INPLASY

INPLASY2026110057

doi: 10.37766/inplasy2026.11.0057

Received: 15 November 2026

Published: 15 November 2026

Effects of respiratory muscle training on inspiratory muscle strength and pulmonary ventilation in patients with stroke: a protocol for a systematic review and meta-analysis

Wang, JQ; Liu, HL; Liu, Y; Fan, H; Fan, XD; Su, GD.

Corresponding author:
Guodong Su

cambuzhan@163.com

Author Affiliation:
Department of Neurological Rehabilitation, Beijing Bo'ai Hospital, China Rehabilitation Research Center, Beijing, China.

ADMINISTRATIVE INFORMATION

Support - None.

Review stage at the time of initial registration - Data analysis.

Conflicts of interest - None declared.

INPLASY registration number: INPLASY2026110057

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 15 November 2026 and was last updated on 15 November 2026.

INTRODUCTION

Review question / Objective Among adults with stroke, does respiratory muscle training (RMT), used alone or in addition to conventional rehabilitation, improve inspiratory muscle strength and pulmonary ventilation compared with conventional rehabilitation, sham training, or other interventions without RMT? The PICOS framework is: Population, adults aged over 18 years diagnosed with ischaemic or haemorrhagic stroke, without restriction on stroke stage; Intervention, inspiratory muscle training, expiratory muscle training, or combined respiratory muscle training delivered using threshold-loading, resistive-loading, or mobile-health-assisted comprehensive respiratory training, with or without conventional rehabilitation; Comparator, conventional rehabilitation, sham training, or other interventions without RMT; Outcomes, maximal inspiratory pressure (MIP), forced expiratory volume in one second (FEV1), and forced vital capacity (FVC); Study design, randomized controlled trials. A secondary objective is to explore whether the initial inspiratory training load modifies the effect on MIP, comparing an initial load of at least 40% MIP with lower loads or non-threshold training.

Rationale Stroke is a leading cause of disability. Beyond motor and activities-of-daily-living impairment, respiratory dysfunction is common but often overlooked. Respiratory muscle strength may be markedly reduced after stroke because of impaired central neural control, denervation of the diaphragm and accessory respiratory muscles, immobility, and disuse atrophy. These changes can reduce ventilatory capacity, exercise tolerance, cough effectiveness, and swallowing safety, and may increase pulmonary complications. RMT applies resistance to inspiratory and/or expiratory muscles through threshold or resistive devices and is an established component of pulmonary rehabilitation in other populations. Randomized trials suggest potential benefits after stroke, but sample sizes, training loads, treatment durations, and measurement methods vary considerably. Previous meta-analyses generally searched

Wang et al. INPLASY protocol 2026110057. doi:10.37766/inplasy2026.11.0057 Downloaded from https://inplasy.com/inplasy-2026-11-0057/

literature before 2020, often combined respiratory outcomes with motor or functional outcomes, and rarely examined dose–response relationships for inspiratory load. Recent randomized trials provide an opportunity to update the evidence. This review therefore focuses specifically on MIP, FEV1, and FVC and includes a subgroup analysis by initial inspiratory load to inform clinical training prescriptions.

Condition being studied Stroke-related respiratory impairment, characterized by reduced inspiratory muscle strength and impaired pulmonary ventilation in adults with ischaemic or haemorrhagic stroke. The review concerns MIP as a measure of inspiratory muscle strength, and FEV1 and FVC as measures of ventilatory function. Stroke type and disease stage are unrestricted.

METHODS

Search strategy Databases: PubMed, EBSCO, China National Knowledge Infrastructure (CNKI), and Wanfang Data, searched from inception to 30 June 2026. Publication type was unrestricted; searches were limited to Chinese and English. Reference lists of included studies and relevant systematic reviews were checked, and manual searches were used when full text was difficult to obtain. Authors were contacted for missing data when necessary.
PubMed strategy:
#1 "Stroke"[Mesh] OR stroke OR "cerebrovascular accident" OR hemiplegia
#2 "Respiratory Muscle Training"[Mesh] OR "respiratory muscle training" OR "inspiratory muscle training" OR "breathing exercise" OR "pulmonary rehabilitation"
#3 "Randomized Controlled Trial"[pt] OR randomized OR randomised OR RCT
#4 #1 AND #2 AND #3
Chinese terms included 呼吸训练, 呼吸肌训练, 吸气肌训练, 呼吸康复, 肺康复, 脑卒中, 中风, 脑血管意外, and 偏瘫. Strategies for other databases were adapted from the PubMed concepts using database-specific subject headings and free-text terms.

Participant or population Adults aged over 18 years with a diagnosis of ischaemic or haemorrhagic stroke according to recognized cerebrovascular disease diagnostic criteria. Stroke type and disease stage were unrestricted. Studies limited to non-stroke populations, such as isolated spinal cord or traumatic brain injury, were excluded.

Intervention Inspiratory muscle training, expiratory muscle training, or both, delivered through threshold-loading or individualized resistive-loading devices, or comprehensive respiratory training assisted by mobile health or related approaches. Interventions could include diaphragmatic breathing, pursed-lip breathing, thoracic mobility exercises, game-based training, or Liuzijue respiratory qigong when these constituted respiratory muscle training. RMT could be delivered alone or added to conventional rehabilitation or another background intervention.

Comparator Conventional rehabilitation, sham respiratory training, or other interventions not containing RMT. When RMT was added to another background intervention, the comparator received that background intervention without RMT.

Study designs to be included Randomized controlled trials (RCTs). Non-randomized studies, animal experiments, abstracts without accessible full text, and duplicate publications were excluded.

Eligibility criteria Inclusion criteria: (1) randomized controlled trials; (2) adults aged over 18 years with ischaemic or haemorrhagic stroke, without restriction on stroke type or stage; (3) inspiratory, expiratory, or combined respiratory muscle training, delivered alone or in addition to conventional rehabilitation; (4) conventional rehabilitation, sham training, or another comparator without RMT; (5) at least one of MIP, FEV1, or FVC reported; (6) means and standard deviations extractable for at least one eligible outcome; and (7) Chinese or English full text available. Exclusion criteria: duplicate publications or duplicate cohort reports; studies limited to non-stroke populations, including isolated spinal cord injury or traumatic brain injury; no eligible outcome or incomplete numerical data that remained unavailable after contacting authors; title or abstract only without accessible full text; animal experiments; and languages other than Chinese or English.

Information sources PubMed, EBSCO, China National Knowledge Infrastructure (CNKI), and Wanfang Data were searched from inception to 30 June 2026. Additional sources included manual searches, reference lists of included articles, and relevant systematic reviews. Authors of primary studies were contacted to obtain missing numerical data when required. Searches were restricted to Chinese and English publications. Search concepts combined stroke, respiratory muscle training, and randomized controlled trial

Wang et al. INPLASY protocol 2026110057. doi:10.37766/inplasy2026.11.0057 Downloaded from https://inplasy.com/inplasy-2026-11-0057/

terms, using subject headings and free-text words adapted to each database.

Main outcome(s) The main outcomes were inspiratory muscle strength and pulmonary ventilation, measured as: (1) maximal inspiratory pressure (MIP) in cmH2O; (2) forced expiratory volume in one second (FEV1) in litres; and (3) forced vital capacity (FVC) in litres. Studies had to report at least one of these outcomes. Post-intervention measurements were used. Effects were expressed as mean differences (MDs) with 95% confidence intervals (CIs) because units were consistent across studies. Means, standard deviations, and sample sizes were extracted for each arm. Longer-term follow-up data were not synthesized because sufficient comparable long-term data were unavailable.

Additional outcome(s) None.

Data management Two reviewers independently screened titles and abstracts and then full texts, and extracted data using a predesigned form. Extracted items included first author, publication year, country, baseline characteristics, training modality, initial load, frequency, session duration, intervention duration, follow-up, outcome means, standard deviations, and sample sizes. Missing information was requested from original study authors. Discrepancies were resolved by discussion and, when necessary, adjudication by a senior researcher. Screening decisions and extracted data were cross-checked before analysis.

Quality assessment / Risk of bias analysis Two reviewers independently assessed randomized trials using both the PEDro scale and the Cochrane RoB 2 tool, with disagreements resolved through discussion with a senior researcher. PEDro contains 11 items; the first is not scored, yielding a 0–10 score. Scores of 9–10, 6–8, 4–5, and 3 or less denoted very high, high, moderate, and low quality, respectively. RoB 2 covered randomization, deviations from intended interventions, missing outcome data, outcome measurement, and selective reporting. Each domain and the overall judgment were rated as low risk, some concerns, or high risk. Evidence certainty for each outcome was rated using GRADE.

Strategy of data synthesis Analyses used a RevMan 5.4-equivalent inverse-variance algorithm, with DerSimonian–Laird estimation of between-study variance (tau^2), following Cochrane Handbook methods. Continuous outcomes measured in consistent units were pooled as MDs with 95% CIs: cmH2O for MIP and litres for FEV1 and FVC. Heterogeneity was assessed using the chi-square test (alpha = 0.10) and I^2. I^2 below 50% was considered low, 50% to below 75% moderate, and 75% or greater high. A fixed-effect model was used when I^2 was below 50%. When I^2 was 50% or greater, clinical and methodological sources were examined before applying a random-effects model. Statistical significance was set at two-sided alpha = 0.05. Publication bias was assessed using funnel plots and Egger regression when at least 10 studies reported an outcome; for fewer studies, funnel plots were interpreted descriptively because of limited power. Certainty of evidence was assessed using GRADE. Studies not contributing numerical data to a specific meta-analysis were described qualitatively.

Subgroup analysis MIP was analysed by initial inspiratory load. Trials with an initial load of 40% MIP or greater formed the higher-load subgroup; trials with an initial load below 40% MIP or without threshold loading formed the low-to-moderate-load subgroup. Between-subgroup differences were examined using an approximate test based on random-effects estimates. The analysis explored dose–response while acknowledging variation in training devices, session parameters, treatment duration, and participant characteristics. Subgroup analyses by stroke stage or stroke type were not undertaken because comparable data were insufficient.

Sensitivity analysis Leave-one-out sensitivity analyses were performed for every pooled outcome by removing each study in turn and repeating the meta-analysis. Changes in effect direction, statistical significance, and heterogeneity were examined. Studies with implausible or otherwise concerning data were considered in additional sensitivity assessments, and their influence on pooled estimates and I^2 was reported. Particular attention was paid to whether conclusions depended on studies at high overall risk of bias or studies with unusually small standard deviations and extreme effects.

Language restriction Chinese and English only; other languages excluded.

Country(ies) involved China.

Other relevant information Registration was initiated while data analysis was ongoing because the authors were unaware of prospective registration requirements when the review began. Database searches covered inception to 30 June 2026; screening, data extraction, and risk-of-bias

Wang et al. INPLASY protocol 2026110057. doi:10.37766/inplasy2026.11.0057 Downloaded from https://inplasy.com/inplasy-2026-11-0057/

assessment had been completed, and data analysis was ongoing at submission. This registration was not in place before study commencement, and the timing will be disclosed in the final publication. A related ongoing INPLASY record, INPLASY202480093, examines respiratory muscle training for activities of daily living and respiratory complications after stroke. The present review is distinct in focusing on MIP, FEV1, and FVC, updating searches to 30 June 2026, and examining initial inspiratory load as a subgroup factor. Related completed reviews cited in the manuscript were also checked. The protocol content reflects the methods reported in the current revised manuscript; any subsequent methodological changes will be documented as amendments and reported as deviations.

Keywords respiratory muscle training; stroke; maximal inspiratory pressure; pulmonary ventilation; meta-analysis.

Dissemination plans The findings will be disseminated through a peer-reviewed journal article. The final manuscript will report the INPLASY registration number and DOI, disclose that registration occurred during data analysis rather than before study commencement, and explain any deviations from the registered methods. After publication, the review status and publication details will be updated on INPLASY. The authors may also use the findings to inform rehabilitation practice, academic presentations, and future randomized trials addressing training dose, reporting standards, and longer-term follow-up.

Contributions of each author

Author 1 - Jianqiao Wang - Jianqiao Wang conceived and designed the review, developed and conducted the database searches, performed the statistical analyses, and drafted the manuscript.
Author 2 - Huilin Liu - Huilin Liu contributed to review design, provided methodological guidance, and critically revised the manuscript.
Author 3 - Yang Liu - Yang Liu participated in study screening, data extraction, risk-of-bias assessment, and data checking.
Author 4 - Hua Fan - Hua Fan participated in study screening, data extraction, risk-of-bias assessment, and data checking.
Author 5 - Xiande Fan - Xiande Fan participated in study screening, data extraction, risk-of-bias assessment, and data checking.
Author 6 - Guodong Su - Guodong Su supervised the review, adjudicated disagreements, and critically reviewed and approved the final manuscript.

Wang et al. INPLASY protocol 2026110057. doi:10.37766/inplasy2026.11.0057 Downloaded from https://inplasy.com/inplasy-2026-11-0057/