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Endurance and strength training in pulmonary rehabilitation for COPD patients

Rasha Daabis [a,*], Marwa Hassan [b], Mohamed Zidan [a]

[a] Dept. of Chest Diseases, Faculty of Medicine, Alexandria University, Alexandria, Egypt
[b] Dept. of Physical Medicine, Rheumatology and Rehabilitation, Faculty of Medicine, Alexandria University, Alexandria, Egypt

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KEYWORDS

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Abstract *Objectives:* This study aimed to evaluate whether strength training is a useful addition to aerobic training in an early pulmonary rehabilitation (PR) program implemented for patients with COPD. Also to assess the outcomes of this program on the patients' symptoms, spirometry, peripheral muscle strength, exercise capacity and health-related quality of life (HRQL).

Patients and methods: The study included 45 patients hospitalized with acute exacerbation of COPD. After receiving standard treatment for acute exacerbations, patients were randomly allocated to three groups. Besides medical treatment, the first two groups were assigned to an early PR program. Group1 performed endurance training (ET) alone, while group 2 performed combined training (CT) in the form of endurance plus strength training. The third group received medical treatment only. Baseline and outcome assessment included Medical Research Council dyspnea scale (mMRC), spirometry, peripheral muscle strength by measuring one repetition maximum (1RM), 6 min walk test and HRQL using St. George's Respiratory Questionnaire.

Results: Both training modalities resulted in significant improvements in the degree of dyspnea, the HRQL and the functional exercise capacity measured by 6MWT. The CT was associated with additional improvements in peripheral muscle strength without increasing the duration of the training sessions ($P < 0.01$).

Conclusion: PR is an effective intervention for the post-exacerbation management of COPD patients. It leads to significant improvements of dyspnea, HRQL and functional exercise capacity. When added to a program of ET, strength training confers additional benefits in muscle force, but not in overall exercise capacity or health status.

* Corresponding author at: Department of Chest Diseases, Faculty of Medicine, Alexandria University, Alazarita, Alkhartoom Square, Egypt.
E-mail addresses: rgdaabis@yahoo.com, rgdaabis@gmail.com (R. Daabis).

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Introduction

Dyspnea, impaired exercise tolerance and reduced quality of life are common complaints in patients with chronic obstructive pulmonary disease (COPD) [1]. However, these features are often impaired out of proportion to lung function impairment [2]. Hence, therapies that improve the patient's lung function may have a relatively limited impact on the above-mentioned outcomes [3]. Other factors, such as peripheral muscle weakness, deconditioning and impaired gas exchange, are now recognized as important contributors to reduced exercise tolerance [4,5].

The consequences of exercise intolerance appear important to COPD patients. Reduced exercise capacity and muscle weakness render these patients disabled with a high utilization of healthcare resources [6]. They refrain from their work due to their disease and become socially isolated. Poor exercise capacity has also been shown to contribute to mortality [7].

Optimal bronchodilatation can be seen as a first step in the treatment of patients with chronic obstructive pulmonary disease **(COPD);** however, greater treatment effects (e.g., improvements in exercise performance, symptoms, and health-related quality of life) are often achieved only after the addition of pulmonary rehabilitation [8].

Comprehensive pulmonary rehabilitation programs aim at tackling the systemic consequences of COPD, as well as the behavioral and educational deficiencies observed in many patients [9].

Guidelines on the management of COPD published by the National Institute for Clinical Excellence (NICE) and the British Thoracic Society recommend that pulmonary rehabilitation should be made available to all appropriate patients [10,11]. Moreover, the GOLD guidelines recommend offering pulmonary rehabilitation to COPD patients who have at least moderate severity of the disease [12].

Exercise training is now considered an essential component of pulmonary rehabilitation in patients with chronic obstructive pulmonary disease (COPD) [13,14]. Although it does not change pulmonary function, exercise training improves exercise capacity and reduces dyspnea. However, there is no consensus about the optimal training strategy and the mechanisms of improvement [15,16]. Whether the goal of training should be strength, endurance, or both is still under investigation.

Lower-extremity aerobic training consistently improves exercise tolerance in patients with chronic obstructive pulmonary disease (COPD), but has little effect on muscle atrophy and weakness, two problems common in patients with COPD and which can contribute to their poor exercise tolerance and quality of life [5,17]. Strength training can promote muscle growth and strengthening in normal subjects [18], and may therefore represent a useful addition to whole-body aerobic training in patients with COPD.

Moreover, most guidelines report extensively on the benefits of pulmonary rehabilitation in patients with stable lung disease. Much less is known about the effects of pulmonary rehabilitation immediately after or even during acute exacerbations [19].

Therefore, this study aimed to evaluate whether strength training is a useful addition to aerobic training in an early rehabilitation program implemented for patients with COPD. Another aim of the study was to assess the outcomes of this early rehabilitation program on the patients' symptoms, pulmonary functions, peripheral muscle strength, exercise capacity and health-related quality of life.

Patients and methods

The present study included 45 patients admitted to chest diseases department, Alexandria Main University Hospital with a primary diagnosis of acute exacerbation of COPD.

The diagnosis of COPD was made by a clinical course that is consistent with chronic bronchitis and/or emphysema, a long history of cigarette smoking, and pulmonary function test findings revealing irreversible airflow obstruction [12].

An exacerbation was diagnosed by a sustained worsening of the patient's respiratory symptoms, that is beyond day to day variations and leads to a change in medication [12]. The worsening of symptoms should be severe enough to warrant admission to the hospital.

Exclusion criteria:

(1) Hypoxemic patients at rest or exercise.
(2) Comorbidity that could limit exercise training like cardiovascular, musculoskeletal or neuromuscular diseases.
(3) Patients who attended a pulmonary rehabilitation program in the preceding year.

All subjects were enrolled in the study after a written informed consent according to a protocol approved by the Ethics Committee of the Hospital.

Protocol

All admitted patients received standard treatment, including nebulized bronchodilators, oral or intravenous antibiotics, non-invasive ventilation (if required), and a one week course of oral prednisolone (30–40 mg daily). Before being discharged on optimal medical treatment, patients were randomly allocated to three groups.

Besides medical treatment, the first two groups were assigned to an early pulmonary rehabilitation program (within 10 days of hospital discharge), which consisted of patients' assessment, exercise training, in addition to patients education in the form of self management of the disease, nutrition, and lifestyle issues. However, these two groups differed in their exercise training program, group one performed endurance training (ET) alone, while group two performed combined training (CT) in the form of endurance plus strength training (ST). Both exercise training programs lasted for 8 weeks, in the form of three sessions per week.

The third group (control group) received medical treatment only and was not enrolled in the rehabilitation program.

Patients' assessment

It included baseline assessment and outcome assessment at the end of the program in the form of:

- *Dyspnea assessment* by modified Medical Research Council dyspnea scale (mMRC dyspnea scale). It is a 5 point scale based on degrees of variable physical activities that precipitate dyspnea with a score ranging from 0 to 4 [20].

- *Pulmonary function tests:* All patients underwent standard spirometry before and after 15 min of bronchodilator inhalation according to American Thoracic Society/European Respiratory Society standards [21].
- *Peripheral muscle strength:* Peripheral muscle strength was assessed by the determination of the one repetition maximum (1-RM). The agreed convention for the 1-RM is the heaviest weight that can be lifted throughout the complete range of motion related to the exercise performed. The 1-RM was assessed for exercises carried on weight training equipment: knee extension machine with pelvic strap, and chest press. A warm up of 3–5 min followed by 10 repetitions with a light load was performed prior to the test to minimize the effect of learning. The 1-RM test was initiated near the suspected maximum to minimize repetition fatigue. All subjects attained the 1-RM within 3–5 attempts. Subjects were allowed to rest for 2–3 min between attempts [22].
- *Six-minute walking distance (6MWD):* A six-minute walking test (6MWT) was performed according to the standard procedure and was used as a measure of exercise capacity. Patients were asked to walk on a 20 m course over a 6 min period. Then the distances covered by the patients during this time interval in minutes were recorded [23].
- *Health-related quality of life (HRQL):* Health-related quality of life (HRQL) was measured using the validated St. George's Respiratory Questionnaire (SGRQ) for COPD patients (SGRQ-C). The results are reported as percent [24].

Exercise training programs

Exercise training programs lasted for 8 weeks, in the form of three sessions per week. The ET consisted of 30 minutes of treadmill training at an intensity of 75% of the results of the 6MWT and an additional 30-min of low-intensity resistance training with free weights. The number of repetitions used was based on physiologic endurance principles, including a high number of repetitions with a low load [25].

The CT consisted of 30 min of ST which consisted of exercises performed on weight training machines, for pectoralis major, deltoid, biceps brachii, triceps and quadriceps muscles. Patients were submitted to three sets of 12 repetitions with a 2-min rest between sets and with a workload at 50–80% of that achieved on the 1-RM test. The 1-RM test was repeated every 2 weeks to reestablish the workload.

The remaining 30 min were devoted to ET at half the volume (i.e., 15 min of walking at a self-determined intensity and an additional 15 min at half the number of repetitions of low-intensity resistance training with free weights). All exercise regimens were conducted in 60 min sessions, which included pacing for breathing [25].

Statistical analysis

Data were collected, tabulated, then analyzed using SPSS Ver.13. Qualitative data were presented as numbers and percentage. Quantitative data were expressed as means and standard deviation. Differences between the groups were analyzed using Student's unpaired *t*-test and $\chi 2$ tests where appropriate. 5% level was chosen as a level of significance in all statistical tests used in the study.

Results

Thirty patients concluded the training protocols with adequate adherence (ET = 15; CT = 15), having completed more than 85% of the scheduled sessions. 15 patients received medical treatment only.

General characteristics of the study population

Baseline characteristics of the 3 groups are presented in Table 1. No significant differences were found between groups in terms of age, BMI, airflow obstruction, or arterial blood gases. According to the GOLD Combined assessment, the patients were grouped as B, C or D. No patient presented evi-

Table 1 General characteristics of the study population randomly assigned to endurance training (ET), combined training (CT) or medical treatment only.

Characteristics	Endurance training (ET)	Combined training (CT)	Medical treatment
Age	61 ± 8	58 ± 7	60 ± 8
BMI (Kg/m^2)	24 ± 7	26 ± 5	27 ± 6
FEV_1%	53.2 ± 9.5	56.4 ± 8.3	54.6 ± 7.1
PaO_2	78 ± 6.6	77 ± 8.4	76 ± 9.5
$PaCO_2$	44 ± 3.3	43 ± 4.1	42 ± 5.7
Gold combined assessment n (%)			
B	2 (13)	3 (20)	1 (7)
C	6 (40)	6 (40)	6 (40)
D	7 (47)	6 (40)	8 (53)
mMRC	2.62 ± 0.76	2.58 ± 0.69	2.53 ± 0.89
Quadriceps strength (1RM, kg)	18.9 ± 5.6	17.9 ± 6.7	18.7 ± 7.2
Chest press (1RM, kg)	21.3 ± 4	22.1 ± 6.2	21.6 ± 3.3
6MWT, m	224.1 ± 108.6	215.1 ± 120.9	240.1 ± 96.4
SGRQ%	68.2 ± 18.6	64.45 ± 20.1	66.9 ± 17.6

Data are expressed as Mean ± SD unless otherwise specified.

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dence of arterial hypoxemia; defined as $PaO_2 < 55$ mmHg/$SpO_2 < 89\%$ at rest or exercise (Table 1).

At the end of the training period, none of the groups presented significant changes in lung function or BMI.

Effects of exercise training on the mMRC dyspnea scale and HRQL

Baseline mMRC dyspnea scale and HRQL did not differ significantly among groups. There was significant improvement in the mMRC dyspnea scale and the HRQL ($P < 0.001$ for both) in the 2 groups who underwent exercise training. However there was no significant improvement in both parameters in the third group who received the medical treatment only (Tables 2–4).

Effects of exercise training on exercise capacity

Baseline 6-min walked distance (6MWD) did not differ significantly among groups. There was a significant improvement in the exercise capacity as measured by the 6MWT ($P < 0.001$ for both) in the 2 groups who underwent exercise training. However there was no significant improvement in the third group who received the medical treatment only (Tables 2–4).

Table 2 FEV1, mMRC dyspnea scale, peripheral muscle strength, 6MWD and HRQOL before and after endurance training.

	Baseline	End of program	*P* value
FEV1%	53.2 ± 9.5	55.1 ± 12.3	NS
mMRC	2.62 ± 0.76	1.48 ± 0.81	< 0.001*
Quadriceps strength (1RM, kg)	18.9 ± 5.6	22 ± 3.6	NS
Chest press (1RM, kg)	21.3 ± 4	23.1 ± 3.2	NS
6MWT, m	224.1 ± 108.6	347 ± 89.3	< 0.001*
SGRQ%	68.2 ± 18.6	49.4 ± 17.7	< 0.001*

Data were expressed as Mean ± SD and compared using student *t*-test.
*: Statistically significant at $P \leqslant 0.05$.

Table 3 FEV1, mMRC dyspnea scale, peripheral muscle strength, 6MWD and HRQOL before and after combined training.

	Baseline	End of program	*P* value
FEV1%	56.4 ± 8.3	57.9 ± 11.7	NS
mMRC	2.58 ± 0.69	1.37 ± 1	$P < 0.001$*
Quadriceps strength (1RM, kg)	17.9 ± 6.7	24.1 ± 2.1	$P < 0.01$*
Chest press (1RM, kg)	22.1 ± 6.2	28.2 ± 3.7	$P = 0.016$*
6MWT, m	215.1 ± 120.9	348 ± 97.3	$P < 0.001$*
SGRQ%	64.45 ± 20.1	46.4 ± 17.7	$P < 0.001$*

Data were expressed as Mean ± SD and compared using student *t*-test.
*: Statistically significant at $P \leqslant 0.05$.

Table 4 FEV1, mMRC dyspnea scale, peripheral muscle strength, 6MWD and HRQOL before and after medical treatment.

	Baseline	End of program	*P* value
FEV1%	54.6 ± 7.1	56.3 ± 9.5	NS
mMRC	2.53 ± 0.89	2.38 ± 0.86	NS
Quadriceps strength (1RM, kg)	18.7 ± 7.2	19.2 ± 1.2	NS
Chest press (1RM, kg)	21.6 ± 3.3	21.8 ± 3.9	NS
6MWT, m	240.1 ± 96.4	249 ± 93.8	NS
SGRQ%	66.9 ± 17.6	63 ± 14.6	NS

Data were expressed as Mean ± SD and compared using student *t*-test.
*: Statistically significant at $P \leqslant 0.05$.

Effects of exercise training on peripheral muscle strength

Baseline peripheral muscle strength did not differ significantly among groups. Patients in the CT group presented a significant post-training improvement in the 1-RM values of the quadriceps muscle and the chest press muscles ($P < 0.01$ and $P = 0.016$ respectively), whereas no significant changes in 1-RM values were observed in the ET or medical treatment groups (Tables 2–4).

Comparison between the studied groups according to% change in mMRC, peripheral muscle strength, 6MWD, SGRQ% by the end of the program

The% change in the 1-RM values of the quadriceps muscle and the chest press muscles was significantly greater in the CT group than in the ET group ($P < 0.001$ for both muscle groups). In contrast, the magnitude of the changes in mMRC dyspnea scale, exercise capacity (6MWD) and quality of life were comparable for the two groups (Table 5).

Discussion

This study sought to evaluate whether strength training is a useful addition to aerobic training in patients with COPD. We found that the combination of aerobic and strength training was safe and well tolerated despite the severity of the underlying lung disease, and was associated with additional improvements in peripheral muscle strength without increasing the duration of the training sessions.

Table 5 Comparison between the studied groups according to % change in mMRC, peripheral muscle strength, 6MWD, SGRQ by the end of the program.

	ET	CT	*P*
% change mMRC	44	46	NS
% change Quadriceps strength (1RM, kg)	15	32	$P < 0.001$*
% change Chest press (1RM, kg)	8	23	$P < 0.001$*
% change 6MWT, m	35	42	NS
% change SGRQ%	20	23	NS

*: Statistically significant at $P \leqslant 0.05$.

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In contrast with previous studies [26,27] that showed increased peripheral muscle strength in COPD patients with endurance training alone we did not find a significant increase in muscle strength in the ET group. On the other hand, similar to our results, other studies [28,29], that compared the effect of strength training alone or combined with endurance training to isolated endurance training in patients with COPD did not observe any change in peripheral muscle strength after endurance training only. These discrepancies may be attributable to the differences in the modalities and the intensity of training employed.

The majority of established exercise programs are based on endurance training of the lower limbs with different exercise modalities, such as walking, treadmill, and stationary bicycle. Although exercise rehabilitation programs have systematically omitted activities of strength training primarily because of fear of an abrupt increase in heart rate and arterial pressure associated with isometric contractions in small muscle groups, recent studies [17,25,26] have shown that strength training is beneficial and well tolerated as well. Moreover, in patients with mild COPD, Clark and colleagues [30] identified reduced isokinetic muscle function in patients with COPD as compared to healthy subjects and showed that intervention with weight training was effective in countering this deficit.

In this study, the strength training program was successful in increasing strength in all muscles that underwent training. The results of the present study confirm that such patients retain the capacity for improved peripheral muscle function with an adequate training stimulus [26].

However, these changes did not translate into further improvement in exercise tolerance as measured in this study. It is possible that a longer duration of training would have produced a greater improvement in exercise capacity with the combination of strength and aerobic training than with aerobic training alone. Perhaps the changes in peripheral muscle function in our study and other studies [26,28] were not of sufficient magnitude to further improve exercise capacity. Another possible explanation for the dissociation between changes in muscle strength and exercise capacity is the relative task specificity of any training stimulus: the greatest improvement in muscle function is shown in tests that closely mimic the characteristics of the training movement [20]. An important implication of this observation is that the training movements should resemble activities that are relevant to the patient's daily activities. Further studies are needed to determine whether greater improvements in peripheral muscle function can be translated into a gain in exercise capacity by increasing the duration of the training sessions or by modifying the training movements to resemble activities relevant to the patients' daily living. [26].

Resistance exercise elicits a reduced cardiorespiratory response compared with endurance exercise. That is, resistance exercise demands a lower level of oxygen consumption and minute ventilation, and evokes less dyspnea. In the clinical setting, this makes resistance exercise an attractive and feasible option for individuals with advanced lung disease or comorbidities; as in patients with severe COPD, who may be unable to complete high-intensity endurance or interval training because of intolerable dyspnea. It may also be an option for training during disease exacerbations [31].

In accordance with the literature on pulmonary rehabilitation, both training modalities examined in the present study resulted in significant improvements in the degree of dyspnea measured by the mMRC score, the health-related quality of life measured by the SGRQ and the functional exercise capacity measured by 6MWT [27]. The benefit of PR in improving exercise capacity, breathlessness and QoL is level of evidence A as demonstrated by the recent ATS official statement on PR [31].

Moreover, this study showed that pulmonary rehabilitation administered shortly after an acute exacerbation of COPD was safe and well tolerated by the patients and was associated with a favorable outcome on breathlessness, exercise capacity and quality of life [32]. A recent meta-analysis summarized the currently available evidence and concluded that pulmonary rehabilitation established after exacerbations enhances health-related quality of life, improves exercise capacity and reduces the risk for re-admissions [33].

There are several possible explanations for this. First, exacerbations lead to significant reductions in muscle function [34] and physical activity [35]. This initial deterioration may render patients more likely to improve from PR. Pulmonary rehabilitation is a particularly potent intervention to revert physical inactivity [36] and it has been shown that patients who improve their physical activity levels have less chance of being readmitted [37]. Second, since those eligible patients had been hospitalized for a COPD exacerbation, there may be an existing deficiency in self-management or education among this group. This deficiency may be partially targeted with the rehabilitation intervention, and patient education may be of particular benefit to modify behavior in these patients [33].

Another advantage of early rehabilitation is that it may provide a window of opportunity for patient education because patients may be more willing to change their health behavior after an exacerbation. Also, continuity of care is possible if patients are immediately referred to PR [33].

In conclusion, pulmonary rehabilitation is an effective intervention for the post-exacerbation management of COPD patients. It leads to significant improvements of dyspnea, health-related quality of life and functional exercise capacity. When added to a program of endurance exercise, resistance training confers additional benefits in muscle force, but not in overall exercise capacity or health status.

Conflict of interest

I declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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