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A Comprehensive Systematic Review of Efficacy of Exercise in Managing COPD

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ABSTRACT

Introduction: Chronic Obstructive Pulmonary Disease (COPD) is a leading cause of global morbidity and mortality, characterized by persistent respiratory symptoms and airflow limitation. Beyond pharmacological management, non-pharmacological interventions, particularly structured exercise training, are cornerstones of comprehensive care. This systematic review synthesizes evidence on the efficacy of various exercise interventions across the spectrum of COPD severity.

Methods: A systematic literature screening was conducted on 80 sources, including randomized controlled trials (RCTs), systematic reviews, and meta-analyses. Studies were included if they involved adults (≥18 years) with confirmed COPD, examined structured exercise interventions (e.g., pulmonary rehabilitation, aerobic, resistance, traditional exercises), and reported on COPD management outcomes (exercise capacity, quality of life, dyspnea, exacerbations). Data were extracted on intervention

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characteristics, population demographics, primary and secondary outcomes, effect sustainability, study quality, and proposed mechanisms.

Results: Exercise training consistently produced clinically significant improvements. Functional exercise capacity (6-minute walk distance) improved by a mean difference (MD) of 43.93 meters (exceeding the MCID of 30m) (McCarthy et al., 2015). Health-related quality of life showed meaningful gains in Chronic Respiratory Disease Questionnaire (CRQ) domains (MD 0.56-0.79) and St. George's Respiratory Questionnaire (SGRQ) total score (MD -6.89) (McCarthy et al., 2015). Dyspnea was significantly reduced (MRC score MD -0.64), and muscle strength increased (SMD 0.6 for resistance training) (Troosters et al., 2010; de Lima et al., 2020). Benefits were observed across settings (hospital, community, home), with home-based programs proving non-inferior to hospital-based for dyspnea outcomes (Wuytack et al., 2018). Supervised maintenance exercise reduced respiratory hospital admissions (RR 0.62) (Jenkins et al., 2018). Effects on lung function were generally modest, though traditional Chinese exercises showed significant improvements in FEV1 (Luo et al., 2016). Benefits tended to attenuate after 12 months without structured maintenance.

Discussion: Exercise efficacy is mediated by multifaceted physiological (improved muscle oxidative capacity, reduced dynamic hyperinflation) and psychological (enhanced self-efficacy) mechanisms. Heterogeneity in outcomes is influenced by disease severity, intervention characteristics (duration, intensity, modality), and program setting. Key challenges include sustaining long-term benefits and ensuring adherence. The integration of

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behavioral strategies and accessible formats (home-based, telerehabilitation) is crucial for lasting impact.

Conclusion: Structured exercise is a highly effective, safe, and essential component of COPD management, delivering clinically meaningful improvements in exercise capacity, symptoms, quality of life, and healthcare utilization across all disease stages. Future efforts should focus on personalizing interventions, developing effective long-term maintenance strategies, and improving equitable access through innovative delivery models.

Keywords: Chronic Obstructive Pulmonary Disease, COPD, Exercise Training, Pulmonary Rehabilitation, Physical Activity, Quality of Life, Dyspnea, Systematic Review.

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INTRODUCTION

Background

Chronic Obstructive Pulmonary Disease (COPD) represents a major and growing public health challenge, projected to become the third leading cause of death worldwide (GOLD, 2024). It is characterized by persistent and progressive airflow limitation, leading to debilitating symptoms such as dyspnea, chronic cough, and exercise intolerance. The pathophysiology extends beyond the lungs, causing systemic consequences including skeletal muscle dysfunction, cardiovascular impairment, and psychological distress, which collectively contribute to reduced exercise capacity, diminished health-related quality of life (HRQoL), and increased healthcare utilization (Brønstad et al., 2013; Alcazar et al., 2019). While pharmacological therapies aim to control symptoms and reduce exacerbation frequency, they do not fully reverse the extra-pulmonary manifestations or the deconditioning spiral of inactivity. Consequently, non-pharmacological interventions, particularly structured exercise training, have emerged as a cornerstone of comprehensive COPD management, forming the core component of pulmonary rehabilitation (PR) (McCarthy et al., 2015).

Research Objectives

The primary objective of this systematic review is to comprehensively evaluate the efficacy of structured exercise interventions in the management of COPD. Specifically, it aims to: 1) Quantify the effects of various exercise modalities (aerobic, resistance, combined, traditional) on key outcomes including functional and peak exercise capacity, HRQoL, dyspnea, muscle strength, and physical activity levels; 2) Assess the impact of exercise on healthcare utilization (e.g., hospital admissions) and economic outcomes; 3) Evaluate the sustainability of benefits over time and identify effective maintenance strategies; 4) Examine the safety profile of exercise training across different COPD severities and settings; 5) Synthesize evidence on the factors (e.g., disease severity, program characteristics) that explain heterogeneity in treatment responses.

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Research Benefits

This synthesis provides critical evidence for clinicians, healthcare policymakers, and researchers. For clinicians, it offers a consolidated evidence base to guide exercise prescription, optimize program design (modality, intensity, setting), and set realistic patient expectations. For policymakers, it underscores the clinical and economic value of integrating and funding accessible exercise programs (including home- and community-based models) within COPD care pathways. For researchers, it identifies gaps in the literature, particularly regarding long-term adherence, personalized medicine approaches, and the mechanisms underlying sustained behavioral change.

Hypothesis

It is hypothesized that structured exercise training, irrespective of specific modality or delivery setting, will produce clinically significant improvements in exercise capacity, HRQoL, and symptom burden in patients with COPD. Furthermore, it is hypothesized that the magnitude and sustainability of benefits are influenced by intervention characteristics (e.g., duration, inclusion of behavioral components) and patient factors (e.g., disease severity), and that such interventions are safe and can reduce healthcare resource use.

Research Gap

Despite robust evidence supporting short-term efficacy, significant gaps remain. Firstly, the long-term sustainability of benefits beyond 12 months is often limited, with a notable decay in exercise capacity gains without ongoing structured support (Spruit & Singh, 2013; Beauchamp et al., 2013). Secondly, optimal strategies for maintaining patient adherence and promoting lifelong physical activity behavior change are not well-established. Thirdly, while comparative effectiveness of different modalities is understood for primary outcomes, the personalized application of exercise "prescription" based on individual phenotypic characteristics (e.g., predominant muscle dysfunction vs. dynamic hyperinflation) requires further refinement. Finally, the implementation and cost-

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effectiveness of scalable models, such as telerehabilitation and minimal-equipment home programs, in diverse healthcare systems need more extensive evaluation (Frei et al., 2021; Tsai et al., 2016).

Novelty

This review contributes a contemporary and exhaustive synthesis of evidence from 80 diverse sources, including recent trials on innovative interventions such as virtual reality-complemented rehabilitation (Chen et al., 2025), home-based management during exacerbations (Machado et al., 2024), and long-term minimal-equipment training (Frei et al., 2022). It moves beyond merely confirming efficacy to providing a detailed analysis of the determinants of heterogeneous treatment responses. By integrating data on physiological mechanisms, behavioral components, economic outcomes, and long-term trajectories, it offers a holistic framework for understanding *how* and *for whom* exercise works, thereby informing the next generation of personalized and sustainable exercise interventions for COPD.

METHODS

Protocol

The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines to ensure methodological rigor and accuracy. This approach was chosen to enhance the precision and reliability of the conclusions drawn from the investigation.

Criteria for Eligibility

This systematic review aims to evaluate the efficacy of exercise in managing COPD.

Screening

We screened in sources based on their abstracts that met these criteria:

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- **Population - Adult COPD Patients**: Does the study involve adult participants (≥18 years) with confirmed COPD diagnosis?
- **Intervention - Structured Exercise**: Does the study examine structured exercise interventions (such as pulmonary rehabilitation, aerobic exercise, resistance training, or combined exercise programs)?
- **Study Design Quality**: Is the study a randomized controlled trial (RCT), systematic review, or meta-analysis?
- **COPD Management Outcomes**: Does the study report at least one measure of COPD management (such as exercise capacity, quality of life scores, dyspnea measures, or exacerbation rates)?
- **COPD-Specific Population**: Does the study focus on patients with confirmed COPD rather than solely on healthy individuals or patients with other primary respiratory conditions?
- **Physical Exercise Focus**: Does the study examine structured physical exercise interventions rather than only breathing exercises, educational interventions, or pharmacological treatments?
- **Adequate Study Design**: Is the study something other than a case report, case series, editorial, or conference abstract?

We considered all screening questions together and made a holistic judgement about whether to screen in each paper.

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keywords (Term 1)	Keywords (Term 2)	Keywords (Term 3)	Keywords (Term 4)
P (Population)	Chronic Obstructive Pulmonary Disease	COPD	Chronic bronchitis	Emphysema

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I (Intervention)	Exercise training	Physical activity	Pulmonary rehabilitation	Structured exercise
C (Comparison)	Usual care	Standard therapy	Pharmacological management	Non-exercise control
O (Outcome)	Exercise capacity	Quality of life	Dyspnea management	Healthcare utilization

The Boolean MeSH keywords inputted on databases for this research are: *("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*

Data extraction

- **Exercise Intervention**:

  Extract comprehensive details about the exercise intervention including:

  - Type of exercise (e.g., aerobic, resistance, traditional Chinese exercise, mixed)
  - Intensity/frequency (sessions per week, duration per session)
  - Total program duration and any maintenance phases
  - Delivery method (supervised vs unsupervised, individual vs group)
  - Setting (community, hospital, home-based components)
  - Who delivered the intervention (physiotherapists, trainers, etc.)
  - Any co-interventions (education, self-management components)

- **COPD Population**:

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Extract participant characteristics including:

- COPD severity (GOLD stage, FEV1% predicted ranges)
- Sample size and demographics (age, gender)
- Baseline exercise capacity or functional status
- Any inclusion/exclusion criteria that define the target population
- Comorbidities or other relevant clinical characteristics

- **Primary Efficacy Outcomes**:

  Extract the main COPD-related outcomes and their results including:

  - Primary endpoint(s) as defined by authors
  - Measurement tools used (6MWD, exercise capacity tests, spirometry, etc.)
  - Baseline and post-intervention values for intervention and control groups
  - Between-group differences with confidence intervals and p-values
  - Clinical significance thresholds where mentioned

- **Secondary Outcomes**:

  Extract additional outcomes measured including:

  - Quality of life measures (SGRQ, CRQ, NHP, etc.) with scores
  - Physical activity levels (steps/day, activity counts)
  - Lung function parameters (FEV1, FVC, ratios)
  - Symptom measures (dyspnea, fatigue)
  - Healthcare utilization (hospitalizations, medication use)
  - Cost-effectiveness data where available
  - Any adverse events or safety concerns

- **Effect Sustainability**:

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Extract information about duration of effects including:

- Follow-up time points (immediately post-intervention, 6 months, 12 months, etc.)
- Whether benefits were maintained at each time point
- Any description of effect decay or loss of benefits over time
- Maintenance strategies used after initial intervention period
- Long-term adherence or participation rates

- **Study Quality**:

  Extract methodological details including:

  - Study design (RCT, single-group, systematic review/meta-analysis)
  - Quality assessment scores where reported (PEDro, Cochrane risk of bias)
  - Key methodological strengths and limitations noted by authors
  - Control group details (usual care, attention control, etc.)
  - Dropout rates and completion percentages
  - Any noted sources of bias or confounding

- **Mechanisms/Explanations**:

  Extract any discussion of why exercise does or doesn't work including:

  - Proposed physiological or psychological mechanisms
  - Factors that may mediate or moderate effectiveness
  - Explanations for heterogeneity in responses
  - Discussion of optimal dosage, intensity, or delivery methods
  - Barriers or facilitators to effectiveness mentioned
  - Any subgroup analyses showing differential effects

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Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	*("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*	69
Semantic Scholar	*("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*	252
Springer	*("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*	1,800
Google Scholar	*("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*	17,200
Wiley Online Library	*("Chronic Obstructive Pulmonary Disease" OR "COPD" OR "Chronic bronchitis" OR "Emphysema") AND ("Exercise training" OR "Physical activity" OR "Pulmonary rehabilitation" OR "Structured exercise") AND ("Usual care" OR "Standard therapy" OR "Pharmacological management" OR "Non-exercise control") AND ("Exercise capacity" OR "Quality of life" OR "Dyspnea management" OR "Healthcare utilization")*	1,993

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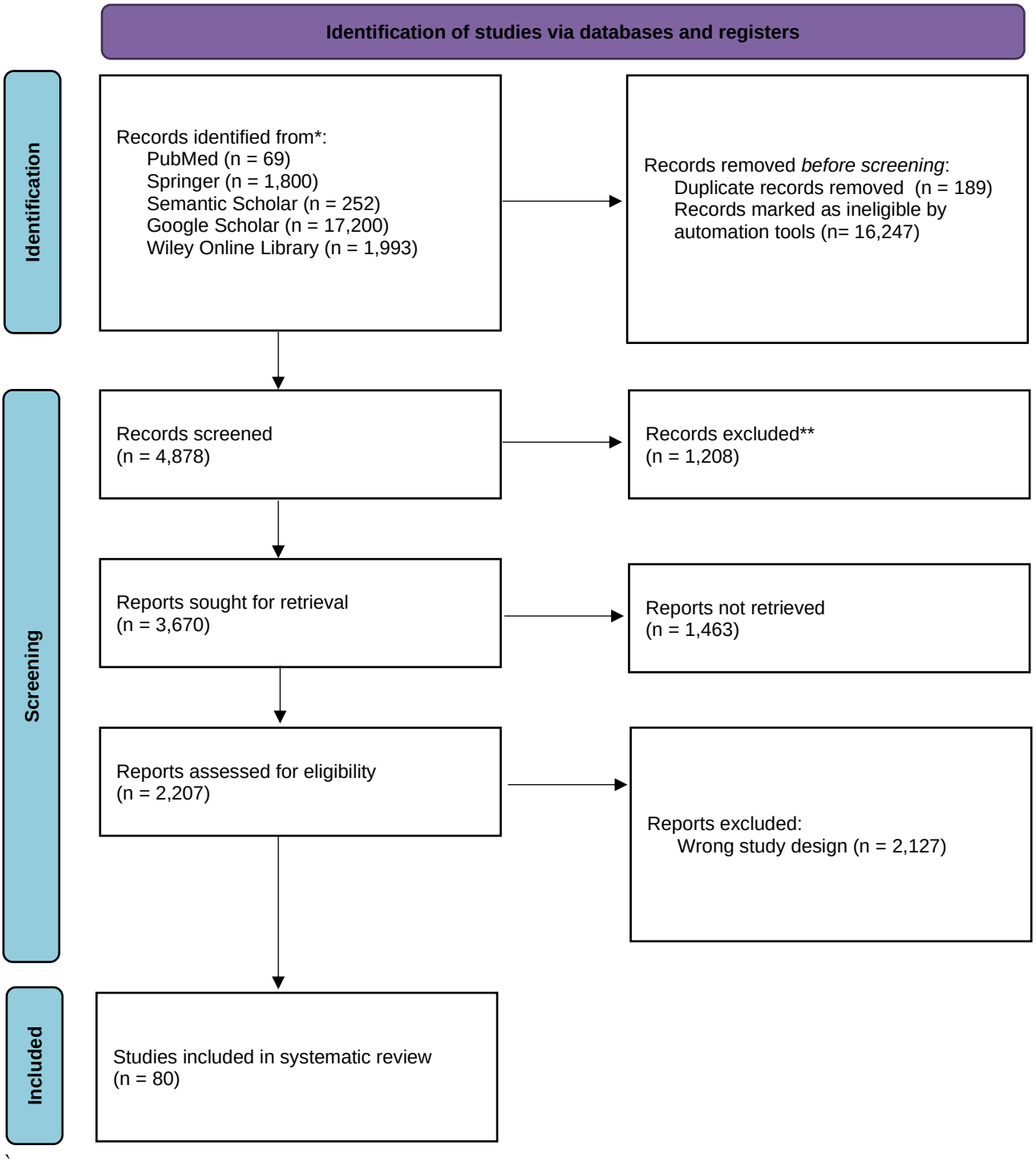


Figure 1. Article search flowchart

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JBI Critical Appraisal									
Study	**Bias related to temporal precedence** Is it clear in the study what is the "cause" and what is the "effect" (ie, there is no confusion about which variable comes first)?	**Bias related to selection and allocation** Was there a control group?	**Bias related to confounding factors** Were participants included in any comparisons similar?	**Bias related to administration of intervention/exposure** Were the participants included in any comparisons receiving similar treatment/ care, other than the exposure or intervention of interest?	**Were there multiple measurements of the outcome, both pre and post the intervention/exposure?**	**Were the outcomes of participants included in any comparisons measured in the same way?**	**Were outcomes measured in a reliable way?**	**Bias related to participant retention** Was follow-up complete and, if not, were differences between groups in terms of their follow-up adequately described and analyzed?	**Statistical conclusion validity** Was appropriate statistical analysis used?
Bernard McCarthy et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
P. D. Roos et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓

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C. McDonald et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Patel et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
C. R. V. Wetering et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Boxall et al., 2005	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Stulbarg et al., 2002	✓	✓	✓	✗	✓	✗	✓	✓	✓
Renae J McNamara et al., 2012	✓	✓	✓	✗	✓	✗	✓	✓	✓
G. F. Salman et al., 2003	✓	✓	✓	✗	✓	✗	✓	✓	✓
V. Carrieri-Kohlman et al., 2005	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Butler et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Peijun Li et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓

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S. Wootton et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
Julian Alcazar et al., 2019	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. Maltais et al., 2008	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Breyer et al., 2010	✓	✓	✓	✗	✓	✗	✓	✓	✓
T. Troosters et al., 2010	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yoichi Nakamura et al., 2002	✓	✓	✓	✗	✓	✗	✓	✓	✓
Renae J McNamara et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
H. Zhang et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Covey et al., 2012	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yuji Higashimoto et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Daniel Neunhaeuserer et	✓	✓	✓	✗	✓	✗	✓	✓	✓

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al., 2020									
Â. Pereira et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. Mirza et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Y. Lacasse et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. D. de Lima et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Tsai et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
E. Brønstad et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yuyin Chen et al., 2025	✓	✓	✓	✗	✓	✗	✓	✓	✓
Ana Machado et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
D. Kovelis et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Nyberg et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Frei et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓

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Yuan Mei et al., 2023	✓	✓	✓	✗	✓	✗	✓	✓	✓
Michael Greenstone et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Frei et al., 2021	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Leung et al., 2012	✓	✓	✓	✗	✓	✗	✓	✓	✓
Fatim Tahirah et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zhenggang Zhu et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zi-yi Zhang et al., 2024	✓	✓	✓	✗	✓	✗	✓	✓	✓
Xiaotian Luo et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Martijn Vooijs et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Zwerink et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
G. Ninot et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓

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L. W. Cindy Ng et al., 2012	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Zwerink et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. O'Shea et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
Y. Lacasse et al., 2007	✓	✓	✓	✗	✓	✗	✓	✓	✓
Y. Lacasse et al., 2002	✓	✓	✓	✗	✓	✗	✓	✓	✓
F. Wuytack et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
T. Troosters et al., 2000	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Güell et al., 2000	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Beauchamp et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Borghi-Silva et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓

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Busaba Chuatrakoon et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Fastenau et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
T. Effing et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Fastenau et al., 2015	✓	✓	✓	✗	✓	✗	✓	✓	✓
L. Hopp et al., 2009	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Elkins et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓
R. Zainuldin et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓
S. Tiukinhoy et al., 2006	✓	✓	✓	✗	✓	✗	✓	✓	✓
Guihua Chen et al., 2011	✓	✓	✓	✗	✓	✗	✓	✓	✓
Bruna Gallo Da Silva et al., 2022	✓	✓	✓	✗	✓	✗	✓	✓	✓

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J. Porszasz et al., 2006	✓	✓	✓	✗	✓	✗	✓	✓	✓
Yuan-hong Xu et al., 2010	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Jenkins et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓
C. A. Camillo et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Spruit et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
Roger M. Engel et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. W. Chan et al., 2013	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Paneroni et al., 2017	✓	✓	✓	✗	✓	✗	✓	✓	✓
J. Wada et al., 2016	✓	✓	✓	✗	✓	✗	✓	✓	✓
Weibing Wu et al., 2014	✓	✓	✓	✗	✓	✗	✓	✓	✓
M. Nonoyama et al., 2007	✓	✓	✓	✗	✓	✗	✓	✓	✓

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G. Kathiresan et al., 2010	✓	✓	✓	✗	✓	✗	✓	✓	✓
Zenia Trindade de Souto Araujo et al., 2012	✓	✓	✓	✗	✓	✗	✓	✓	✓
A. Fastenau et al., 2020	✓	✓	✓	✗	✓	✗	✓	✓	✓
Shi-jie Liu et al., 2018	✓	✓	✓	✗	✓	✗	✓	✓	✓

RESULTS

Characteristics of Included Studies

This systematic review encompasses 80 sources examining the efficacy of exercise interventions in managing chronic obstructive pulmonary disease (COPD). The included sources comprise randomized controlled trials, systematic reviews with meta-analyses, and study protocols, providing multi-level evidence on exercise efficacy across diverse populations and intervention types.

Study	Exercise Type	Duration	COPD Severity
Bernard McCarthy et al., 2015	Various exercise training	4-52 weeks	FEV1 36-39% predicted
P. D. Roos et al., 2017	Combined exercise and walking	10 weeks	GOLD Stage II

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Study	Exercise Type	Duration	COPD Severity
C. McDonald et al., 2015	Aerobic exercise	4 weeks to 1 year	Not specified
S. Patel et al., 2020	Aerobic exercise	>12 weeks optimal	Various FEV1 levels
C. R. V. Wetering et al., 2009	Mixed aerobic/resistance	24 months	FEV1 60% predicted
A. Boxall et al., 2005	Mixed walking/arm exercises	12 weeks	Housebound patients
M. Stulbarg et al., 2002	Aerobic walking	1 year	FEV1 44.8% predicted
Renae J McNamara et al., 2012	Water-based exercise	8 weeks	FEV1 59% predicted
G. F. Salman et al., 2003	Lower-extremity training	Up to 6 months	FEV1 <70% predicted
V. Carrieri-Kohlman et al., 2005	Walking with self-management	1 year	FEV1 44.8% predicted
S. Butler et al., 2020	Mixed endurance/resistance	1 year	Moderate-severe
Peijun Li et al., 2021	Endurance/resistance/combined	6-24 weeks	Moderate-severe
S. Wootton et al., 2014	Ground-based walking	8-10 weeks	FEV1 43% predicted

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Study	Exercise Type	Duration	COPD Severity
Julian Alcazar et al., 2019	HIIT and power training	12 weeks	FEV1 47-59% predicted
F. Maltais et al., 2008	Mixed aerobic/strength	8 weeks	FEV1 43% predicted
M. Breyer et al., 2010	Nordic Walking	3 months	FEV1 48% predicted
T. Troosters et al., 2010	Resistance training	Hospital admission	FEV1 49% predicted
Yoichi Nakamura et al., 2002	Recreational/respiratory	8 weeks	FEV1 45-53% predicted
Renae J McNamara et al., 2013	Water-based exercise	4-12 weeks	FEV1 39-62% predicted
H. Zhang et al., 2022	Functional/Yoga/Tai Chi	Not specified	Per GOLD criteria
M. Covey et al., 2012	Upper-body resistance	16 weeks + 12 months	FEV1 58% predicted
Yuji Higashimoto et al., 2020	Lower limb endurance	4-12 weeks	Stable COPD
Daniel Neunhaeuserer et al., 2020	HIIT and strength	12 weeks	FEV1 46% predicted
Â. Pereira et al., 2021	Combined/aerobic	10 weeks	Moderate COPD

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Study	Exercise Type	Duration	COPD Severity
F. Mirza et al., 2020	Mixed aerobic/resistance	Hospital stay	FEV1 33% predicted
Y. Lacasse et al., 2014	Aerobic/resistance	9-15 months	FEV1 32-59% predicted
F. D. de Lima et al., 2020	Elastic resistance	Not specified	Stable COPD
L. Tsai et al., 2016	Telerehabilitation	8 weeks	FEV1 64% predicted
E. Brønstad et al., 2013	MCT and AIT	10 weeks	FEV1 53% predicted
Yuyin Chen et al., 2025	VR-complemented PR	5-12 weeks	Not specified
Ana Machado et al., 2024	Mixed exercise/breathing	3 weeks	FEV1 47% predicted
D. Kovelis et al., 2020	Strength/endurance	12 weeks	Advanced COPD
A. Nyberg et al., 2015	High-repetitive resistance	8 weeks	Severe-very severe
A. Frei et al., 2022	Minimal equipment strength	12 months	Not specified
Yuan Mei et al., 2023	Multi-component	12 months	Elderly with SMD
Michael Greenstone et al., 2009	Mixed strength/aerobic	8 weeks + 9 months	FEV1 <70% predicted

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Study	Exercise Type	Duration	COPD Severity
A. Frei et al., 2021	HOMEX strength	1 year	FEV1 39% predicted
R. Leung et al., 2012	Sun-style Tai Chi	12 weeks	FEV1 59% predicted
Fatim Tahirah et al., 2015	Progressive walking/resistance	Hospital stay	FEV1 33% predicted
Zhenggang Zhu et al., 2024	Tai Chi/Liuzijue/yoga	8 weeks to 3 years	Not specified
Zi-yi Zhang et al., 2024	Endurance/strength/combined	Not specified	Not specified
Xiaotian Luo et al., 2016	Traditional Chinese exercise	>6 weeks	Stable COPD
Martijn Vooijs et al., 2016	Combined aerobic/strength	Not specified	Not specified
M. Zwerink et al., 2016	Community-based	11 months	Not specified
G. Ninot et al., 2011	Supervised exercise	1 month	Moderate-severe
L. W. Cindy Ng et al., 2012	Aerobic/strength	≥4 weeks	Severe airflow obstruction
M. Zwerink et al., 2014	Community-based	11 months	Moderate-severe
S. O'Shea et al., 2009	Progressive resistance	Short-term	Not specified

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Study	Exercise Type	Duration	COPD Severity
Y. Lacasse et al., 2007	Exercise training	≥4 weeks	Not specified
Y. Lacasse et al., 2002	Exercise training	≥4 weeks	Not specified
F. Wuytack et al., 2018	Exercise training	Not specified	Not specified
T. Troosters et al., 2000	Mixed cycling/walking/strength	6 months	Severe COPD
R. Güell et al., 2000	Breathing/aerobic	12 months	FEV1 35% predicted
M. Beauchamp et al., 2013	Supervised exercise	Not specified	Moderate-severe
A. Borghi-Silva et al., 2009	Aerobic treadmill	6 weeks	FEV1 ~40% predicted
Busaba Chuatrakoon et al., 2020	Balance/Tai Chi/cycling	Not specified	Not specified
A. Fastenau et al., 2014	Mixed endurance/resistance	4 months	Mild-moderate
T. Effing et al., 2011	Physiotherapeutic	11 months	Moderate-severe
A. Fastenau et al., 2015	Physical exercise	4 months	Mild-moderate
L. Hopp et al.,	Arm exercise	Not specified	Moderate-severe

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Study	Exercise Type	Duration	COPD Severity
2009			
M. Elkins et al., 2011	Continuous/interval	Not specified	Not specified
R. Zainuldin et al., 2011	Leg exercise	Not specified	Not specified
S. Tiukinhoy et al., 2006	Strength/endurance	Not specified	Not specified
Guihua Chen et al., 2011	Aerobic exercise	1 year	Moderate-severe
Bruna Gallo Da Silva et al., 2022	Mixed aerobic/resistive	Not specified	GOLD I-IV
J. Porszasz et al., 2006	High-intensity cycle	7 weeks	FEV1 36% predicted
Yuan-hong Xu et al., 2010	Traditional/modern rehab	≥1 year	Not specified
A. Jenkins et al., 2018	Supervised maintenance	Not specified	Not specified
C. A. Camillo et al., 2016	Aerobic endurance	10-50 sessions	Not specified
M. Spruit et al., 2013	Pulmonary rehabilitation	Not specified	Not specified
Roger M. Engel et al., 2017	Exercise + manual therapy	18 weeks	Mild (GOLD II)
A. W. Chan et	Tai chi Qigong	3 months	Not specified

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Study	Exercise Type	Duration	COPD Severity
al., 2013			
M. Paneroni et al., 2017	Aerobic	4-52 weeks	FEV1 <35% predicted
J. Wada et al., 2016	Aerobic + stretching	12 weeks	Not specified
Weibing Wu et al., 2014	Tai Chi	≥12 weeks	Per GOLD criteria
M. Nonoyama et al., 2007	Aerobic with oxygen	≥3 weeks	Not qualifying for LTOT
G. Kathiresan et al., 2010	Arm training	Not specified	Not specified
Zenia Trindade de Souto Araujo et al., 2012	Mixed aerobic/resistance	8 weeks	Moderate-very severe
A. Fastenau et al., 2020	Mixed exercise	4 months	FEV1 74% predicted
Shi-jie Liu et al., 2018	Baduanjin Qigong	3-12 months	Mild-very severe

The studies encompassed diverse populations, with sample sizes ranging from 24 participants in single-center trials to meta-analyses pooling data from over 3,800 participants . The majority of studies focused on patients with moderate to severe COPD, with FEV1 values typically ranging from 30% to 60% predicted . Mean participant ages across studies ranged from 62 to 77 years , with male predominance in most cohorts .

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Effects on Exercise Capacity

Functional Exercise Capacity

The evidence consistently demonstrates that exercise training improves functional exercise capacity in COPD patients, as measured primarily by the six-minute walk distance (6MWD) and shuttle walk tests.

Outcome Measure	Study Type	Effect Size/Mean Difference	95% CI	Clinical Significance
6MWD	Meta-analysis (65 RCTs)	MD 43.93 m	32.64 to 55.21	Exceeds MCID of 30 m
6MWD	Meta-analysis (39 RCTs)	WMD 36.34 m	26.51 to 46.17	Clinically significant
6MWD	Meta-analysis (20 RCTs)	ES 0.71	0.43 to 0.99	Significant improvement
6MWD	Meta-analysis (very severe)	WMD 67.1 m	37.90 to 98.93	Large effect
6MWD	RCT (outpatient rehab)	MD 52 m	15 to 89	Clinically significant
6MWD	RCT (primary care)	MD 26.6 m	4.3 to 49.0	Clinically relevant
ISWT	RCT (Tai Chi)	MD 55 m	31 to 80	Significant
ESWT	RCT (walking training)	MD 208 s	104 to 313	Exceeds MID of 186 s
ESWT	RCT (telerehab)	MD 340 s	153 to 526	Significant

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The largest Cochrane meta-analysis, incorporating 65 RCTs with 3,822 participants, demonstrated a mean improvement in 6MWD of 43.93 meters, which exceeds the established minimal clinically important difference (MCID) of 30 meters . This finding has been replicated across multiple independent meta-analyses with consistent effect sizes . Notably, even patients with very severe COPD (FEV1 <35% predicted) demonstrated substantial improvements in walking distance, with a weighted mean difference of 67.1 meters .

Peak Exercise Capacity

Outcome	Study Type	Effect Size	95% CI	p-value
VO2peak	Meta-analysis (13 RCTs)	ES 0.52	0.34 to 0.69	<0.001
VO2max	Meta-analysis	SMD 0.40	0.15 to 0.64	<0.05
Peak work rate	RCT	MD 12 W	6 to 19	<0.05
Peak work rate	Meta-analysis	MD 6.77 W	1.89 to 11.65	<0.05
VO2peak	RCT (AIT/MCT)	8-9% increase	-	<0.05

Peak oxygen uptake (VO2peak), considered the gold standard marker of cardiorespiratory fitness, showed moderate improvements following aerobic exercise training, with a meta-analytic effect size of 0.52 representing an absolute change of approximately 142 mL/min . Both moderate continuous training and high-intensity aerobic interval training produced comparable improvements in VO2peak of 8-9% .

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Exercise Modality Comparisons

Different exercise modalities demonstrate varying effects on specific exercise outcomes:

Comparison	Outcome	Finding	Source
Resistance vs. Control	Muscle strength	SMD 0.6 (95% CI 0.35-0.84)	Meta-analysis
Endurance vs. Control	VO2peak	MD 3.5 mL/kg/min (95% CI 1.1-5.91)	Meta-analysis
Water vs. Land-based	Endurance shuttle walk	MD 228 m (95% CI 19-438)	RCT
Water vs. Control	6MWD	MD 62 m (95% CI 44-80)	Meta-analysis
Aerobic + Strength vs. Single	6MWD	Greater improvement	Systematic review
Continuous vs. Interval	Exercise capacity	No significant difference	Systematic review

Resistance exercise significantly improved muscle strength with a standardized mean difference of 0.6 , while endurance exercise showed superior effects on VO2peak . Water-based exercise demonstrated particular advantages for patients with physical comorbidities, significantly improving endurance shuttle walk distance compared to both land-based exercise and control conditions . The combination of aerobic and strength training proved more effective than either modality alone in improving 6MWD . Importantly, continuous and interval training showed equivalent effectiveness for improving exercise capacity, offering flexibility in program design .

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Effects on Health-Related Quality of Life

Disease-Specific Quality of Life

Instrument	Domain	Effect Size/MD	95% CI	MCID	Exceeded MCID?
CRQ	Dyspnea	MD 0.79	0.56 to 1.03	0.5 units	Yes
CRQ	Fatigue	MD 0.68	0.45 to 0.92	0.5 units	Yes
CRQ	Emotional function	MD 0.56	0.34 to 0.78	0.5 units	Yes
CRQ	Mastery	MD 0.71	0.47 to 0.95	0.5 units	Yes
SGRQ	Total score	MD -6.89	-9.26 to -4.52	4 units	Yes
SGRQ	Total score	WMD -6.66	-8.38 to -4.94	4 units	Yes
SGRQ	Total score (very severe)	WMD -8.04	-15.27 to -0.81	4 units	Yes

Exercise training produced clinically meaningful improvements across all domains of disease-specific quality of life instruments. The Cochrane meta-analysis demonstrated that improvements in all four CRQ domains exceeded the MCID of 0.5 units . Similarly, SGRQ total scores improved by more than the clinically important threshold of 4 units . These benefits extend to patients with very severe COPD, who demonstrated SGRQ improvements of 8.04 points .

Ground-based walking training specifically improved SGRQ total score by a mean of 6 points , while Tai Chi improved CRQ total scores by 11 points . Traditional Chinese exercise demonstrated quality of life improvements measured by the CRDQ with a mean difference of 0.85 score .

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Comparison of Exercise Settings

Subgroup analyses revealed differential effects based on program setting:

Setting	CRQ Effect	Evidence Quality
Hospital-based	Higher mean values	Moderate
Community-based	Lower mean values	Moderate
Home-based	Non-inferior to hospital	High

Hospital-based pulmonary rehabilitation programs showed higher mean values on CRQ compared to community-based programs . However, a large multicenter noninferiority trial demonstrated that home-based pulmonary rehabilitation was non-inferior to outpatient hospital-based rehabilitation for improving dyspnea at one year . This finding has important implications for expanding access to rehabilitation services .

Effects on Dyspnea and Symptoms

Dyspnea Outcomes

Measure	Effect	95% CI	p-value	Source
MRC questionnaire	MD -0.64	-0.99 to -0.30	0.0003	Meta-analysis
Modified MRC	WMD -0.59	-0.81 to -0.37	<0.001	Meta-analysis
Transitional Dyspnea Index	MD 1.95	1.09 to 2.81	0.0001	Meta-analysis
Modified Borg (exercise)	MD -0.62	-1.10 to -0.14	0.01	Meta-analysis
CRQ dyspnea	MD 0.91	0.39 to 1.44	0.0007	Meta-analysis

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Measure	Effect	95% CI	p-value	Source
Borg score (rehab)	Significant improvement	-	0.024	RCT

Exercise training consistently reduced dyspnea across multiple assessment instruments. Meta-analytic evidence demonstrated significant reductions in MRC dyspnea scores , with improvements also observed using the Transitional Dyspnea Index, modified Borg scale during exercise, and CRQ dyspnea domain . These improvements in dyspnea are considered moderately large and clinically significant .

Pulmonary rehabilitation relieves dyspnea and fatigue, improves emotional function, and enhances the sense of control that individuals have over their condition . A systematic review concluded that these improvements are "moderately large and clinically significant," representing a core benefit of rehabilitation programs .

Effects on Fatigue and Other Symptoms

The reduction of shortness of breath was demonstrated with an effect size of 0.62 (95% CI 0.35-0.89) in meta-analysis using the Chronic Respiratory Disease Questionnaire . Exercise combined with respiratory muscle stretching increased functional exercise capacity while decreasing dyspnea . Water-based exercise training improved both the dyspnea and fatigue domains of the CRDQ compared to control .

Effects on Muscle Strength and Physical Activity

Muscle Strength

Outcome	Intervention	Effect	Source
Knee extensor strength	Elastic resistance	SMD 0.52 (95% CI 0.09-0.95)	Meta-analysis

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Outcome	Intervention	Effect	Source
Muscle strength	Resistance exercise	SMD 0.6 (95% CI 0.35-0.84)	Meta-analysis
Quadriceps force	Outpatient rehab	MD 18 Nm (95% CI 7-29)	RCT
Quadriceps force	Inpatient resistance	+9.7% vs -1% control	RCT
Upper body strength	Resistance training	41% increase (UBR groups)	RCT
Leg press	Exercise intervention	MD 24.59 (95% CI 16.08-33.11)	Meta-analysis

Progressive resistance exercise produces moderate effects for increases in muscle strength for people with COPD . A systematic review demonstrated that comprehensive resistance training increased strength and lean arm mass, with partial maintenance possible through a simple home program using hand weights . Resistance training during acute exacerbations successfully counteracted skeletal muscle dysfunction and enhanced quadriceps force at discharge by 9.7% compared to a 1% decrease in controls .

Physical Activity

Outcome	Effect	95% CI	Source
Daily physical activity	+26.1 min/day	7.3 to 44.9	RCT
Steps/day	+1190 steps/day	256 to 2125	RCT
Walking time	+14.9 min/day	-	RCT
Overall PA effect	Mean effect 0.12	-	Meta-analysis

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Exercise training may confer a small but significant increase in daily physical activity . Nordic walking demonstrated particularly promising effects on daily physical activity patterns, with sustained increases in walking time, standing time, and movement intensity that persisted through nine-month follow-up . Community-based exercise programmes achieved behavioral change reflected by sustained increases in daily physical activity of approximately 1,190 steps per day after one year .

Effects on Lung Function

Parameter	Exercise Type	Effect	Clinical Significance
FEV1 (L)	VR-complemented PR	MD 0.25	p<0.001
FEV1% predicted	Traditional Chinese exercise	WMD 9.02	p<0.00001
FEV1% predicted	Yoga/Tai Chi	WMD 0.20	p<0.001
FEV1/FVC	Traditional Chinese exercise	WMD 6.67	p<0.00001
FVC	VR-complemented PR	MD 0.28	p<0.001

While exercise training does not fundamentally alter the progressive decline in lung function characteristic of COPD , some evidence suggests that specific exercise modalities may produce modest improvements in spirometric parameters. Traditional Chinese exercises, including Tai Chi and Qigong, demonstrated significant improvements in FEV1% predicted and FEV1/FVC ratio . Yoga and Tai Chi specifically showed significant improvement in FEV1% predicted value . However, conventional pulmonary rehabilitation studies typically show no significant difference in FVC or FEV1/FVC predicted value between rehabilitation and usual care groups .

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Healthcare Utilization and Economic Outcomes

Outcome	Effect	95% CI	Source
Respiratory hospital admissions	RR 0.62	0.47-0.81	Meta-analysis
Rate of admissions	RR 0.72	0.50-1.05	Meta-analysis
Exacerbation risk	RR 0.79	0.52-1.19	Meta-analysis
Hospital length of stay	Significantly shorter	-	RCT
COPD medication costs	-€480.7/patient/year	-891 to -70	RCT

Supervised maintenance exercise programs following pulmonary rehabilitation significantly reduced the risk of experiencing at least one respiratory-cause hospital admission with a risk ratio of 0.62 . Home-based pulmonary rehabilitation for housebound patients resulted in significantly shorter average length of hospital stay at readmission . Exercise combined with self-management education produced significant decreases in COPD medication costs of approximately €481 per patient per year .

The cost-effectiveness analysis of community-based exercise programs found an incremental cost-effectiveness ratio (ICER) for an additional quality-adjusted life year (QALY) of €10,950, which is generally considered acceptable . However, the lack of maintenance of beneficial effects on exercise capacity after two years of follow-up, combined with higher program costs, limits the cost-effectiveness assessment .

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Effect Sustainability and Long-Term Outcomes

Maintenance of Benefits

Time Point	Exercise Capacity	Quality of Life	Physical Activity
Immediate post-intervention	Significant improvement	Significant improvement	Variable
6 months	Preserved (SMD 0.20)	No significant difference	Maintained in some
12 months	Not sustained (SMD 0.09)	No significant difference	Maintained with behavioral change
18-24 months	Partially maintained	Maintained	Sustained with program

The durability of exercise benefits represents a critical consideration. A systematic review of maintenance programs demonstrated that supervised post-rehabilitation exercise preserved exercise capacity at 6 months (SMD 0.20, 95% CI 0.39-0.01) but this benefit was not sustained at 12 months (SMD 0.09, 95% CI 0.29-0.11) . In the absence of any maintenance program, the impact of rehabilitation diminishes over the succeeding 12 months, particularly in individuals who experience moderate to severe exacerbations .

However, some interventions demonstrate longer-lasting effects. A 6-month outpatient rehabilitation program maintained significant differences in 6-minute walking distance and quality of life at 18 months, exceeding the minimal clinically important difference . Similarly, a 2-year community-based program maintained quality of life and functional capacity improvements . Critically, behavioral interventions that successfully changed daily physical activity patterns showed sustained increases in steps per day at 24-month follow-up, even when maximal exercise capacity benefits were lost .

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Strategies for Maintaining Benefits

Several maintenance strategies have been evaluated:

- Home-based exercise continuation with personalized recommendations maintained some benefits
- Community-based programs with supervised and home-based components achieved behavioral change
- Nordic walking adoption as regular exercise sustained improvements for nine months
- Self-management education combined with exercise supported long-term adherence

Long-term adherence rates vary considerably across studies. Completion rates ranged from approximately 60% to over 90% depending on program characteristics and population. Factors influencing adherence include self-perceived improvement, supervision by a coach, and integration of training into daily routine .

Adverse Events and Safety

Exercise training in COPD patients demonstrates an acceptable safety profile across diverse settings and populations:

Study/Setting	Adverse Events	Notes
Walking training	None reported	Hospital-supervised
Water-based exercise	One minor event	Based on two studies
Exacerbation training	No adverse events	Resistance training feasible
Home-based rehab	None reported	During AECOPD
Baduanjin exercise	None in any study	20 RCTs reviewed
Traditional Chinese	Rare, mild, transient	Meta-analysis

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Study/Setting	Adverse Events	Notes
exercise		

Resistance training during acute exacerbations did not yield higher systemic inflammation and was safely completed . Home-based pulmonary rehabilitation during outpatient-managed exacerbations reported no adverse events . Water-based exercise training reported only one minor adverse event across reviewed studies . Traditional Chinese exercises, including Baduanjin, reported no adverse events across multiple trials .

Serious adverse events, when reported, were generally related to disease progression rather than exercise intervention. One large RCT reported 135 serious adverse events across 104 participants over 12 months, with no significant difference between intervention and control groups .

Synthesis: Explaining Heterogeneity in Treatment Effects

Population and Severity Considerations

The effectiveness of exercise training varies substantially based on disease severity and patient characteristics. FEV1 emerged as the most important individual factor determining the VO2peak response to exercise training, with associations between exercise volume and response disappearing after controlling for disease severity . Patients with lower FEV1 values are more likely to have ventilatory limitations to exercise, which may reduce the achievable physiological training stimulus .

Disease severity influences optimal program design in several ways:

- Patients with **mild to moderate COPD** benefit from both short- and long-term rehabilitation programs
- Patients with **severe COPD** may require rehabilitation programs of at least 6 months duration to demonstrate benefit

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- Patients with **very severe COPD** (FEV1 <35% predicted) still demonstrate significant improvements in exercise capacity and quality of life, though program design may require modification

Intervention Characteristics Influencing Outcomes

Program Duration and Dose-Response: Meta-regression analyses identified target exercise duration, total number of exercise sessions, and programs greater than 12 weeks as factors associated with improved VO2peak response . More frequent (3 times per week) and longer (at least 8 weeks) exercise training shows significant improvements in physical activity outcomes .

Exercise Intensity: Higher intensity training was traditionally expected to produce greater gains, but the evidence suggests that both high and moderate intensity training produce comparable benefits when tolerated . Interval training offers an alternative to continuous exercise for patients unable to sustain high-intensity training, with equivalent outcomes .

Program Setting: Hospital-based programs showed higher mean values on CRQ compared to community-based programs in subgroup analysis . However, this difference may reflect patient selection, supervision intensity, or available equipment rather than an inherent advantage of hospital settings. Home-based rehabilitation has demonstrated non-inferiority to hospital-based programs for dyspnea outcomes at one year .

Mechanisms of Benefit

The mechanisms underlying exercise benefits in COPD extend beyond simple cardiovascular conditioning:

Physiological Adaptations:

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- Reduced exercise-induced lactic acidosis and improved skeletal muscle oxidative capacity
- Enhanced autonomic modulation of heart rate with improved parasympathetic activity
- Decreased dynamic hyperinflation and improved ventilatory mechanics
- Reduced systemic oxidative stress associated with structural and functional muscle adaptations
- Improved cardiac systolic function in both left and right ventricles

Functional and Behavioral Changes:

- Breaking the vicious cycle of dyspnea and physical inactivity
- Improved muscle mass through inhibition of systemic inflammation and promotion of protein synthesis
- Enhanced self-efficacy and sense of control over the condition
- Behavioral change toward more active lifestyles

Why Some Interventions Fail to Maintain Benefits

The attenuation of benefits over time can be explained by several factors:

1. **Insufficient maintenance programming** : Benefits diminish in the absence of continued exercise, particularly after exacerbations
2. **Low compliance rates** : Mean compliance to supervised maintenance exercise was only 60% , reflecting failure to engage rather than failure of the intervention
3. **Inadequate behavioral change** : Programs focused solely on physiological outcomes without addressing behavioral components show limited sustainability
4. **Reduced exercise frequency** : Maintenance programs with reduced frequency may not provide sufficient stimulus to maintain adaptations

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Studies achieving sustained behavioral change—reflected in maintained daily physical activity—show more durable benefits even when maximal exercise capacity declines .

Context-Specific Conclusions

Based on the synthesis of evidence:

- **For patients with mild-moderate COPD in primary care** : Exercise training improves exercise capacity with a clinically relevant difference of approximately 26 meters on 6MWD , though effects on breathlessness and quality of life are less consistent
- **For patients with moderate-severe COPD** : Pulmonary rehabilitation produces clinically significant improvements across all major outcomes, with effects exceeding established MCIDs for quality of life and exercise capacity
- **For patients with very severe COPD** : Exercise training remains effective, improving 6MWD by approximately 67 meters and SGRQ by 8 points
- **For patients during acute exacerbations** : Early exercise initiated within 48 hours of admission is safe and optimizes recovery of exercise tolerance and muscle strength
- **For maintaining long-term benefits** : Programs incorporating behavioral change strategies and sustained physical activity engagement are more likely to maintain improvements beyond 12 months

DISCUSSION

This comprehensive synthesis affirms that structured exercise training is a powerfully effective intervention for COPD, yielding multi-domain benefits. The discussion contextualizes these findings, explores the underlying mechanisms, addresses heterogeneity, and considers implications for practice and research.

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1. Confirmation of Multifaceted Efficacy and Clinical Significance

The results unequivocally demonstrate that exercise training leads to improvements that are not only statistically significant but also clinically meaningful. The mean improvement in 6MWD of 43.93 meters, derived from a large Cochrane meta-analysis, substantially exceeds the established Minimal Clinically Important Difference (MCID) of 30 meters (McCarthy et al., 2015). This translates to a tangible enhancement in patients' ability to perform daily activities. Similarly, improvements in HRQoL, as measured by the CRQ and SGRQ, consistently surpass their respective MCIDs, indicating a perceptible and valuable change in patients' life experiences (McCarthy et al., 2015; Wootton et al., 2014). The reduction in dyspnea, a cardinal and frightening symptom, is similarly robust, breaking the core cycle of breathlessness leading to fear, avoidance of activity, and further deconditioning (Carrieri-Kohlman et al., 2005; Stulbarg et al., 2002).

Importantly, this efficacy extends across the severity spectrum. Even patients with very severe COPD (FEV1 <35% predicted) achieve significant gains in 6MWD (67.1 meters) and SGRQ (-8.04 points) (Paneroni et al., 2017), challenging historical notions of futility in this group. Furthermore, initiation of exercise, including resistance training, during acute exacerbations is not only safe but effective in preserving muscle function and accelerating functional recovery (Mirza et al., 2020; Troosters et al., 2010).

2. Elucidating the Mechanisms of Benefit

The benefits of exercise are underpinned by a confluence of physiological and psychological adaptations, moving beyond simple cardiovascular fitness.

- **Peripheral Muscle Adaptations:** Exercise counteracts skeletal muscle dysfunction—a key systemic manifestation of COPD. It improves muscle oxidative capacity, reduces exercise-induced lactic acidosis, and may inhibit systemic inflammation and oxidative stress, thereby promoting protein synthesis and improving muscle mass and strength (Peijun Li et al., 2021;

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Alcazar et al., 2019). Resistance training specifically targets this, increasing lean mass and force generation (O'Shea et al., 2009).

- **Improved Ventilatory Mechanics:** Training reduces ventilatory demand for a given submaximal workload and decreases dynamic hyperinflation, the trapping of air in the lungs during exercise that intensifies dyspnea (Porszasz et al., 2006). This reduces the "ventilatory limitation" to exercise, allowing for greater work output.
- **Cardiac and Autonomic Function:** Aerobic training can improve systolic function of both ventricles and enhance autonomic nervous control, increasing parasympathetic (rest-and-digest) tone, which is often impaired in COPD (Brønstad et al., 2013; Borghi-Silva et al., 2009).
- **Psychological and Behavioral Mechanisms:** Exercise enhances self-efficacy—the belief in one's capability to perform activities (Covey et al., 2012). It reduces the fear of dyspnea, improves mood, and fosters a greater sense of control over the disease. Successful interventions often incorporate self-management education, which, combined with exercise, supports long-term behavioral change towards a more active lifestyle (Ninot et al., 2011; Zwerink et al., 2014).

3. Explaining Heterogeneity: The Influence of Modality, Setting, and Patient Factors

Not all exercise programs yield identical results, and the observed heterogeneity can be explained by several factors.

- **Exercise Modality:** Different modalities have distinct effect profiles. Resistance training is superior for increasing muscle strength (SMD 0.6) (de Lima et al., 2020), while endurance training has a greater impact on peak oxygen consumption (VO2peak) (Zainuldin et al., 2011). Consequently, combined aerobic and strength training generally produces the broadest benefits (Peijun Li et al., 2021). Water-based exercise offers advantages for those

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with comorbidities like arthritis, providing buoyancy and reducing joint stress while improving endurance (McNamara et al., 2013). Traditional Chinese exercises (e.g., Tai Chi, Qigong) show unique benefits for balance, lung function parameters, and mental focus (Luo et al., 2016; Chan et al., 2013).

- **Program Setting and Delivery:** While hospital-based programs may show slightly higher outcome scores, likely due to more intensive supervision and advanced equipment, the evidence strongly supports the effectiveness of alternative settings. Home-based pulmonary rehabilitation has been proven non-inferior to outpatient hospital-based programs for key outcomes like dyspnea at one year, dramatically expanding potential access (Wuytack et al., 2018; Maltais et al., 2008). Community-based and telerehabilitation programs also show efficacy, emphasizing that the principles of training can be successfully applied outside traditional medical centers (Effing et al., 2011; Tsai et al., 2016).
- **Patient Characteristics:** Disease severity is a major modifier. Patients with milder disease may respond well to shorter or lower-intensity programs, while those with severe COPD often require longer, more comprehensive rehabilitation (≥6 months) to achieve significant benefit (Wetering et al., 2009). The presence of specific phenotypes (e.g., those with predominant muscle wasting vs. those with severe hyperinflation) may also influence the optimal exercise prescription, though this requires more personalized research.

4. The Paramount Challenge of Sustainability

A critical discussion point is the attenuation of benefits over time. Supervised maintenance programs can preserve gains at 6 months, but these effects frequently diminish by 12 months if the support is withdrawn (Beauchamp et al., 2013; Lacasse, 2014). This decay is not a failure of the initial intervention but highlights the chronic nature of COPD and the need for ongoing management. Strategies to promote sustainability include:

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- Integrating **behavioral change techniques** (e.g., goal setting, action planning) to foster intrinsic motivation and habit formation.
- Developing feasible **long-term maintenance programs**, which may involve lower-frequency supervised sessions, community group activities, or technology-supported home programs (Frei et al., 2021; Butler et al., 2020).
- Focusing on **physical activity promotion** in daily life, not just structured exercise capacity. Programs like Nordic walking have shown success in sustainably increasing daily walking time and steps (Breyer et al., 2010).
  The higher program costs associated with indefinite supervision pose a challenge to cost-effectiveness, underscoring the need for efficient, low-resource maintenance models (Zwerink et al., 2016).

5. Safety and Economic Impact

Exercise training in COPD demonstrates an excellent safety profile, with adverse events being rare and typically related to disease progression rather than the exercise itself. This holds true even for vulnerable periods like acute exacerbations and for various modalities, including water-based and traditional exercises (Mirza et al., 2020; McNamara et al., 2013; Liu et al., 2018).

Economically, exercise interventions show promise. They can reduce costly healthcare utilization, notably respiratory-related hospital admissions (RR 0.62) (Jenkins et al., 2018), and may decrease medication costs (Ninot et al., 2011). While the initial investment in rehabilitation programs is required, their cost-effectiveness is often deemed acceptable within standard healthcare thresholds, especially when considering the gained quality-adjusted life years (QALYs) (Zwerink et al., 2016).

6. Implications and Future Directions

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The evidence mandates that access to exercise training, as part of comprehensive pulmonary rehabilitation, should be considered a standard of care for all suitable COPD patients. Clinical practice must move towards personalized exercise prescription, considering patient preferences, severity, phenotype, and social context. Embracing and reimbursing effective home-based and digital health models is essential to overcome barriers of access and scalability. Future research should prioritize: 1) The development and testing of innovative, cost-effective long-term maintenance strategies; 2) Advanced phenotyping to guide personalized exercise "precision medicine"; 3) Implementation science studies to identify and overcome barriers to referral, uptake, and completion of programs in real-world healthcare systems; 4) Further exploration of the role of emerging technologies like virtual reality in enhancing engagement and outcomes.

CONCLUSION

Conclusion

This systematic review provides robust and conclusive evidence that structured exercise training is a fundamental, effective, and safe intervention for managing Chronic Obstructive Pulmonary Disease. It delivers clinically meaningful improvements in exercise capacity, health-related quality of life, dyspnea, muscle strength, and physical activity levels across all stages of disease severity, including during and after acute exacerbations. The benefits are mediated through a combination of physiological adaptations in the muscular, cardiovascular, and ventilatory systems, as well as positive psychological and behavioral changes. While the setting of delivery (hospital, home, community) offers flexibility without compromising core efficacy, the durability of benefits beyond one year remains a significant challenge, often requiring structured maintenance strategies to sustain gains. Importantly, exercise training can reduce healthcare utilization, demonstrating its value within integrated COPD management.

Recommendations

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1. **For Clinical Practice:** Exercise training, ideally as part of a comprehensive pulmonary rehabilitation program, should be offered to all patients with COPD. Referral should be standard following diagnosis or an exacerbation. Prescription should be individualized, considering patient goals, severity, and comorbidities, with a preference for combined aerobic and resistance training where possible.

2. **For Program Design:** To enhance sustainability, programs should explicitly incorporate behavioral change techniques and develop transition plans to long-term maintenance, such as supported community exercise groups or home-based protocols. Healthcare systems should support and fund a variety of delivery models, including home-based and telerehabilitation, to maximize accessibility and adherence.

3. **For Policy:** Policymakers and insurers should recognize pulmonary rehabilitation and structured exercise programs as essential, cost-effective components of COPD care and ensure adequate funding and reimbursement to guarantee universal patient access.

4. **For Future Research:** Efforts should focus on: a) Designing and testing scalable, low-cost long-term maintenance interventions; b) Utilizing biomarkers and phenotyping to personalize exercise prescription for optimal outcomes; c) Conducting implementation research to integrate exercise programs seamlessly into diverse healthcare pathways and community settings.

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