

Research Article

The effects of adding a six-month Pilates exercise program to three months of traditional community-based pulmonary rehabilitation in individuals with COPD: a prospective cohort study

Marisela Barbosa^{1,2a}, Cristina A. de Melo³, Rui Torres^{4,5}

¹ Physiotherapy, Centro Hospitalar do Baixo Vouga Aveiro - Unidade Local de Saúde da Região de Aveiro, Aveiro, Portugal, ² Physiotherapy, Escola Superior de Saúde Norte da Cruz Vermelha Portuguesa, Oliveira de Azeméis, Portugal, ³ Physiotherapy, School of Allied Health Technologies, Polytechnic Institute of Porto, Porto, Portugal (retired), ⁴ Physiotherapy, CESPU, North Polytechnic Institute of Health, Paredes, Portugal, ⁵ Physiotherapy, CIR, Center for Rehabilitation Research, Polytechnic Institute of Porto, Porto, Portugal

Keywords: COPD, Chronic Obstructive Pulmonary Disease, Dyspnea, Pulmonary rehabilitation, Respiratory rehabilitation, Pilates

<https://doi.org/10.29390/001c.117966>

Canadian Journal of Respiratory Therapy

Vol. 60, 2024

Abstract

Introduction

Pilates exercise may complement traditional pulmonary rehabilitation in individuals with chronic obstructive pulmonary disease (COPD). The objective was to analyze the effects of adding a six-month Pilates exercise program to a three-month pulmonary rehabilitation for individuals with COPD.

Methods

Thirty-five participants with COPD (GOLD B) were assigned to the intervention (n=14) or control (n=21) group. Both groups received an initial three months of a pulmonary rehabilitation program. The intervention group further underwent six months of pilates. Participants were evaluated at baseline and at three, six, and nine months. Lung function and strength of respiratory muscles were defined as primary outcomes. Secondary outcomes included cardiac, physical function, and exacerbation episodes.

Results

There were no consistent statistically significant differences between groups for the lung function outcomes ($p < 0.05$). Maximal inspiratory and expiratory pressure increased significantly at three months in both groups ($p < 0.05$). It was significantly superior in the intervention group at nine months for maximal inspiratory pressure ($p = 0.005$) and six and nine months for maximal expiratory pressure ($p = 0.027$ and $p < 0.001$, respectively). Changes in muscle strength (knee extension and handgrip) were comparable between groups ($p > 0.05$), but exercise-induced fatigue and balance were significantly superior in the intervention group at the six- and nine-month follow-ups ($p < 0.05$).

Discussion

Pilates exercise programs may be implemented to augment traditional pulmonary rehabilitation with the goal of improving the strength of respiratory muscles.

Conclusion

Adding a Pilates exercise program to pulmonary rehabilitation resulted in superior strength of respiratory muscles, higher resistance to exercise-induced fatigue, and improved balance.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a multifactorial and progressive chronic respiratory noncommunicable disease. The worldwide prevalence of COPD is approximately 9% in men and 6% in women,¹ and it is the leading cause of mortality due to chronic respiratory diseases.² Individuals with COPD are often affected by one or more comorbidities,³ increasing their risk of disability, impaired quality of life, and mortality.⁴

The natural course of COPD is marked by acute episodes of exacerbation of respiratory symptoms. Dyspnea and productive coughing with production of sputum are common respiratory symptoms in individuals with COPD. These symptoms result from a chronic airflow limitation caused by airway and/or alveolar abnormalities associated with particles or harmful gases, creating an increased inflammatory response of the lung and recurrent chest infection.⁵ Recurrent exacerbations are common in patients with COPD due to the decline of lung function and are the most common cause of medical hospital re-admission,⁶ which results in high socioeconomic burden.⁷ These health and societal implications highlight the need for cost-effective intervention and secondary prevention strategies to reduce the risk of developing or exacerbating the symptoms of COPD. Therefore, patients with acute exacerbations of COPD should be followed with pulmonary rehabilitation after hospital discharge to decrease the risk of rehospitalizations⁸ and significantly reduce the associated costs.⁹ A myriad of exercise-based programs - including aerobic exercise, resistance exercise, water-based exercise, Yoga and Tai Chi - have shown to be effective in patients with COPD to enhance exercise capacity and function, reduce COPD-related symptoms and impairments, while also improving their health-related quality of life.¹⁰⁻¹⁵ The engagement in physical activity and exercise-based interventions has proven to be a cost-effective strategy with relevant gains in quality-adjusted life years (QALYs).^{16,17} Therefore, it is clear that medication and traditional breathing exercises should always be complemented with exercise-based interventions in patients with COPD.

Due to obstructive airflow impairments that increase airway resistance, patients with COPD have difficulty generating the necessary negative pressure to draw air into the lungs. Consequently, there is an increased workload of the diaphragm that can result in fatigue and reduced efficiency in breathing.¹⁸⁻²¹ Patients with COPD have a rapid and shallow breathing pattern characterized by dynamic hyperinflation and air trapping,²² with breath-to-breath fluctuations.²³ This breathing pattern places extra effort on the accessory respiratory muscles due to the inefficiency of the diaphragm and the intercostal muscles in providing adequate ventilation.²⁴ This mechanism can lead to weakness and fatigue of respiratory muscles that often result in dyspnea that is a hallmark symptom of patients with COPD.

Pulmonary rehabilitation programs implement exercises that promote diaphragmatic breathing aiming to improve thoracic mobility, enhance diaphragm and abdominal movement, and thus decrease the effort placed at the res-

piratory muscles of the ribcage.²⁵ A Pilates exercise program training can help to complement these traditional pulmonary rehabilitation programs, as it provides a more controlled setting of deep breathing exercises, which differ from diaphragmatic breathing exercises commonly seen in pulmonary rehabilitation. Within each set of deep breathing exercises, the individual keeps the abdomen pulled in as they actively contract the transverse abdominal and pelvic floor muscles.²⁶

There are several mechanisms of a Pilates exercise program that can contribute to clinically relevant improvement in individuals with COPD. Pilates can improve the strength of expiratory muscles by increasing the strength and flexibility of the core and lumbopelvic muscles,^{27,28} improved flexibility and enhanced movement patterns in the ribcage²⁹ and upper and lower limbs,^{27,28} which are of utmost importance in patients with COPD.^{27,30} The controlled concentric and eccentric breathing techniques employed during Pilates training can boost lung capacity and improve the functionality of the deeper abdominal muscles (transversus abdominis, lumbar multifidus, and the respiratory and pelvic diaphragms).³¹ The respiratory and breathing techniques employed during the Pilates exercise program can thus contribute to the improvement of strength of respiratory muscles. By improving the strength of respiratory muscles, a Pilates exercise program can prevent wasting respiratory muscles, improve respiratory function, and increase resistance to fatigue of respiratory muscles, thus contributing to decrease common COPD-related symptoms, most notably chronic dyspnea.

Pilates exercise programs have been gaining popularity and have shown positive effects in a wide range of clinical conditions³²; however, there is insufficient evidence of the potential positive effects in individuals with COPD.²⁶ Hence, our main goal was to compare the benefits home-based pulmonary rehabilitation with or without a Pilates exercise program after an initial three months of traditional community-based pulmonary rehabilitation in individuals with COPD. Lung function and strength of respiratory muscles were defined as primary outcomes, while cardiac, physical function, and the number of exacerbation episodes were defined as secondary outcomes. We hypothesized that the group with the Pilates exercise program would significantly improve lung function and strength of respiratory muscles as compared to the control group with home-based exercises.

METHODS

The study was approved by the Institutional Ethical Committee (IRB number: ERS NORTE, study ID T667, No.37/2017). All participants signed an informed consent form before enrolling in this study, and all procedures were conducted according to the Declaration of Helsinki.

DESIGN AND STUDY POPULATION

This study was a non-randomized clinical trial, in which the participants were assigned to the groups by the researchers.

From July 2018 to May 2021, a general practitioner working in the National Health Service (in the north of Portugal) invited adult individuals (≥ 18 years old) with COPD to participate in the current study. Participants of both sexes with COPD and presenting stable symptoms for the last month were eligible for this study. The recruited participants were evaluated according to the updated Global Initiative for Chronic Obstructive Lung Disease (GOLD) system criteria,³³ and only those classified as GOLD B were included in this study. The goal in using this criterion was to homogenize the symptoms of COPD of the included participants.

The exclusion criteria were: (i) over 85 years old; (ii) history of acute cardiac or respiratory events in the last month; (iii) any medical condition that would limit their exercise tolerance (severe cardiac, musculoskeletal, neuromuscular conditions, or recent surgery); (iv) psychiatric conditions or cognitive deficits; (v) history of neoplasia or immunologic diseases; or (vi) unwillingness to attend the community-based exercise program.

SAMPLE SIZE

An *a priori* sample size calculation was conducted using the Software G*Power (Version 3.1.9.2, Kiel, Germany) based on the results of a previous randomized controlled trial,³⁴ using the forced expiratory volume in one second (FEV_1) to forced vital capacity (FVC) ratio (FEV_1/FVC) as the reference outcome after six months of pulmonary rehabilitation.

For the sample size calculation, a power (α) of 95% was considered to detect statistically significant differences ($p < 0.05$) using a two-tailed independent Mann-Whitney test.

A total of 20 participants (10 per group) were needed to find statistically significant power; however, considering that dropout rates in pulmonary rehabilitation interventions are usually under 30%,³⁵ a total of 14 participants were assigned to each group.

PROCEDURES

Participants were divided into control and intervention groups in a non-randomized way. Enrollment of participants was made consecutively within the same community and no purposeful procedures were done for between-group sample matching. We employed a consecutive participant enrollment (within the same group) to allow a temporal matching of participants (schedule-wise) to form groups of community-based classes. All participants (of both groups) followed the same traditional community-based pulmonary rehabilitation program for the first three months of the study. Following this initial intervention, both groups were instructed to perform a set of recommended home-based exercises for the remaining six months of the study (from the 3rd to the 9th month). While the control group was restricted to the home-based exercises, the intervention group also performed a Pilates exercise program in addition to the home-based exercises.

Both groups were evaluated at baseline and at the end of the traditional community-based pulmonary rehabilitation

(three months). Subsequently, both groups were reevaluated at the sixth and ninth month from baseline.

INTERVENTION

TRADITIONAL COMMUNITY-BASED PULMONARY REHABILITATION

An initial community-based pulmonary rehabilitation intervention was equally implemented in both groups twice a week (60 minutes each) for the first three months. Intervention classes (from 4 to 12 participants per class) were provided by the same trained physiotherapist within the community context.

The traditional pulmonary rehabilitation program was composed of a warm-up, aerobic exercise, resistance strengthening, and cooldown.

The warm-up, which lasted ten minutes, consisted of joint mobility and light stretching exercises of the spine, upper, and lower limbs and was combined with breathing exercises.

The aerobic exercise consisted of walking for 20 minutes at an effort of 4–6 on the perceived dyspnea/fatigue on the modified Borg scale.³⁶ Participants started with a walking speed that was perceived as 5 on the modified Borg scale. They were then asked every five minutes about their perceived dyspnea/fatigue, and if it were above 6, the walking speed was decreased until reaching 5 on the modified Borg scale.

Resistance exercises lasted 20 minutes and included the major upper muscle groups (biceps, triceps, deltoid, pectoral major and latissimus dorsi), major lower limb muscle groups (knee flexors and extensors and hip abductors and adductors), the flexor and extensor trunk, and lower back muscles. The exercises for each muscle group changed every three weeks during the three months of the exercise program. Strengthening exercises (2 sets of 10 to 12 repetitions) were performed by the participants using free weights and ankle weights. A load that evokes fatigue after 10 to 12 repetitions was appropriated. The exercise dosage was increased over time (the so-called overload) to facilitate improvements in muscular strength and endurance. This increase occurred when an individual performed the current workload for 1 or 2 repetitions over the desired number of 12, on two consecutive training sessions.³⁶

The ten-minute cooldown included balance training comprising static and dynamic exercises in an upright position in addition to the same exercises used in the warm-up.

At the beginning of the study (baseline), participants in both groups were encouraged to do a set of recommended home-based exercises in order to complement the in-person classes (see Supplement 1). Following the initial three months, both groups were instructed to keep the same home-based exercises twice a week for another six months. Participants were required to keep a home-based exercise diary during the entire duration of the study. At the end of each week, they were contacted to determine if they had performed the recommended home-based exercises. If compliance was under 80% (controlled at each three months), the participant was excluded from the follow-up.



Figure 1. Summary of exercises included in the first three months of the exercise program based on Pilates principles. The first five initial exercises were: (A) Imprinting; (B) One leg stretch; (C) Shoulder bridge; (D) Clam; (E) Saw. The four progression exercises included: (F) Mermaid; (G) Spine stretch forward; (H) Bird dog; (I) Cat stretch.

EXERCISE PROGRAM BASED ON PILATES PRINCIPLES

The intervention group received a Pilates exercise program for six months after the initial 3-months of traditional pulmonary rehabilitation. The Pilates exercise program was led and supervised by the same physiotherapist and implemented twice a week for 45 minutes per session. The Pilates exercise program was divided into two stages: one first stage (4th to 6th months) with a set of more simple and less challenging exercises to accommodate the participants to this type of exercise and a second stage (7th to 9th months) with a new set of more challenging exercises to allow progression while increasing the difficulty of exercises.

The first Pilates session (beginning of the 4th month) started with five basic and less physically demanding exercises (see [Figure 1A-E](#)). Each of the five exercises required two sets of ten repetitions. When performing unilateral exercises, the exercise was completed eight times for each side. The rest between exercises was 60 seconds. Exercises were first demonstrated by the physiotherapist and then repeated by participants. The importance of steady and controlled breathing cycles (inhalation and exhalation) during the pilates exercises were highlighted and shown by the physiotherapist.

Progression in the difficulty of exercises was made at the participant level and occurred when the participant demonstrated that one of the five previous exercises was not sufficiently challenging (below 4 points in the modified Borg scale, asked during the rest time between exercises) and shown that the exercise was done with the proper technique and without compensatory movements. For progression, there were four additional and more challenging exercises (see [Figure 1F-I](#)). However, if the participant was

unable to perform the new exercise, the exercise was regressed to the previous, more basic one. In the following week, the technique with the new exercise was retested. After the first three months of the Pilates exercise program, the set of exercises changed to allow variability and provide more challenging exercises. Five new and more challenging exercises (see [Figure 2A-E](#)) were added with four additional exercises for progression (see [Figure 2F-I](#)). At this second stage, each exercise was completed for 2 sets of 12 repetitions. The same progression and regression rules were applied for this new set of exercises. However, if any participant could not tolerate the difficulty of any of the new exercises, they regressed to the exercises of the set of the first three months of the Pilates exercise program, and then progressed as tolerated. The full exercise Pilates protocol is described in Supplement 2.

OUTCOME MEASURES

At baseline, we collected the sociodemographic and biometric data of all participants. Lung function and strength of respiratory muscles were defined as primary outcomes while cardiac, physical function, and the number of exacerbation episodes were defined as secondary outcomes.

LUNG FUNCTION

Lung function was evaluated by spirometry (MicroLoop® and MicroLab®, Care Fusion, Basingstoke, UK): FVC, FEV₁, and FEV₁/FCV ratio. The MicroLoop® spirometer has been proven to be accurate and precise to measure lung function in the population with COPD.³⁷ The respiratory rate (cycles per minute [CPM]) and oxygen saturation (% of SpO₂) were

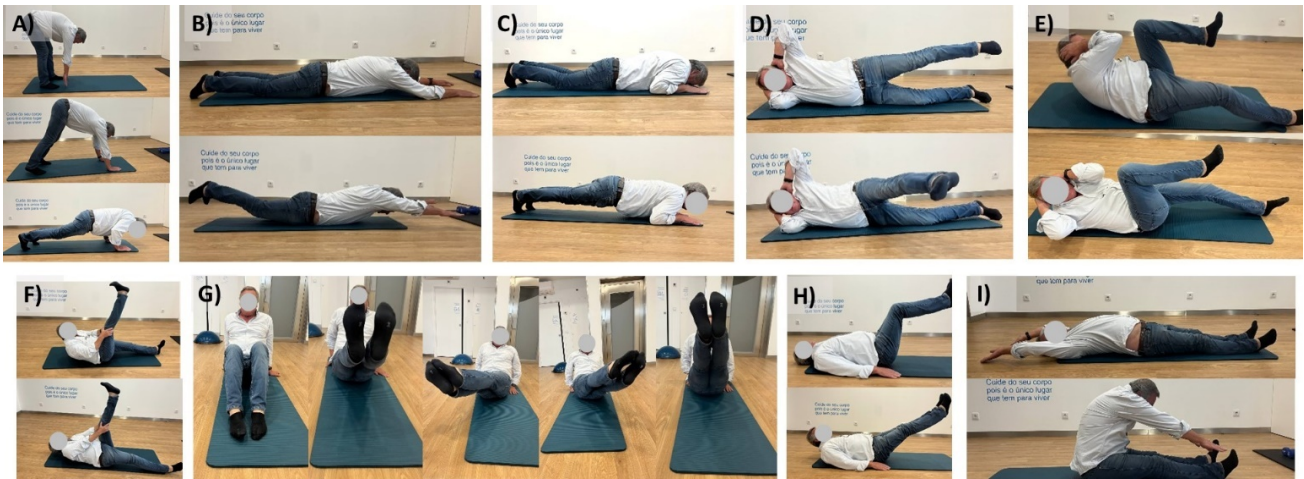


Figure 2. Summary of exercises included in the second 3 months of exercise program based on Pilates principles. The first five initial exercises were: (A) Push up; (B) Swimming; (C) Leg pull prone; (D) Side kick; (E) Criss cross. The four progression exercises included: (F) Scissors; (G) Hip twist; (H) Hundred; (I) Roll up.

also collected. Each metric was repeated five times and the highest value was used.

STRENGTH OF RESPIRATORY MUSCLES

The strength of inspiratory muscles was measured by a digital mouth respiratory pressure meter (MicroRPM®, Care Fusion, Basingstoke, UK) to determine the maximal inspiratory and expiratory pressure. The MicroRPM® is considered the gold standard device to measure the strength of respiratory muscles and has shown high intra- and inter-rater reliability.³⁸ Each metric was repeated five times and the highest value was used.

CARDIAC FUNCTION

Cardiac function was assessed by the systolic and diastolic arterial blood pressure and heart rate using a digital blood pressure cuff device (Omron M6 Comfort, Omron Healthcare Ltd., Kyoto, Japan). This device has proven to be a valid and reliable measure of blood pressure according to defined international protocol.³⁹ Each metric was repeated five times and the highest value was used.

PHYSICAL FUNCTION

Physical function comprised assessment of muscle strength, exercise-induced fatigue, and balance. Muscle strength was evaluated using a hand-held dynamometer (microFET2, Hoggan Health, Salt Lake City, Utah) to measure (in kilogram-force [KgF]) the isometric quadriceps and handgrip strength. The microFET2 device provides excellent intra- and inter-rater reliability to measure quadriceps strength in patients with COPD.⁴⁰ For quadriceps strength, participants were seated with the knee flexed at approximately 90 degrees and were asked to perform knee extension. The dynamometer was placed distally to the anterior leg (5 cm above the lateral malleolus). The handgrip strength was measured with the participant seated and with the elbow unsupported and flexed at 90 degrees. The partic-

ipant was asked to grip the dynamometer as hard as possible. Each strength metric was repeated three times and the highest value was used.

Exercise-induced fatigue was evaluated with the one-minute sit-to-stand and the six-minute walking test (6MWT). Both tests are reliable and provide a valid measure to estimate functional exercise performance in COPD patients.^{41,42}

Balance was measured using the abbreviated version of the Balance Evaluation Systems Test (BESTest): the Brief BESTest.⁴³ The Brief BESTest consists of six items (scored from 0 to 3 points each) for a total of 24 points. Lower scores indicate more severe balance impairment. The Brief BESTest is a valid, reliable, and valuable tool to identify the balance status in patients with COPD.⁴⁴

EXACERBATIONS

The number of respiratory-related exacerbation episodes in the preceding three months was collected at each follow-up endpoint. Exacerbation episodes were defined as acute worsening of respiratory symptoms (e.g., dyspnea, increased cough frequency, or severity and increase of sputum production or change of color) requiring additional treatment or hospitalization.

STATISTICAL ANALYSIS

The software IBM SPSS version 28.0 (Statistical Package for the Social Sciences, Inc.; Chicago, IL) was used for all statistical analyses. Gaussian distribution was assessed through the Kolmogorov-Smirnov test and the skewness and kurtosis absolute values, which displayed a non-normal distribution in most of the included variables. Due to the non-Gaussian distribution and the small sample size, it was decided to conduct non-parametric statistics. Participants lost to follow-up were included in assessments where they were available and discarded in the evaluation endpoints where lost. The continuous variables are described using me-

dian and interquartile range, and categorical variables as count and frequency (%). For the hypothesis test, a P value of 0.05 was used to determine statistical significance.

Between groups statistical differences were compared using the Mann-Whitney U tests. The χ^2 test was used to compare categorical variables between groups as well as the exact Fisher test (when applicable). Within-group statistical differences were compared using the one-way repeated measures Friedman test (for overall changes throughout the follow-up) with the *post hoc* Wilcoxon signed-rank tests for pairwise comparisons between follow-up endpoints.

RESULTS

CHARACTERISTICS OF INCLUDED PARTICIPANTS

Of the 200 participants screened for inclusion in this study, 140 were initially excluded for not fulfilling the eligibility criteria. The most common reasons for exclusion were non-COPD respiratory diseases and the inability to participate in the study due to transportation or scheduling constraint. Moreover, further 65 participants were excluded as they presented other COPD grades besides GOLD B. A total of 35 participants were eligible and enrolled in the study. Each participant was allocated to either the intervention (n=14) or control (n=21) group. One patient in the control group was lost at follow-up at the three-month follow-up ([Figure 3](#)).

The baseline demographic and biometric characteristics were homogenous between the groups ([Table 1](#)). The baseline GOLD characteristics (stage and symptoms) were also mostly homogenous between the groups. Only the rate of exacerbations was statistically different, with the intervention group showing a significantly superior rate of two or more exacerbations in the last year (78.6% vs 0.0%).

PRIMARY OUTCOMES

The respiratory rate (CPM) and oxygen saturation (% SpO₂) were not statistically different between the groups at baseline or during any follow-up end-point ($p>0.05$); neither were the within-group changes throughout the nine months of the study ([Table 2](#)).

The FEV₁ (L) was not significantly different between the groups, and although it improved from baseline to three months in the control group by 0.5 L ($p=0.002$), the effect deteriorated at nine months from the baseline values ($p=0.021$). Both groups showed a non-significant improvement of FEV₁ (%) at three months (change of 10.5% in the intervention group and 9% in the control group), but with significantly superior values in the control group ($p=0.039$). The improvement of FEV₁ (%) deteriorated in both groups at nine months (decrease of 7.5% and 13% in intervention and control group, respectively). The FVC (L) was comparable between the groups at baseline and throughout the follow-up, but with a statistically significant decrease of 0.3 L at nine months in the control group ($p=0.001$). The FVC (%) was significantly superior in the control group at baseline (77.3% and 99.0% at intervention and control group, respectively; $p=0.002$), but it deteriorated signifi-

cantly throughout the follow-up until reaching similar values to the intervention group. The FEV₁/FVC (%) showed a significant 29% increase in the control group at three months ($p=0.001$), which was maintained at six and nine months, always superior compared to the intervention group ($p<0.005$).

The strength of inspiratory and expiratory muscles increased significantly at three months in both groups ($p<0.05$). However, the maximal inspiratory pressure was significantly superior by 37 cm H₂O in the intervention group at nine months for maximal inspiratory pressure ($p=0.005$). Likewise, the maximal expiratory pressure was also significantly superior in the intervention group by 40.5 cm H₂O at six months and by 45 cm H₂O at nine months ($p=0.027$ and $p<0.001$, respectively). Although maximal inspiratory and expiratory pressure showed a marginal improvement at three months in the control group ($p<0.05$), both measures displayed a significant decrease at nine months ($p<0.001$).

SECONDARY OUTCOMES

The systolic and diastolic blood pressure showed significant variant patterns across the nine months of the study. Despite statistically significant differences between groups at nine months ($p=0.009$ and $p<0.001$, respectively; [Table 3](#)), the systolic blood pressure was within Stage 1 of hypertension in both groups. The diastolic blood pressure was within the range of normal values for the control group and at the lowest range of Stage 1 of hypertension (80 mm Hg) for the intervention group.

Isometric quadriceps strength showed an improvement in both groups at three months (13.7 KgF and 6.3 KgF in the intervention and control group, respectively). However, the improvement deteriorated by 4.1 KgF until the ninth-month follow-up in the control group ($p<0.001$). Although the improvement was superior in the intervention group, it was not statistically significant in any of the follow-up endpoints ($p>0.05$). Likewise, the handgrip strength improved in both groups but started to deteriorate at six months in the control group ($p=0.001$). Handgrip strength was not statistically significant between groups in any of the follow-up endpoints ($p>0.05$).

Exercise-induced fatigue (one-minute sit-to-stand and 6MWT) was comparable between groups at baseline ([Table 3](#)). However, after an improvement at three months in the control group ($p<0.05$), both exercise-induced fatigue metrics deteriorated over time ($p<0.001$). The intervention group showed a significantly higher number of repetitions at six months (more 5.5 repetitions, $p=0.027$) and nine months (more 4.5 repetitions, $p=0.004$) in the one-minute sit-to-stand test. Similarly, the intervention group outperformed the control group in the 6MWT, with more 92.5 meters at six months ($p=0.047$) and more 178.5 meters at nine months ($p<0.001$).

Balance (Brief BESTest) was comparable between groups at baseline and after the initial three months of intervention ($p>0.05$), but the intervention group showed superior balance scores at the six months (two points more, $p=0.003$) and nine months (four points more, $p<0.001$; see [Table 3](#)).

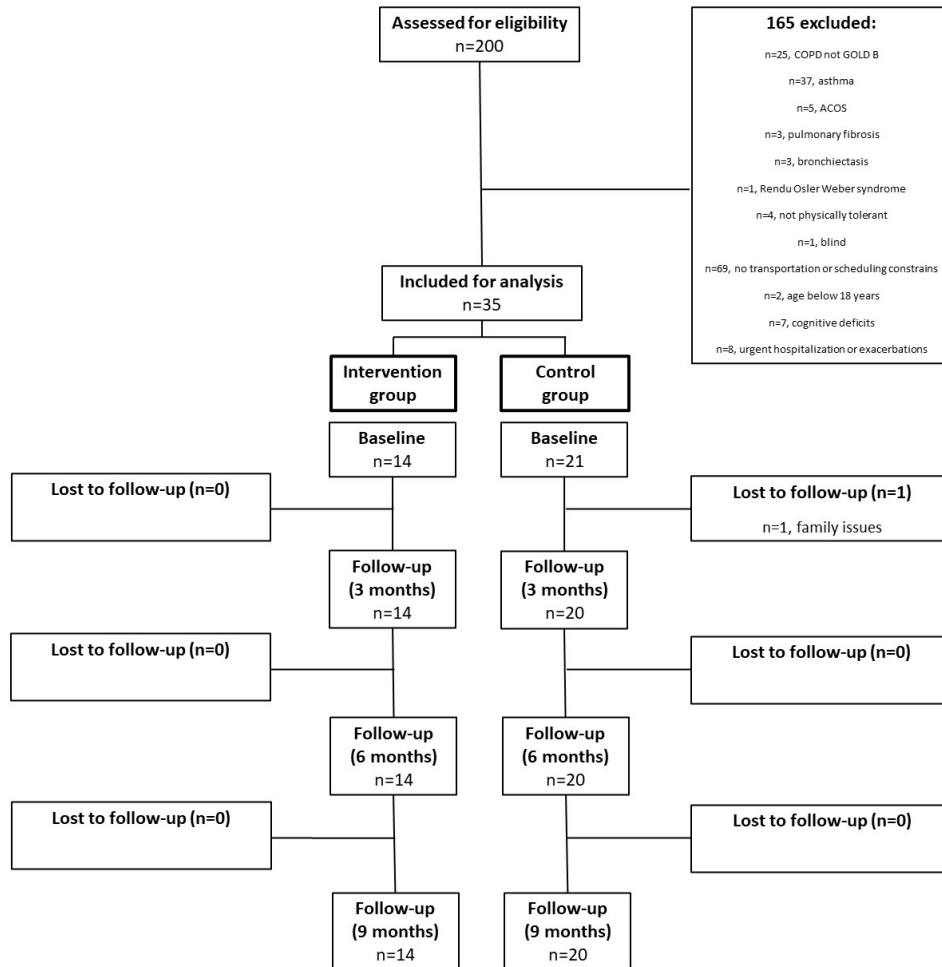


Figure 3. Flow diagram detailing the inclusion and follow-up of participants.

Although the intervention group showed a higher number of exacerbations, the rate was not statistically different between the groups at any follow-up endpoint ($p > 0.05$; see Supplement 3).

DISCUSSION

The main finding of this prospective cohort study showed that adding a six-month Pilates exercise program to a three-month pulmonary rehabilitation program resulted in superior strength of inspiratory and expiratory muscles when compared to the group that only received the initial three months of pulmonary rehabilitation. Moreover, the changes at follow-up in the maximal inspiratory pressure surpassed the minimal clinically important difference (MCID),⁴⁵ showing that the improvement was large enough to be perceived as clinically meaningful by the patient. This finding highlights a potential role that a Pilates exercise program may play on improving the strength of respiratory muscles, which is clinically relevant, as the respiratory muscles play a crucial role in the diaphragmatic function in patients with COPD. Our findings are in line with other studies that show improved strength of respiratory mus-

cles after the implementation of a Pilates exercise program for different pathological conditions.^{27,30} Therefore, physiotherapists may consider complementing their traditional pulmonary rehabilitation program with a structured Pilates exercise program.

Interestingly, the positive findings on the strength of respiratory muscles were not translated into consistent improvement of lung function measured by spirometry. Most lung function outcomes showed a similar behavior between the intervention and control group throughout the nine-month follow-up. This finding may be explained by the fact that the participants in the control group also followed the same recommended set of home-based exercises that may have contributed to the maintenance of improvement in lung function after the initial three months of traditional pulmonary rehabilitation program. In fact, the FEV₁/FVC (%) was significantly superior in the control group at six- and nine-month follow-ups; however, this may be a confounding result because the FEV₁/FVC (%) was already significantly superior in the control group after the initial three months of traditional pulmonary rehabilitation program (before the implementation of the Pilates exercise program). This may partially explain why this outcome was

Table 1. Baseline demographic, biometric and COPD-related characteristics of included participants.

Variables	Intervention group (n=14)	Control group (n=21)	P value
Age (Years)	65.5 (11.8)	65.0 (14.0)	0.907
Sex			
Male	11 (78.6%)	15 (71.4%)	0.712*
Female	3 (21.4%)	6 (28.6%)	
Height (m)	1.65 (0.16)	1.65 (0.12)	0.654
Weight (Kg)	74.0 (19.5)	70.9 (21.5)	0.702
% of fat mass	26.1 (15.4)	22.3 (15.6)	0.127
BMI (kg.m ⁻²)	25.7 (6.9)	25.2 (6.8)	0.881
GOLD stage (%)			
GOLD I	2 (14.29%)	9 (42.86%)	0.080
GOLD II	12 (85.71%)	9 (42.86%)	
GOLD III	0 (0%)	2 (9.52%)	
GOLD IV	0 (0%)	1 (4.76%)	
GOLD symptoms			
CAT < 10	3 (21.4%)	0 (0%)	0.056*
CAT ≥ 10	11 (78.6%)	21 (100%)	
GOLD exacerbations			
AECOPD < 2	3 (21.4%)	21 (100%)	<0.001*
AECOPD ≥ 2	11 (78.6%)	0 (0%)	

BMI – Body Mass Index; GOLD - Global Initiative for Chronic Obstructive Lung Disease system.

* Exact Fisher test

also significantly superior at the six- and nine-month follow-up. Notwithstanding the lack of superiority in lung function of the intervention group at follow-up, the significantly superior positive impact on the strength of respiratory muscles is sufficient to justify the addition of a Pilates exercise program. Indeed, many lung-related ventilatory parameters can be improved with Pilates-based breathing exercises.²⁶

The intervention group also showed superiority in exercise-induced fatigue and balance at follow-up. Improving exercise-induced fatigue is an important outcome in patients with COPD because the resistance to fatigue of these patients is often compromised due to dyspnea-related symptoms and to a smaller proportion of type I fibers that are more resistant to fatigue.⁴⁶ The improvement in the intervention group is clinically meaningful, as it surpassed the MCID for both the 6MWD⁴¹ and number of chair raises.⁴⁷ Moreover, the between-group differences for the 6MWD at the nine-month follow-up (178.5 meters) are larger than the 41 meters that is typically reported when comparing traditional pulmonary rehabilitation interventions to control groups.⁴⁸ These metrics, such as the number of chair raises, are important in evaluating the tolerance of fatigue in patients with COPD and have been associated with symptoms such as dyspnea.⁴⁹ Improvements in the 6MWD and other related to exercise-induced fatigue are also seen in other studies that implemented pilates in other pathological conditions.^{50,51} Likewise, improving balance in patients with COPD is important because impairments and decline in balance are more pronounced in these patients due to exercise intolerance and dyspnea^{52,53} as well as other physiological factors such as muscle weakness⁵⁴ and somatosensory deficits.⁵⁵ The

Pilates exercise program may have contributed to improved balance through better muscle control of the deeper abdominal muscles.³¹ In line with exercise-induced fatigue, the changes at follow-up in the intervention group for the Brief BESTest also surpassed the MCID.⁵⁶ Similar findings on balance after a Pilates exercise program have also been reported for many other populations.^{31,32,57}

Isometric quadriceps and handgrip strength, despite not being statistically significant between groups, indicated that median improvement was higher in the intervention group. Indeed, while both strength metrics stayed relatively constant for the control group, they showed a relevant improvement in the intervention group with the isometric quadriceps strength more than doubling at six months and the handgrip strength being almost twofold that of the control group at nine months follow-up. Quadriceps strength plays an important role in patients with COPD in opposing exercise tolerance⁵⁸ and has an association with longer survival.⁵⁹ The improvements in isometric strength surpassed the MCID at the six-month follow-up and were almost fourfold the MCID at the nine-month follow-up.⁴⁵ Similarly, handgrip strength is important in patients with COPD as it is impaired during exacerbation episodes⁶⁰ and is associated with dyspnea symptoms and functional exercise capacity.⁶¹ Similar improvements in quadriceps muscle strength have been reported in other studies that have implemented a Pilates exercise program for other pathologic populations.^{32,57} The lack of between-group statistical significance in these two strength metrics at follow-up may have been the result of a type II error, which is discussed at more length in the limitations section.

The strengths of our study are the implementation of a structured exercise program during 9 months with a high

Table 2. Baseline and follow-up outcomes of respiratory and lung function in the Intervention (N=14) and Control (n=21) Groups

Variables	Groups	Baseline	3 months		6 months		9 months		Overall*
Respiratory rate (cpm)	Intervention	72.0 (9.0)	71.0 (22.0)	(<i>p</i> =0.123 vs baseline)	77.5 (17.0)	(<i>p</i> =0.396 vs 3 months)	74.0 (19.0)	(<i>p</i> =0.528 vs 6 months)	0.183
	Control	70.5 (14.0)	69.5 (18.0)	(<i>p</i> =0.750 vs baseline)	71.5 (11.0)	(<i>p</i> =0.155 vs 3 months)	70.5 (12.0)	(<i>p</i> =0.970 vs 6 months)	0.484
	Comparison between groups	0.934	0.377		0.129		0.323		
SpO ₂ (%)	Intervention	95.5 (3.0)	95.5 (2.0)	(<i>p</i> =0.645 vs baseline)	96.0 (2.0)	(<i>p</i> =0.526 vs 3 months)	96.0 (1.0)	(<i>p</i> =0.454 vs 6 months)	0.661
	Control	96.0 (2.0)	96.0 (2.0)	(<i>p</i> =0.627 vs baseline)	96.0 (2.0)	(<i>p</i> =0.750 vs 3 months)	96.0 (3.0)	(<i>p</i> =0.356 vs 6 months)	0.481
	Comparison between groups	0.829	0.986		0.592		0.641		
FEV ₁ (L)	Intervention	2.1 (0.9)	2.1 (0.3)	(<i>p</i> =0.802 vs baseline)	96.0 (2.0)	(<i>p</i> =0.572 vs 3 months)	96.0 (1.0)	(<i>p</i> =0.510 vs 6 months)	0.586
	Control	2.0 (1.0)	2.5 (0.8)	(<i>p</i> =0.002 vs baseline)	96.0 (2.0)	(<i>p</i> =0.076 vs 3 months)	96.0 (3.0)	(<i>p</i> =0.021 vs 6 months)	0.003
	Comparison between groups	0.396	0.180		0.691		0.306		
FEV ₁ (%)	Intervention	75.0 (12.3)	85.5 (19.0)	(<i>p</i> = 0.509 vs baseline)	74.5 (20.3)	(<i>p</i> =0.624 vs 3 months)	78.0 (16.5)	(<i>p</i> =0.489 vs 6 months)	0.697
	Control	82.0 (21.3)	91.0 (28.0)	(<i>p</i> = 0.121 vs baseline)	84.0 (34.0)	(<i>p</i> =0.184 vs 3 months)	78.0 (26.3)	(<i>p</i> =0.601 vs 6 months)	0.793
	Comparison between groups	0.235	0.039		0.457		0.522		
FVC (L)	Intervention	3.0 (1.0)	85.5 (19.0)	(<i>p</i> = 0.509 vs baseline)	3.1 (1.6)	(<i>p</i> =0.060 vs 3 months)	3.2 (1.1)	(<i>p</i> =0.258 vs 6 months)	0.156
	Control	3.0 (1.3)	91.0 (28.0)	(<i>p</i> = 0.121 vs baseline)	3.2 (1.8)	(<i>p</i> =0.983 vs 3 months)	2.9 (1.7)	(<i>p</i> =0.001 vs 6 months)	0.022
	Comparison between groups	0.583	0.769		0.877		0.377		
FVC (%)	Intervention	77.3 (17.5)	84.0 (29.0)	(<i>p</i> =0.149 vs baseline)	93.5 (25.0)	(<i>p</i> =0.102 vs 3 months)	89.0 (25.0)	(<i>p</i> =0.068 vs 6 months)	0.033
	Control	99.0 (22.5)	94.5 (19.3)	(<i>p</i> =0.380 vs baseline)	98.0 (22.8)	(<i>p</i> =0.324 vs 3 months)	89.5 (30.0)	(<i>p</i> =0.033 vs 6 months)	0.312

Variables	Groups	Baseline	3 months		6 months		9 months		Overall*
	Comparison between groups	0.002	0.169		0.545		0.341		
FEV ₁ /FVC (%)	Intervention	74.5 (15.0)	72.0 (33.0)	(<i>p</i> =0.683 vs baseline)	68.0 (27.0)	(<i>p</i> =0.286 vs 3 months)	66.5 (15.0)	(<i>p</i> =0.421 vs 6 months)	0.294
	Control	66.5 (12.0)	95.5 (21.0)	(<i>p</i> =0.001 vs baseline)	92.5 (25.0)	(<i>p</i> =0.042 vs 3 months)	93.0 (24.0)	(<i>p</i> =0.681 vs 6 months)	0.006
	Comparison between groups	0.083	0.002		<0.001		<0.001		
Maximal inspiratory pressure (cm H ₂ O)	Intervention	74.5 (39.0)	92.0 (33.0)	(<i>p</i> =0.431 vs baseline)	84.5 (91.0)	(<i>p</i> =0.345 vs 3 months)	98.0 (40.0)	(<i>p</i> =0.004 vs 6 months)	0.021
	Control	66.5 (45.0)	70.5 (47.0)	(<i>p</i> =0.040 vs baseline)	68.0 (36.0)	(<i>p</i> =0.014 vs 3 months)	61.0 (34.0)	(<i>p</i> =0.003 vs 6 months)	< 0.001
	Comparison between groups	0.516	0.180		0.056		0.005		
Maximal expiratory pressure (cm H ₂ O)	Intervention	98.0 (38.0)	121.0 (28.0)	(<i>p</i> =0.008 vs baseline)	130.0 (28.0)	(<i>p</i> =0.801 vs 3 months)	129.0 (34.0)	(<i>p</i> =0.859 vs 6 months)	0.009
	Control	94.0 (38.0)	99.5 (54.0)	(<i>p</i> =0.023 vs baseline)	89.5 (55.0)	(<i>p</i> =0.029 vs 3 months)	84.0 (39.0)	(<i>p</i> =0.002 vs 6 months)	< 0.001
	Comparison between groups	0.630	0.112		0.027		<0.001		

Data presented as median and IQR. * Within group statistics include Friedman test for overall improvement and post hoc Wilcoxon test for pairwise comparisons between follow-up endpoints.
cpm – cycles per minute.

Table 3. Baseline and follow-up outcomes of secondary outcomes.

Variables	Groups	Baseline	3 months		6 months		9 months		Overall*
Systolic arterial blood pressure (mmHg)	Intervention	129.5 (14.0)	127.5 (19.0)	(<i>p</i> =0.916 vs baseline)	138.0 (29.0)	(<i>p</i> =0.005 vs 3 months)	131.5 (16.0)	(<i>p</i> =0.004 vs 6 months)	0.183
	Control	141.3 (23.0)	132.0 (30.0)	(<i>p</i> =0.263 vs baseline)	137.0 (27.0)	(<i>p</i> =0.852 vs 3 months)	133.5 (29.0)	(<i>p</i> =0.411 vs 6 months)	0.484
	Comparison between groups	0.752	0.051		0.004		0.009		
Diastolic arterial blood pressure (mmHg)	Intervention	76.5 (9.0)	80.5 (15.0)	(<i>p</i> =0.328 vs baseline)	79.5 (9.0)	(<i>p</i> =0.593 vs 3 months)	80.0 (13.0)	(<i>p</i> =0.900 vs 6 months)	0.661
	Control	82.0 (13.0)	81.0 (17.0)	(<i>p</i> =0.687 vs baseline)	79.0 (14.0)	(<i>p</i> =1.000 vs 3 months)	78.5 (17.0)	(<i>p</i> =0.262 vs 6 months)	0.481
	Comparison between groups	<0.001	0.004		<0.001		<0.001		
Isometric quadriceps strength (KgF)	Intervention	22.3 (11.5)	36.0 (11.5)	(<i>p</i> = 0.005 vs baseline)	51.6 (45.8)	(<i>p</i> =0.103 vs 3 months)	31.0 (11.3)	(<i>p</i> = 0.048 vs 6 months)	0.586
	Control	22.3 (12.6)	28.6 (8.7)	(<i>p</i> < 0.001 vs baseline)	26.8 (8.8)	(<i>p</i> = 0.004 vs 3 months)	24.5 (8.0)	(<i>p</i> = 0.002 vs 6 months)	0.003
	Comparison between groups	0.145	0.796		0.457		0.959		
Handgrip strength (KgF)	Intervention	32.0 (14.0)	37.0 (9.0)	(<i>p</i> =0.327 vs baseline)	42.5 (13.0)	(<i>p</i> = 0.027 vs 3 months)	41.5 (8.3)	(<i>p</i> =0.472 vs 6 months)	0.697
	Control	23.9 (10.0)	27.6 (9.0)	(<i>p</i> < 0.001 vs baseline)	23.7 (9.0)	(<i>p</i> = 0.001 vs 3 months)	22.2 (7.6)	(<i>p</i> =0.097 vs 6 months)	0.793
	Comparison between groups	0.026	0.259		0.877		0.522		
1-min chair raises (# of reps)	Intervention	28.0 (12.0)	31.5 (8.0)	(<i>p</i> =0.271 vs baseline)	31.5 (16.0)	(<i>p</i> =0.185 vs 3 months)	31.5 (14.0)	(<i>p</i> =0.173 vs 6 months)	0.156
	Control	27.5 (7.0)	30.0 (7.0)	(<i>p</i> < 0.001 vs baseline)	26.0 (8.0)	(<i>p</i> < 0.001 vs 3 months)	27 (7.0)	(<i>p</i> =0.404 vs 6 months)	0.022
	Comparison between groups	0.606	0.691		0.027		0.004		
6MWT (distance covered in meters)	Intervention	440.0 (190.8)	585.9 (168.8)	(<i>p</i> < 0.001 vs baseline)	540.0 (180.0)	(<i>p</i> =0.221 vs 3 months)	600 (142.5)	(<i>p</i> = 0.021 vs 6 months)	0.033
	Control	442.5 (135.0)	470.0 (142.5)	(<i>p</i> = 0.004 vs baseline)	447.5 (131.3)	(<i>p</i> =0.052 vs 3 months)	421.5 (95.3)	(<i>p</i> < 0.001 vs 6 months)	0.312

Variables	Groups	Baseline	3 months		6 months		9 months		Overall*
	Comparison between groups	0.934	0.018		0.047		<0.001		
Brief BESTest (0-24)	Intervention	16.5 (7.0)	23.0 (4.0)	(p=0.001 vs baseline)	23.0 (1.0)	(p=0.089 vs 3 months)	23.0 (1.0)	(p=0.414 vs 6 months)	0.294
	Control	15.0 (9.0)	21.0 (6.0)	(p=0.003 vs baseline)	21.0 (6.0)	(p=0.699 vs 3 months)	19.0 (3.0)	(p=0.377 vs 6 months)	0.006
	Comparison between groups	0.396	0.129		0.003		<0.001		

Data presented as median and IQR. * Within group statistics include Friedman test for overall improvement and post hoc Wilcoxon test for pairwise comparisons between follow-up endpoints.
6MWT – 6-minute walking test.

degree of adherence, which is often challenging in a cohort of COPD patients. Moreover, our study investigates the effects of a particularly relevant and insufficiently researched type of exercise (Pilates) in patients with COPD, showing that the theoretical benefits of pilates in lung and respiratory function in individuals with COPD can translate into measurable and clinically relevant improvements. Future research should improve upon our research design by implementing a randomized control trial comparing the effects of Pilates exercise against a control group with usual care and expand into other subgroups of this population, with other grades of COPD other than GOLD B.

This study has some limitations that need to be acknowledged. Despite being above the *a priori* sample size calculation (at least ten per group), our sample size is still small. Moreover, the intervention group had a lower sample size than the control group due to the exclusion of some patients who were not classified as GOLD B. A total of 25 participants with grades other than GOLD B completed the entire study, but we decided to exclude these from analyses to prevent selection bias. Moreover, subgroups based on GOLD grades were not possible because this would have resulted in very small groups and low representativeness (external validity). These limitations led to a lower statistical power in analyses and may have resulted in a type II error in not finding statistical differences when the between-groups differences were clinically relevant (e.g., for isometric quadriceps and handgrip strength). Another limitation was the lack of randomization and blinding of outcome assessors which may increase the risk of selection and detection bias, respectively. Lastly, the control group was not left without intervention throughout the follow-up period, as it would have been unethical to leave these patients without any guidance. Therefore, the participants of the control group were encouraged to continue performing the recommended home-based exercises throughout the follow-up period. To mitigate a potential performance bias, the intervention group was also encouraged to follow the same home-based exercise program, and adherence to the home-based exercises was monitored to assure that it was over 80% in both groups. The home-based exercises seem not to have yielded an effect in the control group during the follow-up because muscle strength and tolerance to exercise-induced fatigue deteriorated in the control group at the six- and nine-month follow-ups. However, it must be acknowledged that the intervention group followed a structured exercise regimen (Pilates) as compared to solely unsupervised home-based exercises and that results may have arisen from the effects of following a structured exercise program¹⁴ (regardless of being pilates or other type of exer-

cise). Indeed, similar improvements have been observed in patients with COPD following other types of structured exercise programs.¹⁰⁻¹⁵ Moreover, the superior effect on the intervention group could also be (at least partially) attributed to the potential effect of additional exposure to exercise-based intervention. After the initial 3 months of traditional pulmonary rehabilitation, while the control group followed home-based exercises for 6 months, the intervention group received a structured Pilates-based exercise program twice week in addition to the home-base exercises.

CONCLUSION

The intervention group, in which a six-month Pilates exercise program was added to an initial three-month pulmonary rehabilitation program, showed superior strength of inspiratory and expiratory muscles, higher resistance to exercise-induced fatigue, and improved balance in patients with COPD as compared to the control group that only performed the initial three-month pulmonary rehabilitation program. These findings underpin the relevance and possibility of complementing the traditional pulmonary rehabilitation with a structured Pilates exercise program to enhance and/or maintain the improvement of pulmonary rehabilitation.

FUNDING

Not applicable.

COMPETING INTERESTS

All authors have completed the ICMJE uniform disclosure form and declare no conflict of interest.

AI STATEMENT

The authors confirm no generative AI or AI-assisted technology was used to generate content.

ETHICAL DECLARATIONS

The study was approved by the Institutional Ethical Committee (IRB number: ERS NORTE, study ID T667, No.37/2017).

Submitted: January 04, 2024 EDT, Accepted: May 21, 2024 EDT



This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CCBY-NC-4.0). View this license's legal deed at <https://creativecommons.org/licenses/by-nc/4.0> and legal code at <https://creativecommons.org/licenses/by-nc/4.0/legalcode> for more information.

REFERENCES

1. Ntritsos G, Franek J, Belbasis L, et al. Gender-specific estimates of COPD prevalence: a systematic review and meta-analysis. *Int J Chron Obstruct Pulmon Dis*. 2018;13:1507-1514. doi:10.2147/COPD.S146390
2. GBD 2016 Causes of Death Collaborators. Global, regional, and national age-sex specific mortality for 264 causes of death, 1980-2016: a systematic analysis for the Global Burden of Disease Study 2016 [published correction appears in *Lancet*. 2017 Oct 28;390(10106):e38]. *Lancet*. 2017;390(10100):1151-1210. doi:10.1016/S0140-6736(17)32152-9
3. Raheison C, Ouaalaya EH, Bernady A, et al. Comorbidities and COPD severity in a clinic-based cohort. *BMC Pulm Med*. 2018;18(1):117. doi:10.1186/s12890-018-0684-7
4. Li X, Cao X, Guo M, Xie M, Liu X. Trends and risk factors of mortality and disability adjusted life years for chronic respiratory diseases from 1990 to 2017: systematic analysis for the Global Burden of Disease Study 2017 [published correction appears in *BMJ*. 2020 Aug 6;370:m3150]. *BMJ*. 2020;368:m234. doi:10.1136/bmj.m234
5. Singh D, Agusti A, Anzueto A, et al. Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Lung Disease: the GOLD science committee report 2019. *Eur Respir J*. 2019;53(5):1900164. doi:10.1183/13993003.00164-2019
6. Seemungal TA, Donaldson GC, Bhowmik A, Jeffries DJ, Wedzicha JA. Time course and recovery of exacerbations in patients with chronic obstructive pulmonary disease. *Am J Respir Crit Care Med*. 2000;161(5):1608-1613. doi:10.1164/ajrccm.161.5.9908022
7. Tachkov K, Kamusheva M, Pencheva V, Mitov K. Evaluation of the economic and social burden of chronic obstructive pulmonary disease (COPD). *Biotechnol Biotechnol Equip*. 2017;31(4):855-861. doi:10.1080/13102818.2017.1335616
8. Stefan MS, Pekow PS, Priya A, et al. Association between Initiation of Pulmonary Rehabilitation and Rehospitalizations in Patients Hospitalized with Chronic Obstructive Pulmonary Disease. *Am J Respir Crit Care Med*. 2021;204(9):1015-1023. doi:10.1164/rccm.202012-4389OC
9. Toubes-Navarro ME, Gude-Sampedro F, Álvarez-Dobaño JM, et al. A pulmonary rehabilitation program reduces hospitalizations in chronic obstructive pulmonary disease patients: A cost-effectiveness study. *Ann Thorac Med*. 2023;18(4):190-198. doi:10.4103/atm.atm_70_23
10. Barbosa M, Andrade R, de Melo CA, Torres R. Community-Based Pulmonary Rehabilitation Programs in Individuals With COPD. *Respir Care*. 2022;67(5):579-593. doi:10.4187/respcare.09627
11. Benzo-Iglesias MJ, Rocamora-Pérez P, Valverde-Martínez M, García-Luengo AV, López-Liria R. Effectiveness of Water-Based Exercise in Patients with Chronic Obstructive Pulmonary Disease: Systematic Review and Meta-Analysis. *Sensors (Basel)*. 2023;23(20). doi:10.3390/s23208557
12. Cheng SWM, McKeough ZJ, McNamara RJ, Alison JA. Pulmonary Rehabilitation Using Minimal Equipment for People With Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis. *Phys Ther*. 2023;103(5). doi:10.1093/ptj/pzad013
13. Priego-Jiménez S, Cavero-Redondo I, Pascual-Morena C, Martínez-García I, Martínez-Vizcaíno V, Álvarez-Bueno C. Effect of different exercise programs on lung function in people with chronic obstructive pulmonary disease: A network meta-analysis of RCTs. *Ann Phys Rehabil Med*. 2024;67(2):101792. doi:10.1016/j.rehab.2023.101792
14. Priego-Jiménez S, Torres-Costoso A, Guzmán-Pavón MJ, Lorenzo-García P, Lucerón-Lucas-Torres MI, Álvarez-Bueno C. Efficacy of Different Types of Physical Activity Interventions on Exercise Capacity in Patients with Chronic Obstructive Pulmonary Disease (COPD): A Network Meta-Analysis. *Int J Environ Res Public Health*. 2022;19(21):14539. doi:10.3390/ijerph192114539
15. Zhang H, Hu D, Xu Y, Wu L, Lou L. Effect of pulmonary rehabilitation in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis of randomized controlled trials. *Ann Med*. 2022;54(1):262-273. doi:10.1080/07853890.2021.1999494
16. Ramos M, Lamotte M, Gerlier L, Svangren P, Miquel-Cases A, Haughney J. Cost-effectiveness of physical activity in the management of COPD patients in the UK. *Int J Chron Obstruct Pulmon Dis*. 2019;14:227-239. doi:10.2147/COPD.S181194

17. Ninot G, Moullec G, Picot MC, et al. Cost-saving effect of supervised exercise associated to COPD self-management education program. *Respir Med*. 2011;105(3):377-385. doi:10.1016/j.rmed.2010.10.002
18. Kongragunta VR, Druz WS, Sharp JT. Dyspnea and diaphragmatic fatigue in patients with chronic obstructive pulmonary disease. Responses to theophylline. *Am Rev Respir Dis*. 1988;137(3):662-667. doi:10.1164/ajrccm/137.3.662
19. Scheibe N, Sosnowski N, Pinkhasik A, Vonderbank S, Bastian A. Sonographic evaluation of diaphragmatic dysfunction in COPD patients. *Int J Chron Obstruct Pulmon Dis*. 2015;10:1925-1930. doi:10.2147/COPD.S85659
20. Rocha FR, Brüggemann AK, Francisco DS, Medeiros CS, Rosal D, Paulin E. Diaphragmatic mobility: relationship with lung function, respiratory muscle strength, dyspnea, and physical activity in daily life in patients with COPD. *J Bras Pneumol*. 2017;43(1):32-37. doi:10.1590/S1806-37562016000000097
21. Chiu KL, Hsieh PC, Wu CW, Tzeng IS, Wu YK, Lan CC. Exercise training increases respiratory muscle strength and exercise capacity in patients with chronic obstructive pulmonary disease and respiratory muscle weakness. *Heart Lung*. 2020;49(5):556-563. doi:10.1016/j.hrtlng.2020.03.005
22. Macklem PT. The act of breathing. In: Aliverti A, Pedotti A, eds. *Mechanics of Breathing: New Insights from New Technologies*. Springer-Verlag; 2014:3-10. doi:10.1007/978-88-470-5647-3_1
23. Dames KK, Lopes AJ, de Melo PL. Airflow pattern complexity during resting breathing in patients with COPD: effect of airway obstruction. *Respir Physiol Neurobiol*. 2014;192:39-47. doi:10.1016/j.resp.2013.12.004
24. Sarkar M, Bhardwaz R, Madabhavi I, Modi M. Physical signs in patients with chronic obstructive pulmonary disease. *Lung India*. 2019;36(1):38-47. doi:10.4103/lungindia.lungindia_145_18
25. Yamaguti WP, Claudino RC, Neto AP, et al. Diaphragmatic breathing training program improves abdominal motion during natural breathing in patients with chronic obstructive pulmonary disease: a randomized controlled trial. *Arch Phys Med Rehabil*. 2012;93(4):571-577. doi:10.1016/j.apmr.2011.11.026
26. Cancellero-Gaiad KM, Ike D, Pantoni CBF, Borghi-Silva A, Costa D. Respiratory pattern of diaphragmatic breathing and Pilates breathing in COPD subjects. *Braz J Phys Ther*. 2014;18(4):291-299. doi:10.1590/bjpt-rbf.2014.0042
27. Alvarenga GMd, Charkovski SA, Santos LKd, Silva MABd, Tomaz GO, Gamba HR. The influence of inspiratory muscle training combined with the Pilates method on lung function in elderly women: A randomized controlled trial. *Clinics (Sao Paulo)*. 2018;73:e356. doi:10.6061/clinics/2018/e356
28. Finatto P, Silva ESD, Okamura AB, et al. Pilates training improves 5-km run performance by changing metabolic cost and muscle activity in trained runners. *PLoS One*. 2018;13(3):e0194057. doi:10.1371/journal.pone.0194057
29. Tinoco-Fernández M, Jiménez-Martín M, Sánchez-Caravaca MA, Fernández-Pérez AM, Ramírez-Rodrigo J, Villaverde-Gutiérrez C. The Pilates method and cardiorespiratory adaptation to training. *Res Sports Med*. 2016;24(3):281-286. doi:10.1080/15438627.2016.1202829
30. Tozim BM, Navega MT. Effect of pilates method on inspiratory and expiratory muscle strength in the elderly. *Rev Bras Cineantropometria Desempenho Hum*. 2018;20:1-9. doi:10.5007/1980-0037.2018v20n1p1
31. Lim HS, Kim YL, Lee SM. The effects of Pilates exercise training on static and dynamic balance in chronic stroke patients: a randomized controlled trial. *J Phys Ther Sci*. 2016;28(6):1819-1824. doi:10.1589/jpts.28.1819
32. Miranda S, Marques A. Pilates in noncommunicable diseases: A systematic review of its effects. *Complement Ther Med*. 2018;39:114-130. doi:10.1016/j.ctim.2018.05.018
33. Venkatesan P. GOLD COPD report: 2023 update. *Lancet Respir Med*. 2023;11(1):18. doi:10.1016/S2213-2600(22)00494-5
34. Liu W, Mu X, Wang X, Zhang P, Zhao L, Li Q. Effects of comprehensive pulmonary rehabilitation therapy on pulmonary functions and blood gas indexes of patients with severe pneumonia. *Exp Ther Med*. 2018;16(3):1953-1957. doi:10.3892/etm.2018.6396
35. Sohanpal R, Hooper R, Hames R, Priebe S, Taylor S. Reporting participation rates in studies of non-pharmacological interventions for patients with chronic obstructive pulmonary disease: a systematic review. *Syst Rev*. 2012;1:66. doi:10.1186/2046-4053-1-66
36. Spruit MA, Singh SJ, Garvey C, et al. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. *Am J Respir Crit Care Med*. 2013;188(8):e13-64. doi:10.1164/rccm.201309-1634ST

37. Liistro G, Vanwelde C, Vincken W, Vandevoorde J, Verleden G, Buffels J. Technical and functional assessment of 10 office spirometers: A multicenter comparative study. *Chest*. 2006;130(3):657-665. [doi:10.1378/chest.130.3.657](https://doi.org/10.1378/chest.130.3.657)
38. Silveira BMF, Pereira MCB, Cardoso DR, Ribeiro-Samora GA, Martins HR, Parreira VF. New method for evaluating maximal respiratory pressures: Concurrent validity, test-retest, and inter-rater reliability. *Braz J Phys Ther*. 2021;25(6):741-748. [doi:10.1016/j.bjpt.2021.04.012](https://doi.org/10.1016/j.bjpt.2021.04.012)
39. Belghazi J, El Feghali RN, Moussalem T, Rejdych M, Asmar RG. Validation of four automatic devices for self-measurement of blood pressure according to the International Protocol of the European Society of Hypertension. *Vasc Health Risk Manag*. 2007;3(4):389-400.
40. Sentanin A, de Araujo Facio C, Di Lorenzo VAP. Reliability intra and inter-rater of a handheld dynamometer in COPD patients. *Eur Respir J*. 2017;50:PA2518. [doi:10.1183/1393003.congress-2017.PA2518](https://doi.org/10.1183/1393003.congress-2017.PA2518)
41. Singh SJ, Puhan MA, Andrianopoulos V, et al. An official systematic review of the European Respiratory Society/American Thoracic Society: measurement properties of field walking tests in chronic respiratory disease. *Eur Respir J*. 2014;44(6):1447-1478. [doi:10.1183/09031936.00150414](https://doi.org/10.1183/09031936.00150414)
42. Crook S, Büsching G, Schultz K, et al. A multicentre validation of the 1-min sit-to-stand test in patients with COPD. *Eur Respir J*. 2017;49(3):1601871. [doi:10.1183/13993003.01871-2016](https://doi.org/10.1183/13993003.01871-2016)
43. Padgett PK, Jacobs JV, Kasser SL. Is the BESTest at its best? A suggested brief version based on interrater reliability, validity, internal consistency, and theoretical construct. *Phys Ther*. 2012;92(9):1197-1207. [doi:10.2522/ptj.20120056](https://doi.org/10.2522/ptj.20120056)
44. Jácome C, Cruz J, Oliveira A, Marques A. Validity, Reliability, and Ability to Identify Fall Status of the Berg Balance Scale, BESTest, Mini-BESTest, and Brief-BESTest in Patients With COPD. *Phys Ther*. 2016;96(11):1807-1815. [doi:10.2522/ptj.20150391](https://doi.org/10.2522/ptj.20150391)
45. Iwakura M, Okura K, Kubota M, et al. Estimation of minimal clinically important difference for quadriceps and inspiratory muscle strength in older outpatients with chronic obstructive pulmonary disease: a prospective cohort study. *Phys Ther Res*. 2021;24(1):35-42. [doi:10.1298/ptr.E10049](https://doi.org/10.1298/ptr.E10049)
46. Whittom F, Jobin J, Simard PM, et al. Histochemical and morphological characteristics of the vastus lateralis muscle in patients with chronic obstructive pulmonary disease. *Med Sci Sports Exerc*. 1998;30(10):1467-1474. [doi:10.1097/00005768-199810000-00001](https://doi.org/10.1097/00005768-199810000-00001)
47. Vaidya T, de Bisschop C, Beaumont M, et al. Is the 1-minute sit-to-stand test a good tool for the evaluation of the impact of pulmonary rehabilitation? Determination of the minimal important difference in COPD. *Int J Chron Obstruct Pulmon Dis*. 2016;11:2609-2616. [doi:10.2147/COPD.S115439](https://doi.org/10.2147/COPD.S115439)
48. Higashimoto Y, Ando M, Sano A, et al. Effect of pulmonary rehabilitation programs including lower limb endurance training on dyspnea in stable COPD: A systematic review and meta-analysis. *Respir Investig*. 2020;58(5):355-366. [doi:10.1016/j.resinv.2020.05.010](https://doi.org/10.1016/j.resinv.2020.05.010)
49. Vilarinho R, Serra L, Coxo R, et al. Effects of a Home-Based Pulmonary Rehabilitation Program in Patients with Chronic Obstructive Pulmonary Disease in GOLD B Group: A Pilot Study. *Healthcare (Basel)*. 2021;9(5):538. [doi:10.3390/healthcare9050538](https://doi.org/10.3390/healthcare9050538)
50. Duff WRD, Andrushko JW, Renshaw DW, et al. Impact of Pilates Exercise in Multiple Sclerosis: A Randomized Controlled Trial. *Int J MS Care*. 2018;20(2):92-100. [doi:10.7224/1537-2073.2017-066](https://doi.org/10.7224/1537-2073.2017-066)
51. Suárez-Iglesias D, Miller KJ, Seijo-Martínez M, Ayán C. Benefits of Pilates in Parkinson's Disease: A Systematic Review and Meta-Analysis. *Medicina (Kaunas)*. 2019;55(8):476. [doi:10.3390/medicina55080476](https://doi.org/10.3390/medicina55080476)
52. Morlino P, Balbi B, Guglielmetti S, et al. Gait abnormalities of COPD are not directly related to respiratory function. *Gait Posture*. 2017;58:352-357. [doi:10.1016/j.gaitpost.2017.08.020](https://doi.org/10.1016/j.gaitpost.2017.08.020)
53. Beauchamp MK, O'Hoski S, Goldstein RS, Brooks D. Effect of pulmonary rehabilitation on balance in persons with chronic obstructive pulmonary disease. *Arch Phys Med Rehabil*. 2010;91(9):1460-1465. [doi:10.1016/j.apmr.2010.06.021](https://doi.org/10.1016/j.apmr.2010.06.021)
54. Beauchamp MK, Hill K, Goldstein RS, Janaudis-Ferreira T, Brooks D. Impairments in balance discriminate fallers from non-fallers in COPD. *Respir Med*. 2009;103(12):1885-1891. [doi:10.1016/j.rmed.2009.06.008](https://doi.org/10.1016/j.rmed.2009.06.008)
55. Roig M, Eng JJ, Road JD, Reid WD. Falls in patients with chronic obstructive pulmonary disease: a call for further research. *Respir Med*. 2009;103(9):1257-1269. [doi:10.1016/j.rmed.2009.03.022](https://doi.org/10.1016/j.rmed.2009.03.022)

56. Paixão C, Rebelo P, Oliveira A, et al. Responsiveness and Minimal Clinically Important Difference of the Brief-BESTest in People With COPD After Pulmonary Rehabilitation. *Phys Ther*. 2021;101(11):pzab209. [doi:10.1093/ptj/pzab209](https://doi.org/10.1093/ptj/pzab209)
57. Rodríguez-Fuentes G, Silveira-Pereira L, Ferradáns-Rodríguez P, Campo-Prieto P. Therapeutic Effects of the Pilates Method in Patients with Multiple Sclerosis: A Systematic Review. *J Clin Med*. 2022;11(3):683. [doi:10.3390/jcm11030683](https://doi.org/10.3390/jcm11030683)
58. Hamilton AL, Killian KJ, Summers E, Jones NL. Muscle strength, symptom intensity, and exercise capacity in patients with cardiorespiratory disorders. *Am J Respir Crit Care Med*. 1995;152(6 Pt 1):2021-2031. [doi:10.1164/ajrccm.152.6.8520771](https://doi.org/10.1164/ajrccm.152.6.8520771)
59. Swallow EB, Reyes D, Hopkinson NS, et al. Quadriceps strength predicts mortality in patients with moderate to severe chronic obstructive pulmonary disease. *Thorax*. 2007;62(2):115-120. [doi:10.1136/thx.2006.062026](https://doi.org/10.1136/thx.2006.062026)
60. Turan Z, Özyemişçi Taşkıran Ö, Erden Z, Köktürk N, Kaymak Karataş G. Does hand grip strength decrease in chronic obstructive pulmonary disease exacerbation? A cross-sectional study. *Turk J Med Sci*. 2019;49(3):802-808. [doi:10.3906/sag-1811-22](https://doi.org/10.3906/sag-1811-22)
61. Wu ZY, Han YX, Niu ME, Chen Y, Zhang XQ, Qian HY. Handgrip strength is associated with dyspnoea and functional exercise capacity in male patients with stable COPD. *Int J Tuberc Lung Dis*. 2019;23(4):428-432. [doi:10.5588/ijtld.18.026](https://doi.org/10.5588/ijtld.18.026)

SUPPLEMENTARY MATERIALS

Supplement 1 - Home based exercises

Download: <https://cjrt.ca/article/117966-the-effects-of-adding-a-six-month-pilates-exercise-program-to-three-months-of-traditional-community-based-pulmonary-rehabilitation-in-individuals-with/attachment/229788.pdf>

Supplement 2 - Pilates program

Download: <https://cjrt.ca/article/117966-the-effects-of-adding-a-six-month-pilates-exercise-program-to-three-months-of-traditional-community-based-pulmonary-rehabilitation-in-individuals-with/attachment/229789.pdf>

Supplement 3 - Follow up number of of exacerbation episodes

Download: <https://cjrt.ca/article/117966-the-effects-of-adding-a-six-month-pilates-exercise-program-to-three-months-of-traditional-community-based-pulmonary-rehabilitation-in-individuals-with/attachment/229790.pdf>
