

Home-based rehabilitation maintenance with or without an exercise-based pilates program in COPD patients

Mantenimiento con ejercicios domiciliarios con o sin un programa de pilates basado en ejercicio en pacientes con EPOC

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Abstract

Background: Pilates exercise may complement pulmonary rehabilitation of chronic obstructive pulmonary disease (COPD) to improve patient-reported outcome measures (PROMs). **Objective:** To investigate the effects on PROMs after incorporating a six-month Pilates exercise maintenance program compared to a home-only exercise program. **Material and methods:** A total of 32 participants with COPD (GOLD B) were assigned to either the intervention group ($n = 14$) or the control group ($n = 18$). Both groups participated in a three-month pulmonary rehabilitation program. For the next six months, the intervention group engaged in a Pilates exercise program and home-based exercises, while the control group continued with home-based exercises only. Primary outcomes were evaluated at baseline, three, six, and nine months. **Results:** At the nine-month follow-up, the intervention group exhibited significantly fewer activity-related impairments in the St George's Respiratory Questionnaire Activity domain ($p = 0.029$) and experienced less symptoms of anxiety ($p = 0.002$) and depression ($p = 0.014$) according to the Hospital Anxiety and Depression Scale scores. Other PROMs did not show statistically significant differences between the groups. **Conclusion:** Incorporating a six-month Pilates exercise maintenance program resulted in fewer activity-related impairments and reduced anxiety and depression symptoms compared to those who followed a home-based exercise maintenance program alone.

Keywords: COPD. Pulmonary rehabilitation. Community-based. Home-based. Pilates.

Resumen

Antecedentes: El ejercicio de Pilates puede complementar la rehabilitación pulmonar de la enfermedad pulmonar obstructiva crónica (EPOC) para mejorar las medidas de resultado reportadas por los pacientes (MRRP). **Objetivo:** Investigar los efectos en los MRRPs tras incorporar un programa de mantenimiento de ejercicios de pilates de seis meses en comparación con un programa domiciliario de ejercicios. **Material y métodos:** Un total de 32 participantes con EPOC (GOLD B) fueron asignados al grupo de intervención ($n = 14$) o al grupo de control ($n = 18$). Ambos grupos participaron en un programa de rehabilitación pulmonar de tres meses. Durante los siguientes seis meses, el grupo de intervención participó en un programa de ejercicios de Pilates y un programa domiciliario de ejercicios, mientras que el grupo de control continuó solo con un programa domiciliario de ejercicios. Los resultados primarios se evaluaron en la línea de base a los tres, seis y nueve meses.

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Resultados: En el seguimiento de nueve meses, el grupo de intervención presentó significativamente menos limitaciones relacionadas con la actividad en el dominio de Actividad del St George's Respiratory Questionnaire ($p = 0,029$) y experimentó menos síntomas de ansiedad ($p = 0,002$) y depresión ($p = 0,014$) según las puntuaciones del Hospital Anxiety and Depression Scale. Otras MRRPs no mostraron diferencias estadísticamente significativas entre los grupos. **Conclusión:** Incorporar un programa de mantenimiento de ejercicios de pilates de seis meses resultó en menos limitaciones relacionadas con la actividad y una reducción de los síntomas de ansiedad y depresión en comparación con aquellos que siguieron únicamente un programa domiciliario de ejercicios.

Palabras clave: Enfermedad pulmonar obstructiva crónica. Rehabilitación pulmonar. Comunitario. En casa. Pilates.

Introducción

Chronic obstructive pulmonary disease (COPD) is characterized as a disabling and long-term respiratory disease, with most notable symptoms including dyspnea and productive coughing. Pulmonary rehabilitation programs are fundamental to the effective management of COPD. Various settings for pulmonary rehabilitation and strengthening exercise programs have been shown to improve COPD-related symptoms such as dyspnea, as well as other patient-reported outcome measures (PROMs) including decreased activity-related impairments, improved health-related quality of life, and reduced psycho-emotional symptoms¹⁻⁴. Evaluating PROMs is crucial to assess the effectiveness of interventions as perceived by the patient.

Community-based pulmonary rehabilitation programs are cost-effective and may yield better outcomes compared to conventional care interventions⁵. However, it is vital to implement continued supervised maintenance exercise programs following pulmonary rehabilitation to reduce health care utilization and costs⁶. Home-based pulmonary rehabilitation can supplement traditional pulmonary rehabilitation conducted in primary care or community-based settings and has demonstrated positive effects on maintaining or improving PROMs related to COPD symptoms and health-related quality of life⁷⁻¹¹. In turn, a Pilates exercise program can complement traditional pulmonary rehabilitation by providing a controlled setting for deep breathing exercises that enhance the strength of inspiratory and expiratory muscles in COPD patients¹². The breathing techniques used in Pilates training can boost lung capacity, improve the functionality of the deeper abdominal muscles¹³ and enhance the strength of expiratory muscles¹². These improvements are expected to reduce dyspnea symptoms associated with COPD, thereby potentially alleviating

COPD-related anxiety and depression symptoms and enhancing health-related quality of life.

Therefore, our main goal was to compare the benefits of home-based pulmonary rehabilitation with or without a Pilates exercise program following an initial three months of traditional pulmonary rehabilitation in individuals with COPD. The primary outcomes were dyspnea symptoms, anxiety and depression symptoms, and health-related quality of life.

Materials and methods

Design and study population

This study followed a nonrandomized clinical trial design, where the participants were assigned to the groups by the researchers. Participant allocation did not follow specific patient or COPD-related criteria but was mostly based on their geographical location and availability to regularly attend the Pilates classes for the duration of the study.

Individuals with COPD were invited to participate in the study by a general practitioner or family medicine doctor working in the National Health Service (in the north of Portugal). Participant enrollment took place between July 2018 and May 2021. The inclusion criteria comprised male or female adults (≥ 18 years old) with COPD presenting stable symptoms for the previous 3 months. COPD was diagnosed as postbronchodilation Forced Expiratory Volume in 1 second/Forced Vital Capacity (FEV_1/FVC) below 0.7¹⁴. Only those classified as grade B of the Chronic Obstructive Lung Disease (GOLD) 2024 system¹⁴ were included in this study to homogenize the symptoms of COPD among the participants. GOLD B was defined as 0 or 1 moderate exacerbation in the previous year (not leading to hospital admission), and symptoms scored by the modified Medical Research Council (mMRC) as ≥ 2

and COPD Assessment Test (CAT) as ≥ 10 . The exclusion criteria comprised older individuals (≥ 85 years old), those with a history of acute cardiac or respiratory events in the last month, or any medical condition that would limit their exercise tolerance (severe cardiac, musculoskeletal, neuromuscular conditions, or recent surgery). Individuals with psychiatric conditions or cognitive deficits, a history of neoplasia or immunologic diseases, or those unable or unwilling to attend the community-based exercise program were also excluded from the study.

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 trial¹⁵, using the between-group improvement in the St George Respiratory Questionnaire (SGRQ) total score as the reference outcome after 3 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 32 participants (16 per group) would be needed to achieve statistically significant power.

Ethics

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 the study, and all procedures were conducted in accordance with the Declaration of Helsinki.

Procedures

Participants were divided into control and intervention groups using a nonrandomized method. For the first 3 months of the study, both groups followed the same traditional community-based pulmonary rehabilitation program. After the first 3 months, both groups were instructed to continue the recommended home-based exercises for an additional 6 months; however, the intervention group was also assigned to a 6 month Pilates exercise program in addition to the home-based exercises.

Both groups were evaluated at baseline and at the end of the 3 months of initial traditional community-based pulmonary rehabilitation. Additionally, both groups were followed over time and re-evaluated at the 6th and 9th month from baseline.

Intervention

TRADITIONAL COMMUNITY-BASED PULMONARY REHABILITATION

Both groups followed the same community-based pulmonary rehabilitation intervention (2 x/week, 60 minutes each session) for the first 3 months. The same physiotherapist conducted all intervention classes, with 4 to 12 participants per class. The traditional pulmonary rehabilitation program included warm-up, aerobic exercise, resistance strengthening, and cooldown (Table 1). For the aerobic exercise, participants were instructed to walk on a treadmill or in a closed circuit outside the clinic. They started with a walking speed perceived as level 5 on the modified Borg scale. Every 5 minutes, participants were asked about their perceived dyspnea/fatigue, and if above level 6, the walking speed was decreased until reaching level 5 on the modified Borg scale. For resistance strengthening, 2 sets of 10 to 12 repetitions were required for each major muscle group (Table 1). A load that evoked fatigue after 10 to 12 repetitions was selected. Exercise dosage followed the overload principle to promote improvements in muscular strength. Load was increased when the current workload allowed for 1 or 2 repetitions over the desired 12 repetitions after two consecutive training sessions.

In addition to the face-to-face sessions, participants in both groups were encouraged to follow a recommended home-based exercise program (Supplementary data 1) throughout the study to complement the in-person classes. Participants recorded their adherence to the home-based program in an exercise diary. At the end of each week, participants were contacted (via telephone) to report their compliance with the recommended home-based exercises. If compliance was under 80% (controlled every 3 months), the participant was excluded from the follow-up.

EXERCISE PROGRAM BASED ON PILATES PRINCIPLES

The intervention group received an exercise program based on Pilates principles, implemented twice a week (45 minutes per session) and led by the same physiotherapist trained in Pilates exercise. The first session started with demonstrating a set of five basic and less physically demanding exercises (Fig. 1A–E). Each exercise was completed for 2 sets of 10 repetitions (or 8 times for each side for unilateral exercises) with 60 seconds of rest between sets and exercises. The duration of each exercise (2 sets) was around 4 to 8 minutes (including rest time and depending on the difficulty of exercises and if it was a unilateral exercise).

Table 1. Initial 3 month community-based pulmonary rehabilitation intervention program

Activity	Duration	Intensity	Exercise
Warm-up	10 minutes	Low	Joint mobility and light stretching exercises (spine, upper and lower limbs) Breathing exercises
Aerobic exercise	20 minutes	Low (4-6 on perceived dyspnea/fatigue on the modified Borg scale)	Walking
Resistance exercise	20 minutes	Moderate (70-75% RM)	Strengthening exercises of the major upper muscle groups and lower limb muscle groups as well as trunk and low back muscles using free weights and ankle weights
Cooldown	10 minutes	Low	Static and dynamic exercises at the upright position in addition to the same exercises used in the warm-up

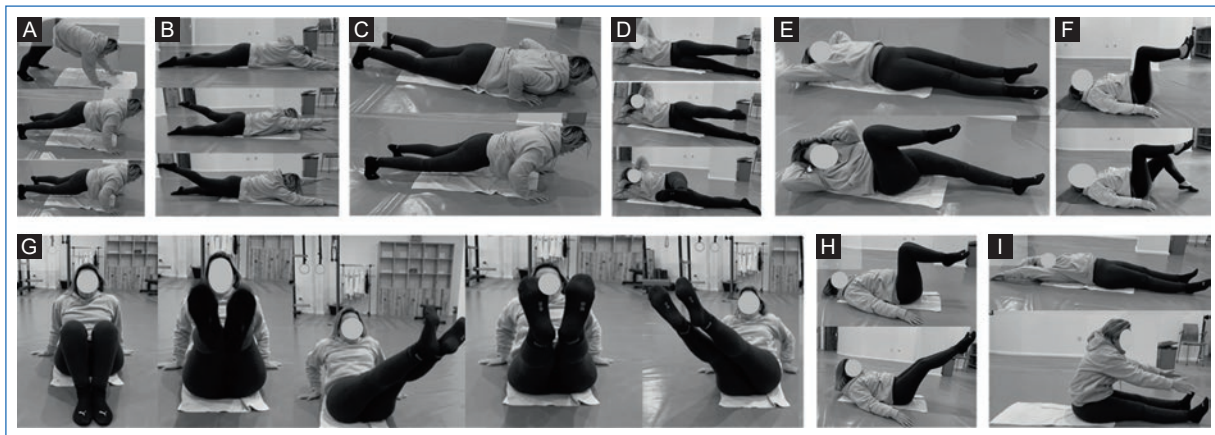


Figure 1. Summary of exercises included in the first 3 months of exercise program based on pilates principles. the first five initial exercises included: **A:** imprinting; **B:** one leg stretch; **C:** shoulder bridge; **D:** clam; **E:** saw. Then, there were four progression exercises: **F:** mermaid; **G:** spine stretch forward; **H:** bird dog; **I:** cat stretch.

Difficulty progression of exercises was made on a case-by-case basis. There were four additional and more challenging exercises available for progression (Fig. 1F–I). Participants progressed in difficulty when demonstrating that one of the five previous exercises was not challenging enough (< 4 points on the modified Borg scale). To progress in difficulty, the participant had to demonstrate that the exercise was performed with proper technique and without any compensatory movements. If the participant was unable to perform the new exercise (after progression), the exercise was regressed to the previous, less challenging one. The following week, the technique with the new exercise was retested, and progression/regression was decided as appropriate.

After the first 3 months of the Pilates exercise program, the physiotherapist introduced a set of five new

exercises (Fig. 2A–E) to provide variability and include more physically demanding exercises. There were four additional exercises available for progression (Fig. 2F–I). During this stage, each exercise was required to be completed for 2 sets of 12 repetitions, using the same progression and regression rules. However, if the participant could not tolerate the difficulty of the new set of five exercises, they regressed to the exercises of the previous stage and then progressed as tolerated. The full Pilates exercise protocol is described in the supplementary data 2.

PATIENT-REPORTED OUTCOME MEASURES

At baseline, we collected the sociodemographic and biometric data of all participants. The PROMs were collected at baseline and at 3, 6, and 9 months follow-up.

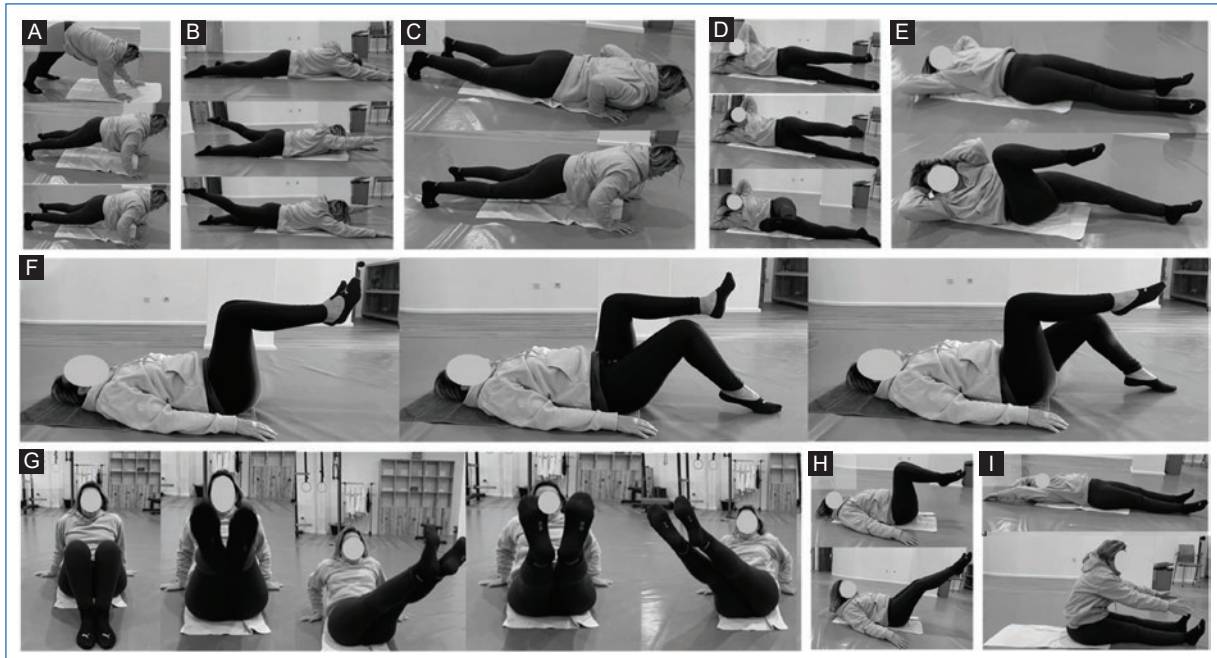


Figure 2. Summary of exercises included in the second 3 months of exercise program based on Pilates principles. The first five initial exercises included: **A:** push up; **B:** swimming; **C:** leg pull prone; **D:** side kick; **E:** criss cross. Then, there were four progression exercises: **F:** scissors; **G:** hip twist; **H:** hundred; **I:** roll up.

The PROMS included those related to dyspnea symptoms evaluated by the mMRC dyspnea scale, COPD-related quality of life evaluated by the CAT and the SGRQ, and psychological status evaluated by the Hospital Anxiety and Depression Scale (HADS). Further information on these PROMs is available in supplementary data 3.

STATISTICAL ANALYSIS

The software IBM SPSS version 29.0 was used for all statistical analyses. Due to the nonGaussian distribution (Kolmogorov–Smirnov test) and the small sample size, nonparametric statistics were conducted. Continuous variables are described using median and interquartile range, and categorical variables as count and frequency (%). A p value of 0.05 was used to determine statistical significance.

Between-group statistical differences were compared using the Mann-Whitney U tests. The χ^2 test was used to compare categorical variables between groups, with the Fisher exact test applied when appropriate. Within-group statistical differences were compared using the one-way repeated measures Friedman test with posthoc

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 due to not fulfilling the eligibility criteria. A further 25 participants were excluded as they presented other COPD grades besides GOLD B, and an additional 3 patients had a GOLD stage III or IV denoting severe airflow impairments. A total of 32 participants were eligible and enrolled in the study, with 14 allocated to the intervention group and 19 to the control group. One patient in the control group was lost to follow-up at 3 months (Fig. 3).

The baseline sociodemographic and biometric characteristics were homogeneous between the groups (Table 2). The baseline GOLD characteristics (stage and symptoms) were not significantly different between the groups. Only the rate of COPD-related exacerbations was statistically different, with the intervention group showing a significantly higher rate of two or more exacerbations in the past year (78.6% vs. 0.0%).

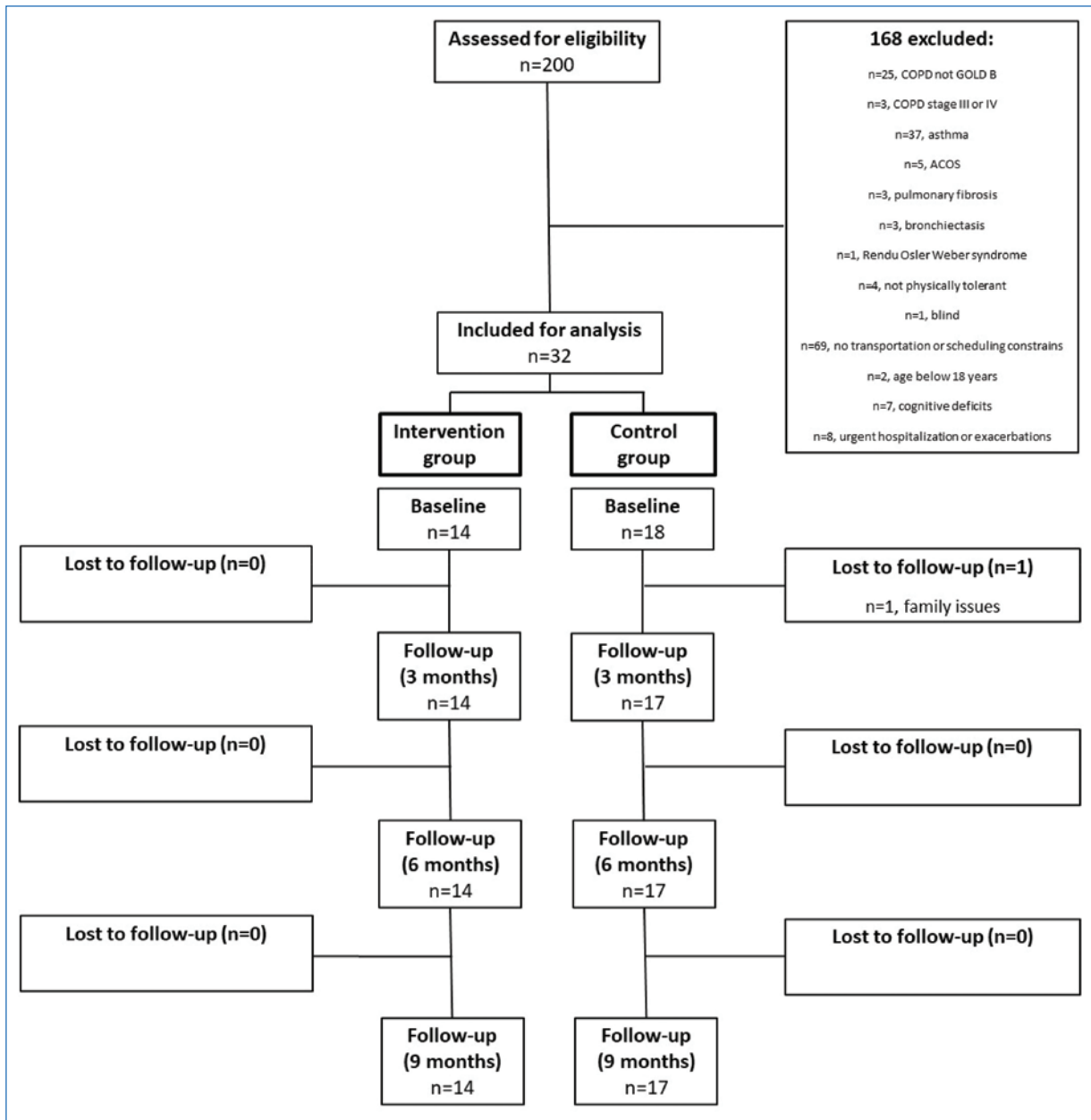


Figure 3. Flow diagram of the study.

Patient-reported outcome measures

The mMRC significantly improved after 3 months of traditional pulmonary rehabilitation in both groups and was not significantly different between groups at baseline and at the 3 month endpoint. Both groups showed a statistically significant improvement over time, but not when comparing the 9 months to 3 months, and without significant differences between groups at each follow-up endpoint (Table 3).

The CAT score was not significantly different between groups at baseline and after 3 months of traditional pulmonary rehabilitation. However, the control group showed a statistically significant improvement of 8 points at 3 months ($p = 0.009$). After 6 months of pilates (9 month follow-up), the intervention group showed a statistically significant decrease of 7 points ($p = 0.033$), while the control group displayed a deterioration of the CAT score from 8 points at 3 months to 14 points at 6 months ($p = 0.023$), which maintained at 9 months.

Table 2. Baseline sociodemographic, biometric and COPD-related characteristics of included participants

Variables	Intervention group (n = 14)	Control group (n = 18)	p
Age (years)	65.5 (11.8)	66.5 (10.5)	0.561
Sex			
Male	11 (78.6%)	12 (66.7%)	0.694*
Female	3 (21.4%)	6 (33.3%)	
Heigh (m)	1.65 (0.16)	1.65 (0.13)	0.955
Weight (Kg)	74.0 (19.5)	72.0 (22.8)	0.925
% of fat mass	26.1 (15.4)	25.3 (18.6)	0.357
BMI (kg.m ⁻²)	25.7 (6.9)	25.3 (7.0)	0.837
GOLD stage (%)			
GOLD I	2 (14.3%)	9 (50.0%)	0.061*
GOLD II	12 (85.7%)	9 (50.0%)	
GOLD symptoms			
CAT < 10	3 (21.4%)	0 (0%)	0.073*
CAT ≥ 10	11 (78.6%)	18 (100%)	
GOLD exacerbations			
AECOPD < 2	3 (21.4%)	18 (100%)	< 0.001*
AECOPD ≥ 2	11 (78.6%)	0 (0%)	

*Exact Fisher test.

AECOPD: acute exacerbations of COPD; BMI: Body Mass Index; CAT: COPD Assessment Test; GOLD: Global Initiative for Chronic Obstructive Lung Disease system.

However, the CAT score was not statistically significant between groups at the 6 and, 9 months follow-up (Table 3).

The SGRQ total score was not significantly different between groups at baseline and after 3 months of traditional pulmonary rehabilitation. However, the control group showed a statistically significant improvement of 17.3 points at 3 months ($p = 0.004$). During the subsequent 6 months of intervention (9 month follow-up), the intervention group showed a statistically significant improvement ($p = 0.023$), whereas the control group did not show any change ($p = 0.326$). There were no significant differences between the groups at any of the follow-up timepoints (Table 3).

When comparing the SGRQ domains, there were no significant differences between groups at baseline and after 3 months of traditional pulmonary rehabilitation. Statistically significant improvements were observed from baseline to 3 months in the SGRQ Activity and Impact domains for the control group, with a median decrease of 12.5 points ($p = 0.022$) and 24.2 points ($p = 0.026$), respectively. Despite these improvements in the control group at 3 months, there were no significant

between-group differences (Table 3). For the SGRQ Activity domain, the control group further improved by 11.2 points at 6 months ($p = 0.030$) but reverted back to 47.7 points at 9 months without any differences compared to 3 months ($p = 0.925$). For the SGRQ Impact domain, the control group showed a deterioration of the score at 6 months with an increase of 14.2 points ($p = 0.044$), which remained at 9 months ($p = 0.152$ compared to 6 months and $p = 0.156$ compared to 3 months). The intervention group did not show any statistically significant improvement between follow-up timepoints (Table 3). However, the SGRQ Activity domain was significantly lower in the intervention group at 9 months (29.8 vs. 47.7 points, $p = 0.029$), indicating less impairment in daily-living activities. No significant changes were observed for the SGRQ Symptoms domain between the two groups or at any timepoints during the follow-up within each group (Table 3).

The HADS score was not significantly different between groups at baseline and after 3 months of traditional pulmonary rehabilitation. The HADS Anxiety domain showed a significant improvement over time in the intervention group, improving by 1 point at 3 months ($p = 0.027$) and

Table 3. Comparison within and between groups at baseline and follow-up of patient-reported outcome measures (PROMs)

Variables	Groups	Baseline	3 months	6 months	9 months	Overall
mMRC (0-4)	Intervention	2.0 (1.0)	2.0 (1.0)*	1.5 (2.0)	0.5 (2.0)	0.002
	Control	2.0 (1.0)	1.0 (0.0)*	1.0 (1.0)	1.0 (1.0)	0.004
	Between groups	0.071	0.161	0.769	0.297	
CAT (0-40)	Intervention	19.5 (14.0)	16.0 (11.0)	11.5 (16.0)	9.0 (17.0) [†]	0.019
	Control	16.0 (9.0)	8.0 (12.0)*	14.0 (8.0) [†]	14.0 (8.0)	0.002
	Between groups	0.866	0.053	0.570	0.215	
SGRQ - Symptoms (0-100)	Intervention	42.4 (36.6)	42.4 (25.6)	38.0 (25.0)	35.8 (51.1)	0.041
	Control	43.3 (30.8)	32.1 (43.4)	42.9 (37.6)	28.5 (33.3)	0.095
	Between groups	1.000	0.493	0.597	0.468	
SGRQ - Activity (0-100)	Intervention	55.3 (46.2)	45.6 (49.1)	34.1 (50.1)	29.8 (32.8)	0.031
	Control	59.5 (15.8)	47.0 (32.6)*	35.8 (39.3) [†]	47.7 (23.4)	0.005
	Between groups	0.357	0.739	0.922	0.029	
SGRQ - Impact (0-100)	Intervention	26.0 (46.9)	25.3 (31.9)	19.3 (32.5)	17.3 (40.7)	0.321
	Control	38.5 (26.8)	14.3 (35.8)*	28.5 (36.6) [†]	26.6 (33.3)	0.014
	Between groups	0.561	0.131	0.262	0.681	
SGRQ - Total (0-100)	Intervention	34.1 (37.8)	35.7 (32.4)	34.4 (33.6)	35.1 (34.8) [†]	0.066
	Control	43.6 (20.8)	26.3 (38.1)*	33.4 (20.1)	29.9 (34.8)	0.005
	Between groups	0.206	0.423	0.681	0.444	
HADS - Anxiety (0-21)	Intervention	7.0 (9.0)	6.0 (6.0)*	4.5 (6.0)	5.5 (7.0) [†]	0.001
	Control	8.0 (8.0)	7.0 (5.0)	9.0 (5.0) [†]	10.0 (5.0) [†]	0.101
	Between groups	0.985	0.681	0.010	0.002	
HADS - Depression (0-21)	Intervention	3.5 (8.0)	4.5 (5.0)	4.0 (4.0)	4.0 (6.0)	0.427
	Control	8.0 (4.0)	6.0 (5.0)*	8.0 (5.0) [†]	6.0 (3.0)	< 0.001
	Between groups	0.054	0.653	0.002	0.015	

Data presented as median and IQR. Lower values denote less dyspnea (mMRC), less impairment (CAT and SGRQ) and less anxiety and depression symptoms (HADS).

*p < 0.05 vs baseline.

[†]p < 0.05 vs 3 months.

CAT: COPD Assessment Test; HADS: Hospital Anxiety and Depression Scale; SGRQ: St George Respiratory Questionnaire; mMRC: modified Medical Research Council.

by another 0.5 points at 9 months ($p = 0.041$ compared to 3 months). The control group deteriorated at 6 months by 2 points ($p = 0.027$) and by another 1 point at 9 months ($p = 0.041$ compared to 3 months). The HADS Depression domain did not show any significant changes in the intervention group. In the control group, although it improved by 2 points after 3 months of traditional pulmonary rehabilitation ($p = 0.016$), it reverted by 2 points at 6 months ($p < 0.001$) without significant differences at 9 months compared to 3 months ($p = 0.303$). The intervention group

showed significantly less anxiety and depression symptoms than the control group at both 6 and, 9 months follow-up (Table 3).

Discussion

The results of the study demonstrate significant improvement in decreasing the impairment in daily activities and reducing the anxiety and depression symptoms following a 6 months combined intervention of

Pilates with home-based exercises as compared to only home-based exercises in individuals with COPD. Participants in the intervention group experienced a significantly higher rate of exacerbations at baseline and it is thus advised some caution when analyzing the results at follow-up as exacerbations may influence treatment indications and prognosis.

In the evaluation of dyspnea carried out through mMRC, both intervention and control groups exhibited a significant improvement in mMRC scores after 3 months of traditional pulmonary rehabilitation. There were no significant differences in mMRC scores between the groups at baseline and the 3 month endpoint, highlighting the effectiveness of both interventions in enhancing breathlessness perceptions. Although there were not statistically significant differences in dyspnea symptoms (as measured by the mMRC) in both groups at 9 months follow-up, there was a significant change over-time within each group ending with a median mMRC of grade 1 in both the intervention and control groups. The median improvement surpassed the minimal clinically important difference (MCID) of -0.5 and -1 units^{16,17} and changed from breathless at a normal walking pace (grade 2) to breathless only when walking at a fast pace or up a slight hill (grade 1). These results are superior to those reported for community-based pulmonary rehabilitation that show no significant improvement in the mMRC as compared to usual care⁵. A recent Cochrane review¹⁸ found significant improvement in dyspnea assessed with the mMRC when comparing inspiratory muscle training against control or sham groups. Likewise, a recent trial¹⁹ found a similar improvement in the mMRC after 3 months of traditional pulmonary rehabilitation in patients with mild COPD. These findings may help explain the improvements in the mMRC after 3 months of traditional pulmonary rehabilitation. Other studies^{20,21} found improvement in mMRC after 3 months home-based pulmonary rehabilitation in mild COPD patients which highlight the role of home-based exercises and why our control group with only home-based exercises also maintained the improvement (from the initial traditional pulmonary rehabilitation) throughout the remaining 6 months of the study.

The CAT scores did not significantly differ between groups initially and after 3 months of traditional pulmonary rehabilitation. Whereas the control group did not show any within-group significant improvement, the Pilates intervention demonstrated a notable improvement at 9 months (median improvement of 7 points), indicating its potential benefit in reducing COPD symptoms captured by the CAT questionnaire. This large improvement is more than 4-fold the established MCID

of -1.6 units for the CAT score¹⁸, ending at 9 months with a low COPD-related symptom burden impact. The improvement in the CAT score by the intervention group is consistent (and event superior) to those reported in a recent study²¹ showing a decrease of 6 points after 3 months of a home-based pulmonary rehabilitation program. Likewise, the median 7 points improvement is also superior to the pooled change of -3 points in CAT score reported in a recent Cochrane review¹⁸ comparing inspiratory muscle training against control or sham groups. Conversely, the CAT of the control group at 6 months reverted back to baseline values, highlighting that home-based exercises may not be enough to maintain the improvement in COPD-related symptom burden obtained after the traditional pulmonary rehabilitation.

In the evaluation carried out by SGRQ, the total scores did not significantly differ between groups at baseline and after 3 months of traditional pulmonary rehabilitation. The control group showed a significant improvement after the initial 3 months traditional pulmonary rehabilitation but deteriorated at follow-up with no significant changes comparing to the baseline values. The improvements in the SGRQ Activity and Impact domains in the control group at 3 months indicate the effectiveness of traditional pulmonary rehabilitation. The intervention group did not show such significant improvement at 3 months, which may be related to the higher rate of exacerbations at baseline. The subsequent improvements in the SGRQ Activity domain in the control group at 6 months suggest that the maintenance with home-based exercises was effective in reducing the COPD impact on daily activities. However, the SGRQ Activity domain deteriorated in the control group at 9 months, with the intervention group showing significantly less breathlessness-related impairment in daily-living activities. The between-group difference at 9 months was almost 18 points which is clinically relevant and surpassing by 450% the -4 units established as MCID^{22,23}. The isolated improvement in the SPGQ Activity domain is also consistent with the findings of a recent meta-analysis⁵ which showed that improvement in the SPGQ score was only significant for the SPGQ Activity domain. While traditional pulmonary rehabilitation programs significantly improve COPD-related quality of life as measured by the SPGQ^{19,24}, further long-term improvements with maintenance pulmonary rehabilitation programs are not expected^{18,25}.

The HADS Anxiety and Depression domains depicted varying patterns of improvement and deterioration over time in both groups. Notably, the intervention group showed significantly reduced anxiety and depression

symptoms relative to the control group at the 6- and 9 month follow-ups highlighting the potential influence of Pilates on these PROMs. While the control group deteriorated or maintained the anxiety and depressive symptoms at 9 months, the intervention group showed a significant decrease in anxiety symptoms after the 6 months of Pilates program. However, the median improvement did not surpass the MCID of -1.8 to -1.3 units²⁶. These findings denote a potential role of Pilates in the psychological status of COPD patients. Indeed, the anxiety symptoms in the intervention group at 9 months were almost half of those for the control group. The control group had a median HADS anxiety score of 10 points at 9 months, which is borderline value and close to the 11 points determined for clinical anxiety²⁷. Although the significant differences in the depression domain at 9 months, it is important to highlight that the intervention group already had fewer depressive symptoms at baseline (albeit not statistically significant), which may partially explain the differences at 9 months follow-up. The improvement in anxiety and depressive symptoms is consistent with those reported in randomized control trials that implement community-based pulmonary rehabilitation programs^{28,29} as well as for clinical trials implementing Pilates exercise in other clinical conditions³⁰⁻³³. However, maintenance programs seem to not improve the anxiety and depression symptoms as compared to usual care³⁴, which may explain why the control group with only home-based exercises experienced deterioration of the HADS score. It may be speculated that improvement in anxiety symptoms in the intervention group may be from a better control of respiratory function and relaxation from the Pilates exercise. Likewise, the lower anxiety and depression symptoms in the intervention group throughout the 6 months after the traditional pulmonary rehabilitation may be related to the group interaction and sociability with other COPD patients during the Pilates sessions. This is an important finding because improving anxiety and depression symptoms is a challenging clinical task in patients with COPD, even when tailored psychological interventions based on a cognitive behavioral approach are implemented³⁵.

Clinical implications

The study findings underscore the importance of traditional pulmonary rehabilitation and Pilates as effective interventions in improving COPD symptoms and patient well-being. The observed improvements in some PROMs suggest potential benefits of these interventions in reducing COPD-related impairments and in enhancing

quality of life and mental health in individuals with COPD. The superior improvement in the SGRQ Activity domain indicate that Pilates exercise may be a useful tool to control the dyspnea symptoms and reduce the COPD-related daily living impairments that are often compromised by respiratory problems such as cough and shortness of breath³⁶. Moreover, the lower anxiety symptoms in the intervention group underpin that face-to-face group rehabilitation should be prioritized when available to promote peer-to-peer interaction and thus decrease the potential risk of worsening of psychological status of COPD patients when undertaking home-based rehabilitation isolated and by themselves. Indeed, it is known that social isolation and loneliness are common issues among patients with COPD³⁷ and that these patients are at risk of for mental disorders as anxiety and depressive states are diagnosed in more than half of COPD patients³⁸. It is important that clinicians, policymakers, and health systems take steps to identify and address social isolation and loneliness in COPD individuals³⁹ and promote group-based sessions where possible. In cases where face-to-face pulmonary rehabilitation is not possible, it is important to identify barriers in the home environment and facilitators to implement home-based strategies for effective self-management interventions.

Future research directions

Future research could focus on exploring the sustainability of intervention effects beyond 9 months and examining the long-term benefits of augmenting the traditional pulmonary rehabilitation with a Pilates exercise program.

Further investigations could also explore the individual variability in response to these interventions (with a higher sample size) and identify optimal approaches for personalized COPD management.

Limitations

This study has some limitations that need to be acknowledged. The small size is small and unbalanced, with the intervention group having a lower sample due to the exclusion of some patients who were not classified as GOLD B. Although 28 participants with grades other than GOLD B or GOLD stage III/IV completed the entire study, it was decided to exclude these from analyses to prevent selection bias. The small sample resulted in low statistical power in analyses and may have led to type II error in not finding statistical differences when the between-groups differences were clinically relevant

(e.g., for mMRC or CAT). Another limitation was the lack of randomization that may have introduced selection bias at the start of the study; although no significant differences were found between groups for PROMs at baseline, the participants in the intervention group experienced a significantly higher rate of exacerbations which may have influenced the follow-up outcomes. Future studies should implement randomization procedures to mitigate risk of selection bias. All patients were from the same region of the country which may have introduce selection and geographical bias and limits the generalizability (external validity) of our findings to individuals with COPD from other regions of the country and other countries. Outcome evaluations were made by the same health professional that delivered the interventions (not blinded) which may have introduced a risk of detection bias and influenced the way that outcome measures were assessed. Moreover, the intervention group received for 6 months a Pilates exercise program (in addition to the home-based exercises) as compared to the control group that only engaged in the home-based exercises which may have had an effect on PROMs due to added exposure to intervention and influence the adherence to a longer-lasting intervention (6 months). The control group receive minor intervention during the follow-up period (home-based exercises), as it would have been unethical to leave these patients without any guidance. To minimize the risk of performance bias, participants in the intervention group were instructed to also follow the same home-based program, with the adherence of both groups being monitored to ensure that it met at least 80% of the recommended frequency.

Conclusion

This study highlights the positive impact of augmenting the traditional pulmonary rehabilitation with a Pilates exercise program in decreasing the impairment in daily activities and reducing the anxiety and depression symptoms in individuals with COPD. These findings contribute to the growing body of evidence supporting the efficacy of comprehensive rehabilitation programs in enhancing COPD management and patient well-being.

Author contributions

All authors were involved in the conception of this study. M. Barbosa performed the interventions, collected all data and conducted the statistical analysis. C. Argel-de Melo and R. Torres guided and provide

advice during all steps, as well as critical revision of the content. All authors contributed to the drafting of the manuscript and approved the final submitted work.

Supplementary data

Supplementary data are available at DOI: 10.24875/RPR.24000039. These data are provided by the corresponding author and published online for the benefit of the reader. The contents of supplementary data are the sole responsibility of the authors.

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Conflicts of interest

None.

Ethical considerations

Protection of humans and animals. The authors declare that the procedures followed complied with the ethical standards of the responsible human experimentation committee and adhered to the World Medical Association and the Declaration of Helsinki. The procedures were approved by the institutional Ethics Committee.

Confidentiality, informed consent, and ethical approval. The authors have followed their institution's confidentiality protocols, obtained informed consent from patients, and received approval from the Ethics Committee. The SAGER guidelines were followed according to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that no generative artificial intelligence was used in the writing of this manuscript.

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