

# Pulmonary rehabilitation in severe chronic obstructive pulmonary disease: Is there any benefit?



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**Background:** Pulmonary rehabilitation (PR) is a key pillar in the management of chronic obstructive pulmonary disease (COPD). Nevertheless, adherence to PR is low, especially in advanced COPD patients who frequently suffer from poor health and severely impaired functional capacity.

**Objectives:** The aim of this study is to evaluate whether a home-based PR programme could benefit severe COPD patients' physical and respiratory functions.

**Method:** This is a prospective interventional study in which stage IV COPD patients received a home-based, customised PR programme for 3 weeks. Baseline Barthel functional scale, dyspnoea grade, COPD assessment test (CAT) score and 6-min walking test (6MWT) were all assessed before and after the programme.

**Results:** Forty patients were enrolled; their mean age was  $66.43 \pm 2.99$  years. A significant reduction in dyspnoea severity was observed, with 40% of patients reaching grade I and 37.5% becoming grade II, while on the other hand, grade III, the most prevalent pre-PR grade, was reduced (7.5%) at the end of the 3 weeks. The mean CAT score, Barthel score and 6MWT distance showed a highly significant (HS) reduction ( $p < 0.001$ ).

**Conclusion:** Home-based, low-intensity PR programmes could be beneficial in severe COPD and can serve as an alternative in case of difficulties in attending clinical settings.

**Contribution:** Home-based PR programmes may ensure long-term adherence to rehabilitation, which decreases patients' disabilities and facilitates a shift towards positive lifestyle changes.

**Keywords:** pulmonary rehabilitation; PR; severe COPD; home-based; physical exertion.

## Introduction

Chronic obstructive pulmonary disease (COPD) is a diverse lung condition marked by chronic respiratory symptoms because of airway abnormalities, ending in persistent and often worsening airflow limitation (Agusti & Vogelmeier 2023). Its management has multiple approaches combining medical therapy with pulmonary rehabilitation (PR) associated with lifestyle modifications (Venkatesan 2024).

Patients with COPD tend to be less physically active compared to individuals of the same age group. This inactivity is often driven by a growing fear of physical exertion. As a result, their physical capabilities decline, particularly in areas such as endurance, coordination and balance (Hanania & O'Donnell 2019). In addition, the muscles in their lower limbs undergo atrophy, characterised by a reduction in muscle fibre size and a decrease in mitochondrial density. This loss of mitochondria, which are crucial for energy production, contributes to further muscular deconditioning and weakness (Henrot et al. 2023).

All these lead to a decline in lung function and recurrent exacerbations, which are common in patients with COPD that end with hospital readmission and a high socioeconomic burden (Hurst et al. 2020; Tachkov et al. 2017).

The health and social consequences of COPD underscore the importance of implementing cost-effective interventions and secondary prevention strategies to reduce its side effects. In this context, engaging in physical activity and exercise-based interventions is a cost-effective approach, offering significant improvements in quality of life (Ramos et al. 2019).

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Pulmonary rehabilitation, which includes structured exercise training, is recognised as a cornerstone of COPD management (Evans & Steiner 2017). Experts emphasise that PR provides broad benefits across all stages of COPD, even in the presence of multiple comorbidities, and it improves various health-related outcomes (Agusti & Vogelmeier 2023, Houben–Wilke et al. 2017), resulting in exacerbation and hospitalisation reduction (Shu et al. 2021). However, maintaining physically active behaviours and adherence to such programmes after completing PR remains low and poses a significant challenge, particularly in patients with severe COPD, as they struggle with poor health and multiple comorbidities. So the gains achieved during PR often diminish within 6–12 months after the programme ends (Blindenbach et al. 2017; Malaguti et al. 2021). This causes muscular atrophy and leads to limitations in physical functioning, endurance and activity (Hsieh, Yang & Tsai 2016).

Therefore, a home-based programme is another method of integrating PR into daily living patterns and may facilitate adherence as an alternative to removing most of the limitations.

It enhances patients' self-confidence, breaks down 'psychological barriers' and promotes long-term adherence to healthier behaviours (Meshe 2023). By facilitating a shift towards positive lifestyle changes, it also helps to reduce financial burdens. Because rehabilitation programmes are designed around everyday activities, it is easy to simplify, explain and supervise this therapy (Yohannes et al. 2021).

Recent studies have demonstrated that implementing a home-based rehabilitation programme can effectively maintain and enhance the self-confidence and quality of life of patients with COPD, in comparison to traditional rehabilitation (Belloumi et al. 2024).

So, we conducted our study to assess the effectiveness of a home-based PR programme in patients with severe COPD and whether it provides a significant benefit to physical and respiratory functions.

## Research methods and design

### Patients

#### Study design

This was a prospective interventional study, approved by the Research Ethics Committee FMASU (R 264/2024), and registered with the PACTR (Pan African Clinical Trial Registry) with registration number PACTR202502532021451.

#### Patients' recruitment

The study was conducted between November 2024 and January 2025 and included clinically stable COPD patients ( $\geq 60$  years) of both sexes who were stage IV, according to the updated Global Initiative for COPD (GOLD-2024) criteria (Agusti & Vogelmeier 2023), and recruitment was performed from the rehabilitation clinic at the authors' institution.

We excluded patients with (1) psychiatric disease, (2) malignancy or immunologic diseases reported in their history or investigation, and (3) respiratory exacerbation requiring hospital admission during the inclusion period.

### Treatment group

A total of 47 patients with COPD were enrolled and 40 of them completed the study. Before enrolment, an explanation of the study was performed and written consent was obtained. Then they received a home-based exercise programme after training on this programme by the therapist.

### Pulmonary rehabilitation programme intervention details

#### Initial assessment and baseline measures

All participants underwent the following baseline evaluations prior to initiation of the PR programme:

- Full medical history and clinical examination
- Baseline oxygen saturation ( $SpO_2$ ) at rest
- Baseline diagnostic spirometry (pre-bronchodilator) (Agusti & Vogelmeier 2023)
- Barthel Index for functional status (Fi 1965)
- Modified Medical Research Council (mMRC) dyspnoea scale (Bestall et al. 1999)
- COPD assessment test (CAT) score (Jones et al. 2009)
- 6-Minute walking test (6MWT) (Sciurba & Slivka 1998)

These assessments were conducted between 8:00 and 10:00 by a multidisciplinary team, including a chest physician and rehabilitation consultant. All patients underwent regular nutritional status assessments and were provided with personalised advice by a qualified clinical dietitian (Geerars-van der Veen et al. 2024).

#### Rehabilitation programme description

A personalised, home-based multidimensional PR programme was developed in line with ERS/ATS guidelines (Rochester et al. 2015), tailored to each patient's physical capabilities and medical status. The programme began only after optimising the medical treatment.

#### Frequency and duration:

- Sessions were prescribed 7 times per week, with at least 15 sessions over 3 weeks.
- Each session lasted approximately 45–60 min, including warm-up, main exercise set and cool-down.
- Patients received weekly video or phone consultations to adjust intensity and monitor progress.

#### Intensity prescription and progression criteria:

- Exercise intensity was guided using the (mMRC) dyspnoea scale and Rate of Perceived Exertion (RPE), targeting RPE 4–6 (moderate to somewhat hard).
- Heart rate was monitored with a pulse oximeter, aiming for 50% – 70% of estimated HRR (Heart Rate Reserve).

- Progression by, the ability to complete current exercise set with RPE < 4, No desaturation events ( $\text{SpO}_2 < 88\%$ ), No reports of increased dyspnoea or fatigue during the session.

**Exercise components:** The programme included the following components, using minimal or no equipment for feasibility:

- Warm-up and stretching exercises (5–10 min).
- Active range of motion (AROM): exercises for upper and lower limbs, shoulder circles, elbow flexion and extension, wrist rotations and hip, knee, and ankle movements. Two sets with 10–12 repetitions per joint (rest: 30 s between sets).
- Strengthening exercises: using light dumbbells 1 kg – 2 kg or resistance bands, bicep curls, shoulder presses, seated leg extensions and heel raises, 2 sets with 8–10 repetitions (rest: 1 min between sets).
- Endurance training: brisk walking, progressive increase weekly (goal: 10–30 min based on baseline 6MWT and tolerance).
- Respiratory exercises: diaphragmatic breathing, pursed-lip breathing, chest expansion and respiratory muscle training (with incentive spirometer or balloon blowing 5–10 repetitions each).
- Balance and gait training: Trunk–abdominal exercises, seated marches (20 repetitions), pelvic tilts (10 repetitions), 2 sets, single-leg stand (hold 10–15 sec per leg, 3 repetitions), heel-to-toe walking (10 steps), 2 sets.
- Postural drainage uses gravity-assisted positioning to mobilize bronchial secretions from peripheral to central airways, with patient positioning based on the affected lung segments and maintained for 5–15 min. This is followed by effective coughing, involving deep inhalation, breath-holding, and a forceful, controlled cough to expel secretions.
- Relaxation techniques: 5–10 min of progressive muscle relaxation (post-exercise) and guided breathing.

**Safety instructions:** Patients received both oral and written safety guidelines for home-based exercises, including:

- Clear instructions to stop exercise if  $\text{SpO}_2$  drops below 88%, or if they experience chest pain, dizziness or severe shortness of breath.
- All participants were advised to exercise in well-ventilated areas and keep a phone nearby in case of emergency.
- Adequate hydration and, for those with low BMI, a high-protein diet.

**Adherence monitoring:** Adherence was defined a priori as completing at least 30 min of physical activity per day on five or more days per week, with a minimum of 150 min weekly. Patients maintained daily logbooks recording:

- Duration and type of exercise
- RPE
- Any symptoms experienced

Weekly follow-up was conducted via phone or WhatsApp, where patients reported on their performance and barriers to adherence.

**Equipment used:** Minimal home-based equipment was used:

- Resistance bands or dumbbells
- Incentive spirometers or balloons for breathing exercises
- Pulse oximeter
- Chairs for seated and support-based exercises

**Adverse events monitoring:**

- Patients were instructed to report any falls, significant desaturation episodes ( $\text{SpO}_2 < 88\%$  for > 30 s) or COPD exacerbations.
- Weekly safety checks were part of the follow-up protocol.
- No serious adverse events were reported. Minor symptoms included temporary muscle soreness ( $n = 6$ ), transient mild dyspnoea ( $n = 4$ ) and one case of a missed session because of an unrelated viral illness.

## Post-intervention reassessment

After 3 weeks, the following measures were reassessed to evaluate programme effectiveness.

Primary outcome:

- mMRC dyspnoea scale
- CAT score
- 6MWT
- Barthel Index

Secondary outcome:

- $\text{SpO}_2$

## Sample size

Based on the results of Lan et al. (2018), with improvement of dyspnoea score after exercise from 5.7 to 4.8, the alpha error was 5% and the power of the study was 90%; therefore, the required sample size was 40 patients. STATA 10 was the programme used for sample size calculation.

## Statistical analysis

The data were gathered, reviewed, coded and input into the Statistical Package for Social Science (IBM SPSS) (IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0., Armonk, New York, United States). Quantitative data were expressed as means, standard deviations (s.d.) and ranges for parametric data, while medians and interquartile ranges (IQR) were used for non-parametric data. Qualitative variables were summarised using numbers and percentages.

The Wilcoxon signed-rank test was applied for non-parametric data or when comparing paired ordinal data. A 95%

confidence interval was used, with a 5% margin of error accepted. The  $p$ -value was interpreted as follows:  $p$ -value > 0.05: Non-significant (NS);  $p$ -value < 0.05: Significant (S);  $p$ -value < 0.01: Highly significant (HS).

## Ethical considerations

Ethical clearance to conduct this study was obtained from the Ain Shams University, Faculty of Medicine Research Ethics Committee (No. FMASU R264/ 2024).

## Results

Forty-seven COPD (GOLD IV) patients were enrolled in the study; 7 of them were excluded because of having respiratory exacerbation with a need for hospital admission during the inclusion period, and 40 patients completed the study. We analysed data from patients at baseline, before the beginning of PR and after 3 weeks of the home-based PR programme.

## Demographics and disease characteristics data

The mean age of the included patients was  $66.43 \pm 2.99$  years. The mean disease duration was  $8.45 \pm 3.07$  years (Table 1).

## Baseline assessment of clinical parameters

Baseline assessment of clinical parameters showed that nearly half of the patients (47.5%) had dyspnoea grade III, while more than a third (35%) had grade II. The mean CAT score was  $26.95 \pm 3.61$ , the mean Barthel Index score was  $17.53 \pm 1.57$ , and the mean 6MWT distance was  $224.25 \pm 107.19$  metres (Table 2).

**TABLE 1:** Demographic data and characteristics of the studied patients ( $N = 40$ ).

Characteristic	<i>n</i>	%	Mean $\pm$ s.d.	Range
Age (years)	-	-	$66.43 \pm 2.99$	61–72
Sex				
Female	16	40	-	-
Male	24	60	-	-
Duration of COPD	-	-	$8.45 \pm 3.07$	4–16

s.d., standard deviation; COPD, chronic obstructive pulmonary disease.

## Comparison of the parameters studied before and after pulmonary rehabilitation

A comparison of the results before and after PR revealed a HS improvement in all assessed parameters. A substantial improvement in dyspnoea severity was observed, with 40% of patients reaching grade I and 37.5% becoming grade II, while on the other hand, grade III, the most prevalent pre-PR grade was reduced (7.5%) at the end of the programme. These findings reflect a significant reduction in dyspnoea severity. The mean CAT score improved to  $21.85 \pm 3.94$ , showing a HS reduction compared to the pre-PR values. Similar improvements in Barthel score and 6MWT distance ( $p < 0.01$ ) were observed (Table 3).

## Reported adherence

Across the study population, the mean adherence rate  $\pm$  s.d. was  $88.2\% \pm 7.5\%$ , indicating good compliance. Notably, 38 out of 40 participants (95%) achieved adherence rates exceeding 75%.

**TABLE 2:** Studied parameters before pulmonary rehabilitation ( $N = 40$ ).

Studied parameters	<i>n</i>	%	Mean $\pm$ s.d.	Range
Dyspnoea grade (mMRC)				
Grade 0	0	0.0	-	-
Grade I	5	12.5	-	-
Grade II	14	35.0	-	-
Grade III	19	47.5	-	-
Grade IV	2	5.0	-	-
CAT score	-	-	$26.95 \pm 3.61$	20–35
Barthel score (0–20)	-	-	$17.53 \pm 1.57$	14–20
FEV <sub>1</sub> (L)	-	-	$0.75 \pm 0.10$	0.54–0.89
FEV <sub>1</sub> (% predicted)	-	-	$68 \pm 9$	49–81
6MWT SPO <sub>2</sub> at rest (%)	-	-	$93.98 \pm 2.20$	90–99
6MWT SPO <sub>2</sub> after (%)	-	-	$87.77 \pm 5.08$	79–95
6MWT Distance (m)	-	-	$224.25 \pm 107.19$	50–400

s.d., standard deviation; mMRC, modified Medical Research Council; CAT, COPD assessment test; FEV<sub>1</sub>, forced expiratory volume in the first second; 6MWT, six-minute walking test; SPO<sub>2</sub>, oxygen saturation.

**TABLE 3:** Comparison between studied parameters before and after pulmonary rehabilitation treatment.

Studied parameters	Before PR				After PR				Test value ( <i>df</i> )		<i>p</i> -value
	<i>n</i>	%	Mean $\pm$ s.d.	Range	<i>n</i>	%	Mean $\pm$ s.d.	Range	<i>z</i>	<i>t</i>	
Dyspnoea grade (mMRC)	-	-	-	-	-	-	-	-	25.433*	-	< 0.001 HS
Grade 0	0	0.0	-	-	6	15.0	-	-	-	-	-
Grade I	5	12.5	-	-	16	40.0	-	-	-	-	-
Grade II	14	35.0	-	-	15	37.5	-	-	-	-	-
Grade III	19	47.5	-	-	3	7.5	-	-	-	-	-
Grade IV	2	5.0	-	-	0	0.0	-	-	-	-	-
CAT score	-	-	$26.95 \pm 3.61$	20–35	-	-	$21.85 \pm 3.94$	15–30	-	(39) = 16.36	< 0.001 HS
Barthel score	-	-	$17.53 \pm 1.57$	14–20	-	-	$18.28 \pm 0.96$	16–20	-	<i>t</i> (39) = -5.27†	< 0.001 HS
6MWT SPO <sub>2</sub> at rest (%)	-	-	$93.98 \pm 2.20$	90–99	-	-	$94.55 \pm 2.22$	91–99	-	<i>t</i> (39) = -2.22†	0.032 S
6MWT SPO <sub>2</sub> after (%)	-	-	$87.77 \pm 5.08$	79–95	-	-	$89.35 \pm 4.90$	81–96	-	<i>t</i> (39) = -2.08†	0.044 S
6MWT Distance (m)	-	-	$224.25 \pm 107.19$	50–400	-	-	$320.90 \pm 108.99$	100–450	-	<i>t</i> (39) = -8.06†	< 0.001 HS

Note:  $p$ -value < 0.05: Significant (S);  $p$ -value < 0.01: Highly significant (HS);  $p$ -value > 0.05.

NS, non-significant; PR, pulmonary rehabilitation; mMRC, modified Medical Research Council; CAT, COPD Assessment Test; 6MWT, six-minute walking test; SPO<sub>2</sub>, oxygen saturation; *df*, degree of freedom.

†, Paired *t*-test.

\*, Wilcoxon signed-rank test.

## Discussion

We conducted our study to assess the effectiveness of a home-based PR programme in severe COPD patients and whether it provides a significant benefit to physical and respiratory functions.

It is widely recognised that individuals with COPD tend to be less physically active compared to their peers in the same age group, often because of a heightened fear of physical exertion linked to dyspnoea (Hanania & O'Donnell 2019). However, participation in physical activity and exercise-based interventions is a cost-effective approach, yielding significant improvements in quality of life (Ramos et al. 2019).

These fears, in association with multiple comorbidities, COPD acute exacerbations and increased financial costs, make the adherence to PR programmes a challenge for these patients, especially in severe COPD cases. This is supported by Belloumi et al. (2024), who demonstrated that poor adherence negatively affects dyspnoea scores, and by Braeken et al. (2017), who found that severe acute exacerbations are associated with non-completion of the programme.

Despite all these limitations, multiple studies recommend a long-term rehabilitation programme for persistent results; Lan et al.'s (2018) study proved that the benefits of long periods of PR tend to decline over the years when PR stops, and maintenance of PR is associated with greater benefits. A 2-year follow-up study by Yohannes et al. (2021) for COPD patients showed that maintained exercise programmes sustain an improvement in anxiety and quality of life. Similarly, the study by Candemir, Ergün and Şahin (2021) showed clinically maintained improvements in exercise capacity and health-related quality of life after 1 year of PR.

These findings highlight the need for home-based programmes as a possible solution for most of the limitations and a suitable alternative with many benefits. In this context, our results are promising, as we observed that although our patients were severe COPD cases, they showed associated improvements in dyspnoea grade (mMRC), CAT score, Barthel score and 6MWT. The severity of dyspnoea was reduced, with the majority of patients reaching grades I and II (40% and 37.5%, respectively) compared to the pre-programme assessment when 47.5% of them were in grade III category. The CAT score improved significantly from  $26.95 \pm 3.61$  to  $21.85 \pm 3.94$ . This suggests that a maintained PR programme may be associated with positive outcomes, even in GOLD IV patients.

This is similar to Cheng et al. (2014), who found that patients with severe COPD who followed a PR programme experienced minimal dyspnoea at the end of the study. Exercise training is the preferred method to improve dyspnoea, as it addresses both its psychological and physiological aspects. The improvement in dyspnoea is

largely attributed to enhanced tolerance and adaptation to exercise at a muscular and cellular level, particularly involving mitochondria in skeletal muscles, including the primary and accessory respiratory muscles. Furthermore, exercise training enhances cardiac autonomic function and reduces lung hyperinflation (Leite et al. 2015). Our study showed a statistically significant change in SpO<sub>2</sub> after PR, indicating reduced exertional desaturation, which could be clinically relevant in patients with respiratory compromise.

The patients' quality of life improved, as indicated by the HS improvement in Barthel score. This is similar to the study by Li et al. (2019), which involved 414 elderly patients and demonstrated that PR led to significant improvements in exercise capacity and quality of life. The researchers observed that the enhancement in quality of life was linked to a reduced fall risk. It showed that both ageing and chest diseases (e.g. COPD) negatively impact postural control. However, various exercises that enhance physical capacities, sensorimotor strategies, postural stability and respiratory function have been shown to reduce the frequency of falls, even in the absence of balance-specific exercise programmes (Boffino et al. 2019).

Our findings are similar to those of Spielmanns et al. (2023), who reported that participation in a PR led to significant improvements in the assessed parameters in patients with COPD, regardless of age group, including those over 80 years. Similarly, Belloumi et al. (2024) found a difference in dyspnoea scores, especially in adherent compared to non-adherent patients.

Our exercise programme was tailored according to each patient's condition, allowing flexibility in selecting the level of exercise intensity, the number of repetitions and the number of sessions per week. Hansen et al. (2020) state that the ultimate objective of PR is to enhance patient autonomy, improve exercise capacity and reduce the limitations imposed by their respiratory condition, promoting long-term adherence. In our study, the mean adherence was about 95%, indicating good compliance and demonstrating a high level of engagement and feasibility of the tailored home-based exercise protocol.

Most of our exercises were low intensity to maximise physiological effects while considering the impact of ageing and the severity of COPD. In addition, long-term adherence is associated with low-intensity training (Gloeckl, Marinov & Pitta 2013). Breathing exercises such as diaphragmatic breathing and pursed-lips breathing were recommended for patients unable to engage in physical exercise. These techniques have the potential to improve pulmonary function, exercise endurance, dyspnoea, quality of life and respiratory muscle strength in COPD patients (Ceyhan & Tekinsoy 2022; Junita et al. 2022).

Implementing home-based rehabilitation programmes enables physicians to extend care to a larger number of

patients than would be possible through traditional rehabilitation centres. This approach supports cost-effective interventions as part of secondary prevention strategies, helping to reduce the risk of developing COPD or experiencing exacerbations, thereby lowering the likelihood of rehospitalisations. These programmes typically involve mild-intensity exercises with adjustable intensity levels to ensure patient safety, build self-confidence and gradually progress to higher intensity aerobic workouts. Home-based rehabilitation is particularly beneficial for patients who face barriers to accessing clinical settings or during pandemics when gatherings are risky or impractical.

A key strength of our study is the inclusion of elderly patients with advanced (severe) COPD, a population that faces significant challenges in maintaining daily activities because of both ageing and the underlying lung disease. Our study provides preliminary evidence that targeting this vulnerable subset of the population with a simple, yet effective, home-based PR programme is a promising approach.

However, our study has some limitations. Although our study included a statistically representative sample size, as determined by an expert statistician at our institution, the relatively small number of participants may still limit the generalisability of the findings. Furthermore, the number of sets and the intensity of exercises were different, tailored according to each patient's ability and fitness. We did not have a comparable control group.

These limitations suggest that our results be interpreted with some caution.

## Conclusion

Home-based, low-intensity PR programmes could be beneficial in severe COPD and can serve as an alternative in case of difficulties in attending clinical settings.

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### Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

### CRedit authorship contribution

Hala A.E. Sabah: Conceptualisation, Methodology, Investigation, Writing – original draft, Validation, Data curation, Writing – review & editing, Funding acquisition. Rehab Mohammed: Conceptualisation, Methodology, Writing – original draft, Visualisation, Validation, Supervision, Funding acquisition. Samia M. Rashad: Methodology, Formal analysis, Writing – original draft, Visualisation, Validation, Supervision, Funding acquisition. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication, and take responsibility for the integrity of its findings.

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## Data availability

The authors declare that all data that support this research article and findings are available in the article and its references.

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