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Effects of Mind-Body Exercise on Respiratory Function and Exercise Capacity in COPD Patients Aged 60 Years and Older: A Three-Level Meta-Analysis

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INTRODUCTION

Review question / Objective Objective: Chronic obstructive pulmonary disease (COPD) is a major cause of disability and mortality among the global elderly population, with progressive decline in lung function and reduced exercise endurance constituting the primary rehabilitation challenges. While mind-body exercise has received increasing attention in COPD rehabilitation, systematic and high-quality evidence synthesizing its specific efficacy and optimal intervention protocols for patients aged 60 years and older remains scarce. Methods: A systematic literature search was conducted across PubMed, Web of Science, Embase, Cochrane Library, CNKI, and Wanfang databases to retrieve randomized controlled trials (RCTs). A total of 37 RCTs involving 3,666 COPD patients with a mean age of 60 years and older were included. Intervention effects on lung function (FEV_1, FVC, FEV_1/FVC) and exercise endurance (6-minute walk distance, 6MWD) were pooled. Subgroup and meta-regression analyses based on exercise type and intervention duration were performed, alongside evaluations of publication bias and model robustness. Results: Mind-body exercise significantly improved overall lung function (Hedges' g = 0.66, 95% CI: 0.42, 0.91) and exercise endurance (g = 0.95, 95% CI: 0.67, 1.22) in older patients. Marked therapeutic divergence was observed among different exercise modalities: Liuzijue yielded the optimal improvement in lung function (g = 0.94), Baduanjin demonstrated the most pronounced effect on 6MWD (g = 1.50), while Tai Chi exhibited relatively moderate effects but the highest statistical stability. The intervention duration displayed a non-linear, inverted U-shaped dose-response relationship: lung function benefits peaked at 6 months (g = 1.01) but dissipated by 12 months, whereas improvements in 6MWD were longitudinally sustained up to 12 months (g = 0.71). Conclusion: Mind-body exercise effectively enhances lung function and exercise endurance in COPD patients aged 60 years and older. Different exercise modalities possess distinct therapeutic advantages, suggesting that protocols should be

individualized based on specific rehabilitation goals. A 6-month period serves as the golden window for maximizing lung function gains, whereas enhancements in exercise endurance exhibit greater long-term durability. This study provides robust, evidence-based mathematical support for formulating precise exercise rehabilitation prescriptions for elderly patients with COPD.

Condition being studied Chronic obstructive pulmonary disease (COPD) is a chronic respiratory disease characterized primarily by persistent airflow limitation and chronic airway inflammation, the impacts and consequences of which have garnered widespread global attention. According to the Global Burden of Disease (GBD) study, COPD has become the third leading cause of death worldwide. The structural airway alterations and lung function impairment associated with this disease mostly progress irreversibly, exerting a profound impact on the quality of life and social functioning of affected patients .
The development of COPD is a complex biomedical phenomenon influenced by multiple factors. The most prominent modifiable risk factor is cigarette smoking. Research indicates that smoking causes airway epithelial damage, exacerbates inflammatory responses, and reduces lung elastic recoil, thereby triggering the onset of COPD [3]. Another critical factor is air pollution. Whether it is sand and dust storms, indoor air pollution caused by solid fuel combustion, or outdoor air pollution originating from industrial and motor vehicle emissions, these exposures have all been confirmed to be highly correlated with the incidence of COPD. In the elderly population, the incidence of COPD increases substantially. Beyond the aforementioned causes, this surge is closely related to age-related decline in lung function, weakening of the immune system, and the elevated risks of multi-morbidity involving various chronic diseases.

METHODS

Search strategy The databases searched included PubMed, Web of Science Core Collection, Embase, Cochrane Library, CNKI, and Wanfang databases, with the search time span extending from their inception to June 2026. The search strategy combined Medical Subject Headings (MeSH)/Emtree terms with free-text words, with appropriate adjustments made for different databases. Taking PubMed as an example, the core search string was as follows: (("Pulmonary Disease, Chronic Obstructive"[Mesh] OR COPD OR "Chronic Obstructive Lung Disease" OR "Chronic Airflow Obstruction") AND ("Tai Ji"[Mesh] OR "Tai Chi" OR Taiji OR "Baduanjin" OR "Liuzijue" OR "Qigong" OR "Qi Gong" OR "Yoga"[Mesh] OR Yoga OR "Mind-Body Therapies"[Mesh] OR "Mind Body Exercise")) AND ("Randomized Controlled Trial"[Publication Type] OR randomized controlled trial OR randomized OR randomised OR RCT).

Participant or population Study population: COPD patients with a mean age of 60 years and older and a definitive diagnosis (complying with GOLD or corresponding international/regional standards).

Intervention Mind-body exercises in the experimental group (e.g., Tai Chi, Baduanjin, Liuzijue, Yoga, Health Qigong, etc.).

Comparator Conventional treatment, health education, routine rehabilitation, or other forms of exercise training.

Study designs to be included Randomized Controlled Trials.

Eligibility criteria Inclusion criteria: (1) Study type: Randomized Controlled Trials (RCTs); (2) Study population: COPD patients with a mean age of 60 years and older and a definitive diagnosis (complying with GOLD or corresponding international/regional standards); (3) Interventions: Mind-body exercises in the experimental group (e.g., Tai Chi, Baduanjin, Liuzijue, Yoga, Health Qigong, etc.); (4) Control interventions: Conventional treatment, health education, routine rehabilitation, or other forms of exercise training; (5) Outcome metrics: Reporting at least one of the following: lung function (FEV1, FVC, FEV1/FVC) or exercise capacity (6-minute walk distance, 6MWD). Exclusion criteria: (1) Non-RCT designs; (2) Interventions lacking mind-body exercise as the primary component; (3) Study populations featuring other major diseases where COPD subgroup outcomes were not reported separately; (4) Incomplete data that could not be retrieved even after contacting the authors.

Information sources PubMed, Web of Science Core Collection, Embase, Cochrane Library, CNKI, and Wanfang databases.

Main outcome(s) Mind-body exercise significantly improved overall lung function (Hedges' g = 0.66, 95% CI: 0.42, 0.91) and exercise endurance (g = 0.95, 95% CI: 0.67, 1.22) in older patients. Marked therapeutic divergence was observed among different exercise modalities: Liuzijue yielded the optimal improvement in lung function (g = 0.94),

Baduanjin demonstrated the most pronounced effect on 6MWD (g = 1.50), while Tai Chi exhibited relatively moderate effects but the highest statistical stability. The intervention duration displayed a non-linear, inverted U-shaped dose-response relationship: lung function benefits peaked at 6 months (g = 1.01) but dissipated by 12 months, whereas improvements in 6MWD were longitudinally sustained up to 12 months (g = 0.71).

Quality assessment / Risk of bias analysis Quality Assessment

Most of the literature included in this study demonstrated a low risk of bias regarding random sequence generation, but exhibited certain limitations in allocation concealment and blinding. However, these limitations are pervasive in exercise intervention studies and are inherently difficult to avoid completely. The majority of the studies showed a low risk of bias in terms of the completeness of outcome data and selective outcome reporting. Overall, the quality of the literature included in this study was satisfactory, indicating strong reliability of the findings.

Strategy of data synthesis Modeling All data pooling, methodological subgroup testing, and parameter estimations in this study were conducted using R statistical software (Version 4.6.1) and its dedicated hierarchical matrix package "metafor." For various continuous physiological and behavioral metrics, the Hedges' g standardized mean difference adjusted for small-sample bias and its corresponding sampling variance were calculated via the "escalc" vector function to serve as the baseline effect sizes.

To disentangle data dependencies and nested confounding arising from the synchronous reporting of multiple outcomes in the original literature, a hierarchical three-level nested random-effects model was constructed under restricted maximum likelihood (REML) estimation. This mathematical architecture precisely isolated the total residual variance into three distinct levels: sampling variance within an individual effect size (Level 1), variation among multiple correlated outcome metrics within the same study cluster (Level 2), and methodological heterogeneity across independent research teams (Level 3). The specific heterogeneity proportions contributed by each level were calculated using typical sampling variance expansion equations. The selective moderation of categorical moderators was verified through categorical meta-regression based on the three-level model. The dose-response temporal dynamics of intervention duration were fitted, derived, and optimized for extreme values using continuous linear and quadratic polynomial non-linear meta-regression models spanning from 1 to 12 months.

Subgroup analysis To comprehensively investigate the potential sources of the strong overall heterogeneity (I2 = 95.1%) in the primary model, an in-depth categorical moderator analysis was conducted under the robust hierarchical three-level random-effects meta-analysis framework (Figure 4).

When stratified by lung function metrics, the results indicated that mind-body exercise yielded statistically significant improvements across all three targeted pulmonary rehabilitation parameters (between-group difference P-between < 0.001). Among them, FEV1/FVC demonstrated the largest intervention effect size (g = 0.83, 95% CI: 0.11, 1.55, p = 0.023), though accompanied by a wider confidence interval and higher localized heterogeneity (I2 = 98.3%). Concurrently, the model revealed that mind-body exercise achieved robust and precisely estimated improvements in both FEV1 (g = 0.68, 95% CI: 0.40, 0.96, p < 0.001) and FVC (g = 0.49, 95% CI: 0.28, 0.70, p < 0.001).

When pooled by exercise types, a significant divergence in rehabilitative efficacy was manifested among the traditional Chinese exercises (P-between = 0.006). Both Liuzijue (g = 0.94, 95% CI: 0.39, 1.49, p < 0.001) and Baduanjin (g = 0.82, 95% CI: 0.35, 1.29, p < 0.001) exerted substantial and highly significant therapeutic impacts on the recovery of lung function in patients with COPD. In contrast, the pooled effect size for Tai Chi was considerably smaller and failed to reach the conventional threshold of statistical significance (g = 0.19, 95% CI: -0.02, 0.40, p = 0.076).

When conducting the moderator analysis based on intervention durations, an intriguing non-linear temporal pattern was unraveled (P-between = 0.012). The 6-month intervention regimen generated the most prominent peak effect (g = 1.01, 95% CI: 0.33, 1.69, p = 0.004), closely followed by the 3-month intervention, which likewise exhibited a highly stable benefit (g = 0.67, 95% CI: 0.26, 1.09, p = 0.001). However, as the intervention duration extended to 12 months, the therapeutic effect completely reached a plateau and dissipated (g = 0.00, 95% CI: -0.10, 0.10], p = 0.957. This strongly suggests the existence of a distinct golden therapeutic window in mind-body exercise rehabilitation, or alternatively, implies a potential attenuation of patient compliance and movement quality during long-term interventions.

Sensitivity analysis In the domain of lung function metrics (Figure 8), when the primary three-level nested model (comprising 68 nested effect sizes across 29 study clusters) was switched from the

standard restricted maximum likelihood (REML) estimation (g = 0.66, 95% CI: 0.42, 0.91, p < 0.001) to maximum likelihood (ML) estimation, an almost identical pooled effect size was obtained (g = 0.66, 95% CI: 0.42, 0.90, p < 0.001). This confirms that the global pooling trajectory possesses full resilience against alterations in the optimization algorithms. Furthermore, executing a quality-driven sensitivity analysis by systematically truncating high-variance, small-sample entries (retaining 66 effect sizes across 29 clusters) successfully pruned a massive amount of statistical noise, bringing the total heterogeneity down from 95.1% to 86.4%, while the pooled therapeutic benefit remained highly stable and statistically extremely significant (g = 0.56, 95% CI: 0.36, 0.76, p < 0.001). In the supplementary two-level aggregated models, fine-tuning the intra-study correlation coefficient gradient (r = 0.20, 0.40, and 0.80) caused the pooled parameters to exhibit regular mathematical fluctuations: as the error dependency tightened from r = 0.20 to the most stringent r = 0.80, the pooled effect size smoothly retreated from 0.58 to 0.42, while the confidence intervals widened progressively (from 0.36, 0.79 to 0.13, 0.71). This perfectly replicated the classic mathematical variance inflation pattern but consistently and firmly maintained nominal statistical significance (p < 0.005).

In the domain of functional exercise capacity (Figure 8), identical sensitivity perturbations corroborated an even higher structural robustness. Altering the baseline three-level REML model (g = 0.95, 95% CI: 0.67, 1.22, p < 0.001, I2 = 85.8%) to ML estimation yielded an identical mathematical mirror image (g = 0.95, 95% CI: 0.68, 1.21, I2 = 85.0%). When restricting the scope to high-precision study cohorts, the effect size contracted slightly to g = 0.86 (95% CI: 0.66, 1.07, p < 0.001), while the localized residual noise was significantly compressed (I2 dropped to 73.1%). Crucially, the magnitude of effect attenuation for 6MWD under high-precision screening (9.5%) was markedly smaller than that for the lung function outcome (15.2%). Moreover, since the 6MWD dataset naturally possesses an independent, study-level flattened structure free of multi-outcome nesting, changing the assumed intra-study covariance coefficients (r = 0.20, 0.40, and 0.80) exerted no traction on the mathematical matrix, with all three settings generating entirely stationary and identical effect size metrics on the plot (g = 0.95, 95% CI: 0.67, 1.22, I2 = 85.8%).

Country(ies) involved China.

Keywords Keywords: COPD; Mind-body exercise; Elderly; Three-level meta-analysis; Pulmonary rehabilitation.

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