Original Article

Efficacy of pulmonary rehabilitation: exercise capacity, respiratory muscle strength and quality of life in patients with chronic obstructive pulmonary disease*

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Background: Pulmonary rehabilitation is widely recommended for the treatment of chronic obstructive pulmonary disease.

Objective: To evaluate the efficacy of pulmonary rehabilitation in improving exercise capacity, respiratory muscle strength and quality of life of chronic obstructive pulmonary disease patients.

Method: This was an open, non-randomized clinical trial involving 27 clinically stable ex-smokers with chronic obstructive pulmonary disease who were enrolled in a pulmonary rehabilitation program. All were evaluated before and after pulmonary rehabilitation.

Results: Mean age was 65 ± 5 years, mean body mass index was 25 ± 4 kg/m^2, mean forced expiratory volume in one second was 55 ± 25% of predicted, mean ratio between forced expiratory volume in one second and forced vital capacity was 50 ± 12%, and mean arterial oxygen tension was 70 ± 7 mmHg. Comparison of pre- and post-pulmonary rehabilitation values revealed improvement in the distance walked in the 6-minute walk test (513 ± 99 m vs. 570 ± 104 m), maximum upper limb load (2 ± 1 kg vs. 3 ± 1 kg) and maximal inspiratory pressure (-89 ± 23 cmH_2O vs. -102 ± 23 cmH_2O), as well as in the activity domain, impact domain and total score on the Saint George's Respiratory Questionnaire.

Conclusion: Pulmonary rehabilitation, when performed with care and with a focus on physical training, is efficacious in increasing not only the distance walked in the 6-minute walk test but maximum upper limb load, maximal inspiratory pressure and quality of life as well.

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Key words: Pulmonary rehabilitation. Chronic obstructive pulmonary disease. Quality of life. Respiratory muscles.

*Study carried out at the Hospital Universitário de Brasília (HUB) and at the Universidade Católica de Brasília (UCB).

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by chronic airflow limitation that is not fully reversible through the use of bronchodilators. The airflow limitation is frequently progressive and accompanied by an abnormal inflammatory response of the lungs to noxious gases or particles[1].

A diagnosis of COPD should be considered in patients who present cough, sputum production, dyspnea or a history of exposure to predisposing risk factors such as smoking, environmental pollution or occupational exposure to noxious gases or particles. The diagnosis can only be confirmed through spirometry[1].

Patients with COPD present altered pulmonary function[2,3], peripheral skeletal muscle dysfunction[4], and dyspnea[5]. These factors lead to exercise intolerance and progressive worsening of physical condition to the point of limiting daily life activities. This may cause social isolation, anxiety, depression and dependence[6]. In addition, these patients frequently experience changes in weight and body composition, factors which may also contribute to their physical limitation[2]. Physical incapacity, loss of productivity and worsening of quality of life become substantially exacerbated as COPD progresses[7].

There are several means of treatment designed to minimize or correct the dysfunctions caused by COPD and to limit its progression. Among these are the reduction of risk factors (such as smoking), pharmacological treatment, oxygen therapy, ventilation support and pulmonary rehabilitation (PR)[1,7], which is a multidisciplinary program of personalized care for patients with chronic pulmonary diseases, designed to optimize the physical performance, social functioning and autonomy of each patient[8].

Well-planned PR programs result in improved ability to perform daily life activities, greater exercise capacity, relief from respiratory symptoms, reduced anxiety, less depression and an overall better quality of life for patients with chronic pulmonary diseases[8,9]. It is well documented in the literature that PR promotes improvement in functional exercise capacity and quality of life, as well as reducing dyspnea[10], hospital admissions, length of hospital stays and frequency of exacerbations[11]. However, there are no studies in the Brazilian literature on the structure and effects of PR programs developed in the country.

In order to reap the benefits mentioned above, it is recommended that the PR, being a multidisciplinary program, include the participation of doctors, physical therapists, nurses, occupational therapists, psychologists and nutritionists[7,11]. These professionals must be involved in activities such as education, psychosocial and nutritional support of the patient, in addition to the physical training[1,7,11], which is essential to the PR program[12,13].

The objective of this study was to assess the efficacy of a well-planned PR program focused on exercise capacity, respiratory muscle strength and quality of life of patients with COPD.

METHODS

This study involved 27 patients diagnosed with COPD according to the criteria defined by the Global Initiative for Chronic Obstructive Lung Disease[1].

Patients with COPD who were ex-smokers, had stopped smoking at least six months prior and were clinically stable (no exacerbations) were included in the study. Exacerbations were defined as increased or altered respiratory secretion, cough, fatigue and greater dyspnea[1]. None of the patients presented any cardiovascular or orthopedic disease that might impair their performance of the PR protocol exercises, or any other comorbidity that would place them at risk during the exercises. At the moment of their inclusion in the PR program, all of the patients were using bronchodilators and oral theophylline, and none made continuous use of oxygen or were on corticosteroid therapy.

This study, classified as an open non-randomized clinical trial, was approved by the Ethics Committee of the *Hospital Universitário de Brasília* (Brasília University Hospital). All patients gave written informed consent.

The patients were submitted to a PR program consisting of assessment, medication, education and physical training, as described herein.

The evaluations were carried out before and immediately after six weeks of PR in the Pulmonary Function Laboratory of the Pulmonary Rehabilitation Clinic of the Brasília University

Hospital and in the Pulmonary Rehabilitation Center of the *Universidade Católica de Brasília* (Catholic University of Brasília).

This absolute values of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1) and FEV1/FVC ratio were measured (Vmax series 22 spirometer; Sensor Medics, Yorba Linda, CA, USA), and the relative values predicted for gender, age and height were calculated based on the values described by Knudson et al.[14]. Spirometry was carried out according to the norms established by the American Thoracic Society[15]. The classification of airflow obstruction was classified in accordance with the Global Initiative for Chronic Obstructive Lung Disease system of classification[1]. When the patient presented an FEV_1/FVC ratio < 70%, COPD was classified as: mild (when FEV_1 was e" 80% of predicted); moderate IIA (when 50% d" FEV_1 was < 80% of predicted); moderate IIB (when 30% d" FEV_1 was < 50% of predicted); or severe (when FEV_1 was < 30% of predicted).

Values were determined for mean arterial oxygen tension (PaO_2), as well as arterial carbon dioxide tension ($PaCO_2$) and arterial oxygen saturation (SaO_2) (Ciba Corning 278 Gas System, Ciba Corning, Diagnostics Corp., Medfield, MA, USA).

Body mass index (BMI) was evaluated, calculated using the formula weight/height^2 (kg/m^2), which is a tool for determining nutritional status based on the World Health Organization classification system[16]: underweight (BMI < 18.5), normal weight (BMI 18.5-24.9), overweight (BMI 25-29.9), class I obesity (BMI 30-34.9), class II obesity (BMI 35-39.9) or class III obesity (BMI e" 40).

A translated version of the Saint George's Respiratory Questionnaire (SGRQ), created by Jones et al.[17] and specific for chronic pulmonary diseases, was applied. The questionnaire was translated and validated for COPD patients in Brazil by Souza et al.[18].

A GeRar® pressure manometer was used to measure maximal respiratory pressures. In order to determine maximal inspiratory pressure (MIP), the patient was asked to inhale through the mouthpiece, beginning at residual volume and inhaling as deeply as possible. To determine maximal expiratory pressure (MEP), the patient was asked to exhale, beginning at total lung capacity and continuing until no longer possible. To rule out mouth pressure interference, a 1-mm diameter perforation was made in the mouthpiece that was connected to the equipment[19]. Five inspiratory and five expiratory maneuvers were performed, and the peak pressure values were registered. The highest MIP and MEP values, expressed in cmH_2O, were then registered.

The Borg scale[20] was used to evaluate dyspnea at the beginning and end of the upper limbs incremental test and of the 6-minute walk test (6MWT), as well as during all physical training sessions.

The 6MWT was used to determine the functional exercise capacity of each patient. This test consisted of determining the maximum distance walked by the patient during six minutes, expressed in meters. At the beginning and end of the walk test, arterial oxygen saturation by pulse oximetry was determined using a model 920M pulse oximeter (Healthdyne technologies, Marietta, GA, USA), and dyspnea was quantified using the Borg scale.

Because its objective was to select the appropriate intensity of the aerobic training[7], the stress test was carried out only prior to initiation of the PR. It was performed on a treadmill, following the Harbor incremental protocol[21]. This protocol consists of programming the treadmill to a comfortable speed for the patient and increasing the inclination by 1% per minute until reaching the limit for the patient.

The incremental test for upper limbs was carried out in order to determine exercise capacity and the initial load for the upper limb training. This test consisted of weightlifting with a shoulder flexion of up to 90° with the dominant limb for two minutes alternated with a two-minute rest. The initial load of 0.5 kg was progressively increased by 0.5 kg every two minutes, up to the tolerance limit of the patient, defined as either when the patient was incapable of performing the movement in a coordinated way or when it was physically impossible for the patient to complete the sequence initiated within the allotted time[22]. The maximum load was determined by the last complete sequence. The parameters measured before, during and after the test, oxygen saturation was measured and dyspnea (Borg) scale score was determined.

At the time of patient admission into the PR program, it was ensured that all were adequately medicated and, when necessary, the program pulmonologist instituted or altered the treatment regime.

During the PR program, in accordance with patient requests, lectures and orientations were given on several subjects, such as COPD, medication, oxygen therapy and PR, as well as on relaxation and conservation of energy techniques.

The physical training lasted six weeks and consisted of three sessions a week, always in the morning. Each session included warm-up, upper-body strength training, aerobic conditioning and cool-down. The warm-up consisted of upper-body calisthenics interspersed with lower-body calisthenics, both involving a variety of muscular groups. The upper-body strength training was carried out initially with 50% of maximum load reached in the incremental upper limbs test, increased by 0.5 kg/wk until reaching the tolerance limit of the patient. The strength training was performed using elbow flexion, shoulder flexion and shoulder abduction. Two two-minute series, two minutes apart, were conducted. The aerobic conditioning was performed on an ergocycle. Sessions were 20-minutes in length in the first week of training, increasing to 25 minutes in the second week and 30 minutes from the third week forward. The intensity of the exercise was based on 80% of the maximum cardiac frequency obtained in the stress test[7], which corresponds to intense activity. The cool-down consisted of stretching the neck muscles, the scapular girdle and the upper and lower limbs. Each stretching position was performed three times held for 20 seconds on each repetition. During the sessions, dyspnea, arterial pressure, cardiac frequency and oxygen saturation were monitored.

With regard to statistical analysis, the variables studied are presented as mean ± standard deviation. The Kolmogorov-Smirnov test was used to characterize the distribution of data. Since the data presented parametric distribution, the Student's *t*-test was applied for paired samples to compare the numeric and objective variables measured before and after the PR program, and the Wilcoxon test was used to compare the subjective variables measured before and after the PR program. Alterations presenting $p < 0.05$ were considered significant.

RESULTS

Of the 27 patients studied, five were female. Mean patient age was 63 ± 5 (range, 54 to 72), and mean cigarette consumption was 54 ± 25 pack-years (range, 12 to 108 pack-years). Based on BMI, 2 (7%) of the patients were thin, 8 (30%) were eutrophic, 16 (59%) were overweight, and 1 (4%) presented class I obesity. Among the 27 patients studied, the obstruction observed was severe in 7 (26%), moderate class IIA in 10 (37%), moderate class IIB in 5 (19%) and mild in 5 (19%).

Table 1 shows the variables measured in the 27 patients studied, before and after PR. There were no statistically significant differences between pre-PR and post-PR BMI, spirometric variables, blood gas analysis or dyspnea. However, there was significant improvement in the 6MWT results (pre-PR = 513 ± 99 m vs. post-PR = 570 ± 104 m), the maximum load achieved in the incremental test of the upper limbs (pre-PR = 1.9 ± 1.0 kg vs. post-PR = 2.6 ± 1 kg) and the MIP (pre-PR = -89 ± 23 cmH_2O vs. post-PR = -102 ± 23 cmH_2O). In addition, after the six weeks of PR, there was a statistically significant decrease in the SGRQ scores: activities (pre-PR = 55 ± 21% vs. post-PR = 52 ± 19%), impact (pre-PR = 38 ± 16% vs. post-PR = 29 ± 14%) and total score (pre-PR = 46 ± 15% vs. post-PR = 38 ± 15%) ($p < 0.05$).

DISCUSSION

Despite the growing numbers and descriptions of PR programs, there is no definite standard regarding their structure. The duration of PR programs varies considerably. Various studies have described programs lasting six weeks[10], eight weeks[23], nine weeks[24], ten weeks[25], twelve weeks[26] and twenty-six weeks[14].

The location at which the program is conducted also varies. It is possible to execute a PR in the home of the patient[25], at the hospital[27] or at the outpatient clinic[10]. The advantages of outpatient PR are the low cost to the patient and the greater accessibility. In addition, the multidisciplinary team and the necessary resources are not at the disposal of the patient when the PR is conducted in the home[8]. In the present study, a six-week outpatient PR, identical to that used by Torres et al.[10], was adopted.

TABLE 1

Pre- and post-pulmonary rehabilitation BMI, spirometry, blood gas analysis, exercise capacity, dyspnea, respiratory pressures and quality of life of the 27 patients studied

	Pré-RP	Pós-RP
BMI (kg/m2)	25 ± 4	25 ± 4
FVC (% of predicted)	85 ± 27	87 ± 22
FEV1 (% of predicted)	55 ± 25	55 ± 22
FEV1/FVC (%)	50 ± 12	50 ± 12
PaCO2 (mmHg)	35 ± 5	35 ± 5
PaO_2 (mmHg)	70 ± 7	71 ± 9
SaO_2 (%)	94 ± 2	94 ± 2
Maximum load for upper limbs (kg)	1,9 ± 1,0	2,6 ± 1,0*
Distance walked in the six-minute walk test (m)	513 ± 99	570 ± 104*
Dyspnea after the six-minute walk test	4 ± 2	3 ± 2
Maximal inspiratory pressure (cmH2O)	-89 ± 23	-102 ± 23*
Maximal expiratory pressure (cmH2O)	95 ± 31	99 ± 24
SGRQ – symptoms domain (%)	46 ± 20	38 ± 20
SG – atividades (%)	55 ± 21	52 ± 19*
SGRQ – activities domain (%)	38 ± 16	29 ± 14*
SGRQ – impact domain (%)	46 ± 15	38 ± 15*

*$p < 0.05$

PR: pulmonary rehabilitation; FVC: forced vital capacity; FEV1: forced expiratory volume in one second; PaCO2: arterial carbon dioxide tension; PaO2: arterial oxygen tension; SaO2: arterial oxygen saturation; SGRQ: Saint George's Respiratory Questionnaire

We demonstrated that PR was effective because it promoted increased distance walked in the 6MWT, maximum upper-limb load, MIP and quality of life as measured by the SGRQ ($p < 0.05$).

Peruzza et al.[28] demonstrated that the distance walked in the 6MWT was shorter in patients with COPD than in healthy individuals. According to Redelmeier et al.[29], a 54-m increase in the distance walked is clinically significant. Our study showed a 57-m increase in the distance walked after PR, a value identical to that presented by Neder et al.[30] after eight weeks of aerobic training. Torres et al.[10] reported a 58-m increase after six to eight weeks of PR. Young et al.[31] found an increase of 65 m after 4 weeks of PR.

Dyspnea assessed at the end of the 6MWT was unchanged after six weeks of PR. This result is contrary to that demonstrated by Goldstein and Lacasse et al.[12], who stated that dyspnea decreases after PR. This fact may be interpreted as maintenance of the same level of dyspnea after a significantly higher effort (longer distance walked). This indicates clinical reduction of dyspnea, even though no statistical difference occurred.

Increased maximum upper-limb load after PR has also been widely reported in the literature[22,32]. Although the exercise capacity of the upper limbs can be measured by an arm ergometer, it is also possible to use the repetitive movement test[32] and the maximum load test for upper limbs[22]. It has been shown that upper-body training is specific for strength and endurance[32].

Another system of measurement that has shown the efficacy of PR is pressure manometry. The increased MIP observed resulted from the general conditioning of the patient, since there was no training of the respiratory muscles and no change in BMI after PR. The same effect was shown in the study conducted by Neder et al.[30] Mean pre-PR MIP values were -89 ± 23 cmH_2O, very similar to the ones presented by Neder et al.[30], which were -86 ± 21 cmH_2O and apparently higher than the -60 ± 19 cmH_2O presented by Sturdy et al.[33] Although the respiratory pressure values obtained

in the present study were not compared with the reference values for healthy individuals[34], it is worth mentioning that Wijkstra et al.[35] observed lower MIP in COPD patients than in healthy individuals.

In the present study, SGRQ scores related to quality of life were all higher, with the exception for the symptoms. Finnerty et al.[36] observed that, after six weeks of PR, there was an increase in scores for the activity, impact and symptoms domains of the SGRQ, although total scores were unchanged. In contrast, Garuti et al.[37] observed a post-PR increase in the total SGRQ score only. We are unaware of any studies using the translated version of this questionnaire to assess the effect of PR on the quality of life of COPD patients in Brazil.

However, despite the improvement in functional parameters seen in the present study, maximum physical capacity was not assessed, thereby precluding the observation of possible physiological alterations, such as increased oxygen consumption, decreased minute volume and improved oxidative capacity of cells. These parameters are widely referred to in the literature[30] and should be studied. In addition, the present study had no control group, a fact which makes the results difficult to interpret.

The findings of this study lead us to the conclusion that PR can break the vicious cycle of COPD, improving the quality of life and the functional exercise capacity of the patients.

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