

Comparative Rehabilitation Benefits of Water-Based versus Land-Based Exercise in Patients with Chronic Obstructive Pulmonary Disease: A Systematic Review and Meta-Analysis

INPLASY202610046
doi: 10.37766/inplasy2026.1.0046
Received: 14 January 2026
Published: 14 January 2026

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ADMINISTRATIVE INFORMATION

Support - This research was funded by Ningxia Natural Science Foundation project titled “Exercise Intervention in Mitigating Respiratory Disease Risk in the High Frequency Dust Storm Environment of Ningxia and Its Underlying Mechanisms”. Project No. (2025AAC030630).

Review Stage at time of this submission - Completed but not published.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202610046

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 14 January 2026 and was last updated on 14 January 2026.

INTRODUCTION

Review question / Objective This systematic review and meta-analysis aimed to compare the effects of water-based versus land-based exercise on lung function, exercise capacity, and respiratory muscle function in patients with COPD, thereby providing evidence to inform the optimization of pulmonary rehabilitation exercise modalities.

Rationale Chronic obstructive pulmonary disease (COPD) is a prevalent chronic respiratory condition characterized by persistent airflow limitation, reduced exercise tolerance, and respiratory muscle dysfunction, which together lead to substantial impairment in functional capacity and quality of life. Pulmonary rehabilitation, with exercise training as its core component, is strongly recommended by international guidelines; however, conventional rehabilitation programs predominantly rely on land-

based exercise. In clinical practice, many patients with COPD experience poor tolerance to land-based training due to dyspnea, lower-limb muscle weakness, joint disorders, or obesity, which may limit exercise intensity, adherence, and overall effectiveness.

Water-based exercise has emerged as a potential alternative or adjunct to land-based rehabilitation. The unique physical properties of the aquatic environment, including buoyancy, water resistance, and hydrostatic pressure, may reduce joint loading, enhance exercise tolerance, and provide additional respiratory muscle loading. Although several randomized controlled trials have investigated the effects of water-based exercise in patients with COPD, their findings remain inconsistent, and existing studies vary considerably in intervention protocols and outcome measures. Importantly, robust evidence directly comparing the effects of water-based versus land-based exercise on key

functional outcomes—such as lung function, exercise capacity, and respiratory muscle strength—remains limited.

Therefore, a systematic review and meta-analysis is warranted to synthesize available randomized controlled evidence and to comprehensively compare the rehabilitation effects of water-based and land-based exercise in patients with COPD. Clarifying the relative benefits of these exercise modalities may help optimize exercise prescription strategies and inform evidence-based pulmonary rehabilitation practice for diverse patient populations.

Condition being studied Chronic obstructive pulmonary disease (COPD) is a common chronic respiratory disorder characterized by persistent airflow limitation, with its prevalence and global disease burden continuing to increase worldwide. In addition to progressive declines in lung function, patients with COPD frequently experience marked reductions in exercise tolerance, respiratory muscle weakness, and limitations in activities of daily living. These impairments substantially compromise quality of life and are associated with an increased risk of acute exacerbations, hospitalization, and mortality. Although pharmacological therapy plays an important role in symptom relief and exacerbation prevention, its effects on improving exercise capacity and functional status are limited. Consequently, non-pharmacological interventions particularly pulmonary rehabilitation centered on exercise training have become an integral component of comprehensive COPD management. Owing to the unique properties of the aquatic environment, water-based exercise may provide rehabilitation benefits that differ from those of traditional land-based exercise. Therefore, the present study conducted a systematic review and meta-analysis to synthesize evidence from existing RCTs and to comprehensively compare the effects of water-based versus land-based exercise on lung function, exercise capacity, and respiratory muscle function in patients with COPD. The aim was to provide a more objective, robust, and clinically relevant evidence base to inform the optimization of exercise prescriptions within pulmonary rehabilitation programs.

METHODS

Search strategy In accordance with the PRISMA guidelines, a systematic literature search was performed to identify studies examining the effects of water-based versus land-based exercise interventions on patients with chronic obstructive

pulmonary disease (COPD). The following electronic databases were searched from inception to October 2025: PubMed, Web of Science, China National Knowledge Infrastructure (CNKI), Wanfang Data, and VIP Database.

The search focused on the effects of aquatic exercise (aquatic exercise or water-based exercise) and land-based exercise on functional outcomes in patients with COPD, including lung function, exercise capacity, and respiratory muscle strength. Eligible studies were required to include adult patients with a confirmed diagnosis of COPD and to adopt a randomized controlled trial or controlled interventional design. The intervention had to involve at least one form of water-based exercise and include a comparator consisting of land-based exercise or conventional pulmonary rehabilitation. A combination of Medical Subject Headings (MeSH) terms and free-text keywords was used. The main search terms included, but were not limited to: “chronic obstructive pulmonary disease” OR “COPD”; “aquatic exercise” OR “water-based exercise” OR “hydrotherapy”; and “land-based exercise” OR “exercise training” OR “pulmonary rehabilitation”. Boolean operators (“AND” and “OR”) were applied as appropriate. In addition, reference lists of all included studies were manually screened to identify potentially eligible articles that may have been missed during the electronic search.

Participant or population Adult patients diagnosed with chronic obstructive pulmonary disease (COPD) according to established clinical or spirometric criteria (e.g., GOLD guidelines) will be included. Participants of either sex and any ethnicity will be eligible, regardless of disease duration. Most patients are expected to have stable COPD with mild to severe airflow limitation (GOLD stages I–IV), provided that baseline characteristics are comparable between intervention groups.

Studies enrolling patients during acute exacerbations, individuals with other primary respiratory diseases (e.g., asthma, bronchiectasis), or participants with severe comorbid conditions that substantially limit exercise participation (such as advanced cardiovascular, neurological, or musculoskeletal disorders) will be excluded, unless data for COPD patients are reported separately.

Intervention The intervention of interest is water-based exercise (also referred to as aquatic exercise or aquatic training) conducted in an aquatic environment such as a swimming pool or therapeutic pool. Eligible interventions include structured water-based exercise programs

designed for patients with COPD, such as aquatic aerobic exercise, aquatic resistance or endurance training, aquatic breathing or respiratory muscle training, and aquatic mind–body exercise (e.g., water-based traditional or low-impact exercise).

Interventions may vary in exercise intensity, frequency, session duration, total intervention length, water temperature, and immersion depth, provided that the program is clearly described and implemented as a planned rehabilitation or exercise intervention. Water-based exercise must be the primary component of the experimental intervention and delivered alone or as part of a comprehensive pulmonary rehabilitation program.

Comparator The comparator will be land-based exercise, conventional pulmonary rehabilitation, or usual care delivered in a non-aquatic environment. Eligible comparators include structured land-based exercise programs such as walking, cycling, aerobic training, resistance training, breathing exercises, or land-based mind–body exercise commonly used in pulmonary rehabilitation for patients with COPD.

The land-based exercise programs may vary in intensity, frequency, session duration, and total intervention length, provided that they are clearly described and represent standard or commonly accepted rehabilitation or exercise practices. In studies using usual care as a comparator, usual care may include standard medical management, health education, or routine clinical follow-up without a structured water-based exercise component.

Study designs to be included Randomized controlled trials (RCTs) and controlled clinical trials comparing water-based exercise with land-based exercise or usual care in patients with COPD will be included. Both parallel-group and cluster-randomized designs will be eligible, provided that an appropriate comparator group is available. Studies must report quantitative outcome data that can be extracted or calculated for meta-analysis. Quasi-randomized trials or non-randomized controlled studies may be considered if randomization procedures are clearly described and baseline characteristics between groups are comparable.

Eligibility criteria Inclusion criteria

Studies will be included if they meet all of the following criteria:

Population: Adult patients with a confirmed diagnosis of chronic obstructive pulmonary disease (COPD) based on recognized clinical or spirometric criteria.

Intervention: Water-based (aquatic) exercise as the primary intervention, including aquatic aerobic exercise, resistance or endurance training, breathing training, or aquatic mind–body exercise.

Comparator: Land-based exercise, conventional pulmonary rehabilitation, or usual care delivered in a non-aquatic environment.

Study design: Randomized controlled trials or controlled clinical trials with at least one comparator group.

Outcomes: Studies reporting at least one extractable quantitative outcome related to lung function, exercise capacity, or respiratory muscle function (e.g., FEV₁% predicted, FEV₁/FVC, six-minute walk distance, maximal inspiratory pressure, or maximal expiratory pressure).

Data availability: Sufficient data reported to allow calculation of effect sizes (e.g., mean and standard deviation, or data convertible to these measures).

Exclusion criteria

Studies will be excluded if they meet any of the following criteria:

Non-interventional studies, observational studies without a control group, case reports, case series, reviews, meta-analyses, conference abstracts, or editorials.

Studies enrolling non-COPD populations or mixed populations in which data for COPD patients cannot be extracted separately.

Interventions that do not include water-based exercise or in which the effects of water-based exercise cannot be clearly distinguished from other interventions.

Studies conducted during acute exacerbations of COPD.

Studies lacking relevant outcome data or sufficient information for quantitative synthesis.

Information sources Electronic literature searches will be conducted in the following databases from inception to the date of the final search: PubMed, Web of Science, Embase, and the Cochrane Library. In addition, major Chinese databases, including China National Knowledge Infrastructure (CNKI), Wanfang Data, and the VIP Database, will be searched to identify relevant studies published in Chinese.

To ensure comprehensive coverage, the reference lists of all included studies and relevant reviews will be manually screened for additional eligible articles. When necessary, corresponding authors of included studies may be contacted to obtain missing or unpublished data.

Main outcome(s) The primary outcomes of this review will be exercise capacity and respiratory muscle function in patients with COPD. Exercise capacity will be assessed primarily by the six-

minute walk distance (6MWD). Respiratory muscle function will be evaluated using maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP).

These outcomes are widely used in pulmonary rehabilitation research and reflect clinically meaningful functional improvements in patients with COPD.

Quality assessment / Risk of bias analysis The methodological quality and risk of bias of the included studies will be independently assessed by two reviewers using the Cochrane Risk of Bias tool (RoB 2) for randomized controlled trials. The following domains will be evaluated: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in outcome measurement, and bias in the selection of the reported results.

Each domain will be judged as having low risk of bias, some concerns, or high risk of bias, and an overall risk-of-bias judgment will be assigned to each study. Any disagreements between reviewers will be resolved through discussion or consultation with a third reviewer.

Strategy of data synthesis Quantitative data synthesis will be performed using meta-analysis where sufficient and comparable data are available. Continuous outcomes will be pooled using weighted mean differences (WMDs) or standardized mean differences (SMDs) with corresponding 95% confidence intervals (CIs), depending on the measurement scales used across studies.

Statistical heterogeneity among studies will be assessed using Cochran's Q test and the I^2 statistic. A fixed-effects model will be applied when heterogeneity is low ($I^2 < 50\%$ and $p > 0.10$); otherwise, a random-effects model will be used. Meta-analyses will be conducted using appropriate statistical software.

Where meta-analysis is not feasible due to insufficient or highly heterogeneous data, findings will be summarized narratively.

Subgroup analysis Where sufficient data are available, subgroup analyses will be conducted to explore potential sources of heterogeneity. Subgroup analyses will be performed according to intervention duration, comparing short-term interventions (≤ 8 weeks) with longer-term interventions (> 8 weeks).

Subgroup analyses will be applied to primary outcomes, including exercise capacity and respiratory muscle function, and to selected secondary outcomes where appropriate.

Sensitivity analysis Sensitivity analyses will be performed to assess the robustness of the pooled results. A leave-one-out approach will be applied, whereby each study will be sequentially removed from the meta-analysis to evaluate the influence of individual studies on the overall effect estimates.

The stability of the pooled effect sizes and confidence intervals will be examined to determine whether the main findings are unduly driven by any single study.

Country(ies) involved China - School of Physical Education, Ningxia Normal University.

Other relevant information The studies included in this review are expected to involve authors and institutional affiliations from multiple countries, including China, Brazil, Australia, Thailand, Turkey, and the United States, reflecting the international

Keywords chronic obstructive pulmonary disease; water-based exercise; land-based exercise; pulmonary rehabilitation; meta-analysis.

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