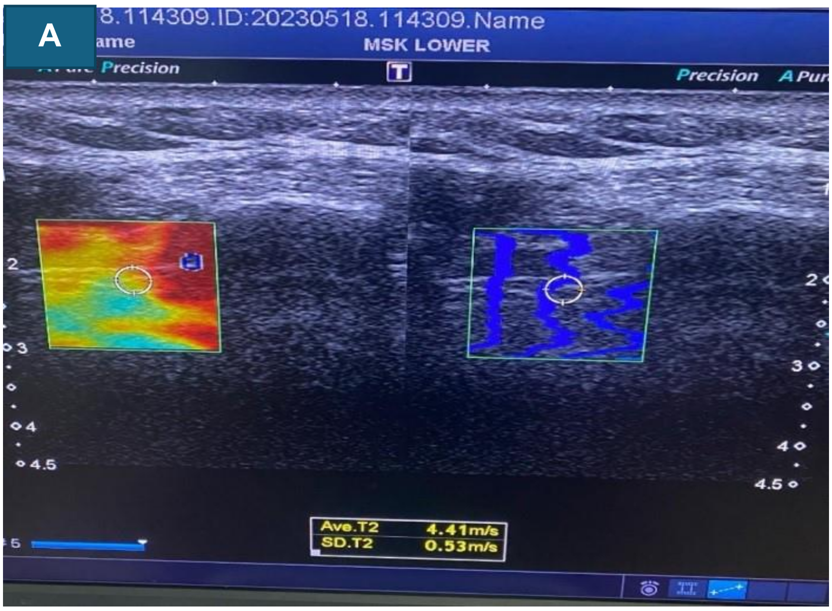
[7]. Patients were classified according to DTF%, either having diaphragm dysfunction (DTF ≤ 20%) or having normal diaphragm function (DTF ≥20%) [19].

A. Patient and probe position for ultrasound measurement of diaphragm thickness A high frequency linear probe (9.5-15 MHz) was placed mid-way between the anterior and mid axillary line in longitudinal plane, between 7th and 9th intercostal space in the ZOA.

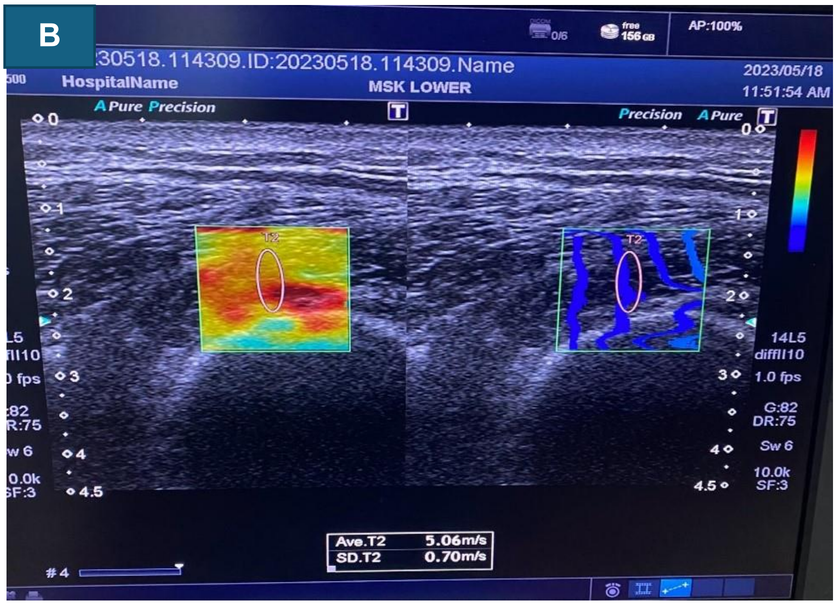
B. B-mode US of diaphragm thickness: the diaphragm appears as a thick echogenic linear structure between highly reflective pleural and peritoneal membranes. The thickness was measured as the distance from the middle of the diaphragmatic pleura to the middle of the peritoneal membrane

Figure (2): Ultrasonographic measurements of diaphragm thickness

The SWE of the diaphragm and quadriceps muscle was done using (Toshiba Aplio 500 Platinum, Japan). The patient was lie in supine position. After good quality image of the right diaphragm was obtained, the SWE-mode was switched on, and the elastic range was adjusted to 0-160 kPa. When the patient quietly holding his breath at the end of inspiration, the elastic modulus of the diaphragm and quadriceps muscle in the region of interest (ROI) was measured by using Q-BOX. When assessing the diaphragm, a circular area with a width of (1cm X 1cm) was selected as the ROI, that covered as much of the diaphragm as possible. When assessing the quadriceps muscle, the ROI was set to an oval area with a width of 1cm x 2cm. The average values of SWE velocity (m/s) were automatically created in each ROI by the US system [20] (figure 3).



A. SWE of the diaphragm When measuring SWE of the diaphragm muscle, a circular area with a diameter of (1cm X 1cm) was selected as the ROI, that covered as much of the diaphragm as possible in each image.



B. SWE of quadriceps muscles Regarding the quadriceps muscles The ROI was set to an oval area with a diameter of 1cm x 2cm. The average values of shear wave velocity (m/s) were automatically created in each ROI by the US system.

Figure (3): Shear wave elastography of diaphragm and quadriceps muscled

Resting transthoracic echocardiography was done by using (Vivid-E9 GE system, China), with tissue doppler and speckle tracking imaging capability attached to Echo-Pac workstation version 201, following guidelines from the American Society of Echocardiography and the European Association of cardiovascular imaging [21]. The right ventricular systolic pressure (RVSP) gradient was measured in the presence of tricuspid regurgitation the peak systolic gradient across the tricuspid valve and inferior vena cava diameters and collapse was used. The RV Tei-index reflects both systolic and diastolic RV functions = (isovolumic relaxation time + isovolumic contraction time)/ejection time. Patients were classified according to RVSP either having PH (RVSP $\geq$ 21 mmHg) or having no PH (RVSP <21 mmHg) [11].

The spirometric-indices, CAT score, mMRC scale, 6MWT, US assessment of DTF% and TDE, SWE of diaphragm and quadriceps muscle, ABG, and RVSP were measured at baseline and after 12 weeks of PR program that including the following multicomponent intervention; exercise training, education, dietary advice, psychological and behavioural intervention.

- **Breathing exercises**

1. **Diaphragmatic breathing:** the patient lied on his/her back on a flat surface, the knee was bent, the head was supported by cushion, and another cushion was put under the knees to support the legs. patient placed one hand on the upper chest and the other just below the rib cage, so he feels the diaphragm move as he breathe. Then the patient was asked to breath slowly through the nose so that the stomach moves out against the hand. The hand on the chest remained in its position. Thereafter, the patient contracts the abdominal muscles, letting them fall inward as place exhales through pursed lips. The hand on the upper chest remained in its place [22].

2. **Pursed lip breathing:** the patient inhale deeply through the nose (like smelling something), for about two seconds, therefore, the abdominal muscles were used to fill the lungs with air. Then, the patient pursed his lips as if he is about to blow out a candle and then exhale slowly through the mouth. Exhale twice as long as when he inhales then make a quiet hissing sound as he exhales [22].

- **Secretion clearance exercises**

1. Huffing (huff cough) technique: the patient inhale through his mouth, somewhat deeper than he would when taking a normal breath, and contract abdominal muscles to exhale the air out in three breaths while creating the sounds "ha, ha, ha. [23].
2. Percussion: the caregiver cupped hand arcs to the chest wall and tricks a cushion of air to soften the clapping, it was performed powerfully and with a steady beat. Each beat has a hollow sound. Most of the movement was wrist the wrist with the arm relaxed, making percussion less exhausting to the patient [24].
3. Vibration: The caregiver firm flattened hand was placed on the chest wall over the part of the lung being drained and the muscles of the arm and shoulder were tensed to generate a fine shaking motion. Then, light pressure was applied over the area being vibrated. The patient then blow air slowly and as complete as he can [24].

- **Lower limb exercises**

1. **Home-based walking exercise:** the patient performed self-monitor walking exercise activity three days / week, up to 30 minutes per session [25].
2. **Supervised lower extremity resistance training:** the patients attended three exercise resistance training sessions / week. The patient completed 3 sets of 8 repetitions of knee extension, leg press, leg curls, and squat and toe rise exercises, supervised by a trainer. Body weight squat, squat to oblique crunch, "leg flexion" (for the biceps femoris and gastrocnemius), and "leg extension" (for the quadriceps femoris). The patient achieved 4 series of 6-8 repetitions for each exercise included in strength-training program [25].

- **Arm strengthening exercise**

In each session the patient performed 10 minutes of general warm-up, 20 minutes of upper-limb circuit training, and 10 minutes of cool off. The strength exercises were done with the following procedures: "butterfly" (for the pectoralis major muscle) and "chest pull" (for the latissimus dorsi), The patients completed 4 series of 6-8 repetitions for each exercise included in the strength-training program [26].

Statistical analysis

The SPSS version 24 was used for data analysis. The Kolmogorov-Smirnov test was used to assess the distribution of the quantitative data. As the studied quantitative data were non-parametric it was expressed as median and interquartile range (IQR). Frequency and percentage were used to present qualitative data. The Wilcoxon signed-rank test (Z-score) was used for comparing the difference in quantitative variables at baseline and after PR. The delta changes (Δ %) of studied variables was calculated as [(Post PR value – Baseline value) / (Baseline value) X 100]. . The p-value < 0.05 was considered significant (95% confidence interval).

RESULTS

The characteristics of the studied COPD patients were presented in table (1).

Table (1): Characteristics of the studied COPD patients

Characteristics		COPD patients n= 60
Age (yrs.)	Mean ± SD	59.3 ± 5.6
	Range	49 – 71
BMI	Mean ± SD	26.5 ± 3.2
	Range	20.7 – 34.8
Gender	Males	56 (93.4%)
	Females	4 (6.6%)
COPD Severity	Moderate	29 (47.5%)
	Severe - very severe	31 (52.5%)
Pulmonary hypertension	PH	37 (62.3%)
	No PH	23 (37.7%)
Diaphragm function	Diaphragm dysfunction	20 (32.7%)
	Normal Diaphragm function	40 (67.2%)

Yrs.: Years, BMI: Body mass index, COPD: chronic obstructive pulmonary disease, PH: Pulmonary hypertension, SD: Standard deviations

Table (2): Effect of pulmonary rehabilitation on ventilatory function in patients with COPD

Spirometric indices	Baseline n= 60 Median (IQR)	After rehabilitation n= 60 Median (IQR)	Δ %	Stat. test	p-value
FEV_1/FVC ratio	63(54-66)	64(59-67)	4.5±4.5	Z=5.99	0.001*
FEV_1%	48(32-55)	53(36-61)	10.2±6	Z=6.64	0.001*
FVC%	74(62-87)	76(64-88)	2.1±3.1	Z=4.67	0.001*
FEF25-75%	48(44-54)	50(45-55)	3.8±3.9	Z=5.37	0.001*

IQR: Interquartile range, FEV_1%: Forced expiratory volume in first-second percent predicted, FVC%: Forced vital capacity percent predicted, FEF25-75%: Forced expiratory flow between 25 and 75% of vital capacity percent predicted, Δ%: Delta change percentage, Z: Wilcoxon signed-rank test, *: Significant p-value (<0.05).

Table (2) shows that there was significant improvement of all spirometric-indices in COPD patients after 12 weeks of PR compared to baseline value ($p < 0.05$). Table (3) shows that the O_2 sat% and PaO_2 mmHg were significantly increased, and $PaCO_2$ mmHg and pH were significantly decreased after PR compared to baseline value ($p < 0.05$).

Table (4) shows that the DTF %, and TDE were significantly increased after PR compared to baseline value ($p<0.05$). The diaphragm SWE, quadriceps SWE, and RVSP were significantly decreased after PR compared to baseline value ($p<0.05$).

Table (5) shows that the CAT score and mMRC scale were significantly decreased ($p <0.001$), and 6MWD, and pre and post 6MWT SpO_2 % were significantly increased ($p <0.001$) in COPD after PR compared to baseline value.

Table (3): Effect of pulmonary rehabilitation on arterial blood gases in patients with COPD

ABG parameters	Baseline n= 60 Median (IQR)	After rehabilitation n= 60 Median (IQR)	Δ %	Stat. test	p-value
SaO_2 %	94(93-95)	95(93-97)	1.5±1.3	Z=5.96	0.001*
PaO_2 mmHg	76(69-79)	79(72-83)	4.1±1.9	Z=6.71	0.001*
$PaCO_2$ mmHg	39(36-43)	38 (36-42)	-1.4±7.2	Z=2.73	0.006*
HCO_3	24 (23-25)	24 (23-25)	-0.3±3.1	Z=1.14	0.254
pH	7.41(7.39-7.44)	7.4(7.38-7.42)	-0.1±0.2	Z=3.05	0.002*

SaO_2: Oxygen saturation %, PaO_2: Arterial partial pressure of oxygen, $PaCO_2$: Arterial partial pressure of carbon dioxide, HCO_3: Bicarbonate, pH: Power of hydrogen, Δ%: Delta change percentage, Z: Wilcoxon signed-rank test, Significant p-value (< 0.05).

Table (4): Effect of pulmonary rehabilitation on diaphragm function, diaphragm and quadriceps elastography, and pulmonary artery pressure in patients with COPD

US parameters	Baseline n= 60 Median (IQR)	After rehabilitation n= 60 Median (IQR)	Δ %	Stat. test	p-value
DTF%	31 (23-39)	34 (25-43)	8.4±6.1	Z=6.34	0.003*
Tidal breathing DE (cm)	1.98 (1.7-2.4)	2.37 (1.9-2.8)	17.9±6.5	Z=6.74	0.001*
Diaphragm SWE velocity m\s	3 (2.4-3.9)	2.87 (2.0- 3.7)	-8.2±6.1	Z=6.63	0.001*
Quadriceps SWE velocity m\s	3.22 (2.5-4.2)	2.93 (2.2-3.9)	-8.9±7	Z=6.71	0.001*
RVSP mmHg	30 (20-43)	20 (20-40)	-8.6±26.6	Z=5.09	0.001*

DTF: Diaphragm thickness fraction, DE: diaphragm excursion, SWE: Shear wave elastography, RVSP: Right ventricular systolic pressure, Δ%: Delta change percentage, Z: Wilcoxon signed-rank test, Significant p-value (< 0.05).

Table (5): Effect of pulmonary rehabilitation on exercise tolerance in patients with COPD

Exercise tolerance parameters	Baseline n= 60 Median (IQR)	After rehabilitation n= 60 Median (IQR)	Δ %	Stat. test	p-value
CAT score	26 (24-29)	22 (20-28)	-11.7±7.7	Z=6.62	0.001*
mMRC score	2 (2-3)	2 (1-2.5)	-17.5±24.4	Z=4.64	0.001*
6 MWD (m)	210 (170-284)	221 (181-294)	5.9±4.8	Z=6.12	0.001*
Pre 6MWT SpO_2	93(92-95)	95(93-97)	1.6±1.2	Z=6.06	0.001*
Post 6MWT SpO_2	92(91-93)	93(92-95)	1.5±1.4	Z=5.67	0.001*

CAT: COPD assessment test, mMRC: Modified medical research council, 6 MWD: Six-minutes Walk distance, cm: Centimetre, Δ%: Delta change percentage, Z: Wilcoxon signed-rank test, Significant p-value (< 0.05).

DISCUSSION

One previous study proposed that the alterations of diaphragm functions in COPD are fundamentally due to the adaptive processes of a complex muscle adaptations to the changes of its mechanical environment rather than a form of dysfunction. If these diaphragmatic alterations are seeming in COPD patients, the diaphragm might respond to treatment, which would be an imperative goal [27]. Our outcomes support this theory as we found significant improvement of diaphragm contractility (DTF% and TDE) in COPD patients after PR. In COPD, hence air trapping decrease DE, therefore, decreasing air trapping with PR may lead to enhanced diaphragm movements. In the same context, the reduced air trapping after PR might cause the diaphragm to appear 'thicker' since the diaphragm returns into a better physiologic place [6]. Therefore, it is crucial to demonstrate that alterations of diaphragmatic function can be improved with PR at every stage of COPD. Similarly, Güneş et al. [6], and Crimi et al. [28] reported that the PR led to increase in diaphragm thickness in COPD patients irrespective of COPD severity. Corbellini et al. [29] reported that the PR improve diaphragmatic mobility and skeletal muscle function in COPD. Chun et al. [30] used fluoroscopy and showed augmented diaphragmatic mobility after PR.

In the same context, exercise training remains the single known intervention to inverse some of the underlying skeletal muscle alterations COPD patients [31]. Again, our study confirms this hypothesis as we found significant improvement of diaphragm and quadriceps elastography, both were decreased in COPD patients after PR. To the best of our knowledge, this is the first research assessing the influence of PR on diaphragm and quadriceps elastography in COPD patients.

The significant improvement of spirometric-indices after PR encountered in this study ($p<0.001$) indicate that the diaphragmatic breathing technique and puffing technique may improve respiratory muscle function with subsequent improvement of ventilatory functions. Moreover, inspiratory muscle training increases transpulmonary pressure, and increase inspiratory muscles volume and performance, thereby enhancing ventilatory functions. Additionally, exercise improves pulmonary function via respiratory muscles strengthening, increasing airway calibre and reducing airway resistance. Our result agreed with other previous studies that reported significant increase of FVC% and FEV_1%, after 2 weeks. [32] or 12 weeks [33] of PR compared to pre-PR values in stable COPD patients. Also, Greulich et al. [34] performed retrospective analysis of patients with very-severe COPD who underwent an in-house PR program and reported that the FEV_1 was increased by 99 ml above baseline. Dissimilarity, Mercken et al. [35] found no changes of pulmonary functions after a training program.

In the present study, the significant increase in SaO_2 %, PaO_2, with significant decrease in $PaCO_2$ and pH after PR (table 3) suggest that breathing exercises induce breathing pattern adaptations and increased duration of both inspiration and expiration with resulting increase in tidal volume leading to homogenous lung emptying, thus preserving the intrabronchial pressure and supporting both gas exchange and ventilation [36]. Same result was reported in several studies that reported increased PaO_2 [36] [37] [38], and decreased $PaCO_2$ and HCO_3 [36] [37] after PR than before PR. Moreover, another study conducted on COPD patients with respiratory failure and found that PaO_2 and SaO_2 increased significantly in normocapnic and hypercapnic patients after PR; the hypercapnic patients demonstrated more increase of SaO_2 and more decrease in $PaCO_2$ [~~37~~39].

The improvement (decrease) of CAT score and mMRC scale, and 6MWT parameters in our COPD patients after PR (table 5) may be attributed to an improvement of respiratory and skeletal muscle functions, improvement of airway function, breathing pattern adaptations, decrease in dynamic hyperinflation, decrease in the breathing effort, and decrease in oxygen demand associated with improvement of the oxygen consumption in peripheral muscles. Also, decreasing the frequency of hyperventilation can reduce the O_2 cost. Our results agreed with two previous studies that documented that the post-PR mMRC scale and CAT scores were significantly decreased than baseline values [4] [9]. Moreover, Vitacca et al. [40] study reported that the total CAT improved, with no significant difference between GOLD grade 4 and GOLD 1 to 3 combined. Shehata et al. [41] reported that significant decrease in mMRC score and increase in 6MWD in stable COPD patients after PR. Although the improvement in mMRC scale and 6MWT distance after PR did not reach an acceptable clinical value, we consider this improvement clinically significant, as the change in 6MWD is an indicator of the functional performance of the COPD patients.

The significant decrease of RVSP in COPD patients after PR found in the current study (table 4) may be related to an increase in PaO_2 and decrease in $PaCO_2$ with subsequent abolishment of hypoxic and / or hypercapnic pulmonary vasoconstriction. Also, exercise enhance pulmonary circulation, induce pulmonary vasodilatation, and increase adrenaline and cortisol secretion that led to pulmonary vasodilatation and decrease pulmonary vascular resistance with subsequent of reduction of pulmonary artery pressure [42]. However, one study stated that the mechanisms via which exercise training impacts pulmonary artery pressure are not entirely clear, and large clinical trials are needed to confirm its safety and efficacy [43]. Several studies reported significant decrease of pulmonary artery pressure after rehabilitation program in patient with pulmonary hypertension [44] [45] [46].

CONCLUSION

PR confers benefits to COPD patients that manifest in diverse ways as improvement of ventilatory functions, arterial blood gases, exercise capacity, and diaphragm functions, with decrease of diaphragm and quadriceps muscle stiffness and pulmonary artery pressure. Therefore, PR should be part of the standard care of COPD patient. PR clinics should be present in primary health care settings for COPD patients. Another study to compare impacts of different types of breathing exercise on functional status and quality of life of COPD patients is recommended.

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الملخص العربي

تأثير التأهيل الطبي الرئوي على مرضي ضيق الشعب الهوائية المزمن

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ملخص البحث

الخلفيه: مرض ضيق الشعب الهوائية المزمن له تأثيرات عامه كثيره على الجسم والتي تحدد مدي شده المرض والقدرة الحركية وتطور المرض نفسه. ان برنامج التأهيل الرئوي يساعد في تقليل الاعراض وتحسين القدرة العامة على الحركة.

الهدف: دراسة تأثير التأهيل الطبي الرئوي على القدرة الحركية والعضلات الطرفية والحجاب الحاجز في الحالات المستقرة لمرضي ضيق الشعب الهوائية المزمن.

الطرق: دراسة تداخليه مترقبه شملت ستون مريض ذو حاله مستقرة من مرض ضيق الشعب الهوائية المزمن حيث تم عمل وظائف التنفس وتحليل غازات الدم وسونار علي الحجاب الحاجز لقياس سمك وحركه الحجاب الحاجز والسونار الالاستوجرافي علي الحجاب الحاجز والعضلة الرباعية للفخذ وسونار علي القلب لقياس ارتفاع ضغط شريان الرئة وتم تقييم القدرة الحركية للمرضي عن طريق: مقياس التنفس لمرضي ضيق الشعب الهوائية المزمن و مقياس قصر النفس واختبار المشي لسته دقائق تم عمل كل هذه الاختبارات مره اوليه ثم تم اعادتها جميعا بعد اثني عشر أسبوعا من التأهيل الرئوي.

النتائج: تحسنت وظائف التنفس (النسبة ما بين السعه الحيوية القسرية \حجم الزفير القسري في الثانية الاولي ‘السعه الحيوية القسرية ‘حجم الزفير القسري في الثانية الاولي وتدفق الزفير القسري 25-75% بعد التأهيل الرئوي مقارنه بالقيم الأولية وأيضا تحسنت قيم غازات الدم مقارنه بالقيم الأولية حيث زاد تشبع الاكسجين وقلت قيمه حموضه الدم وثاني أكسيد الكربون. تحسنت قيمه سمك الحجاب الحاجز وأيضا حركته بعد التأهيل الرئوي مقارنه بالقيم الأولية. تحسنت قيم السونار الاستوجرافي للحجاب الحاجز وأيضا لعضله الفخذ مقارنه بالقيم الأولية بعد التأهيل الرئوي. تحسنت قيمه ضغط شريان الرئة وقيم تقييم القدرة الحركية في صوره مقياس التنفس واختبار المشي لسته دقائق وأيضا مقياس قصر النفس مقارنه بالقيم الأولية بعد التأهيل الرئوي.

الاستنتاجات: التأهيل الرئوي يساعد بطرق كثيره في تحسين وظائف التنفس وغازات الدم والقدرة الحركية ووظائف الحجاب الحاجز وقساوة الحجاب الحاجز وعضله الفخذ وأيضا ارتفاع ضغط شريان الرئة.

الكلمات المفتاحية: ضيق الشعب الهوائية المزمن، تمرين التنفس عن طريق الحجاب الحاجز، مقياس قصر النفس، تمرين التنفس عن طريق الصفير.

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