INPLASY

Impact of Mobile Health-Supported Perioperative Pulmonary Rehabilitation on Motor Function and Psychological Status in Lung Cancer Patients: a Meta-Analysis

INPLASY202640044
doi: 10.37766/inplasy2026.4.0044
Received: 13 April 2026
Published: 13 April 2026

Corresponding author:
Shaofang Luo

191297335@qq.com

Author Affiliation:
The Sixth Affiliated Hospital of South China University of Technology (Nanhai District People's Hospital of Foshan), Foshan, 528200.

Fang, XL; Ou, JF; Dai, MF; Li, YH; Wang, MZ; Yang, D; Luo, SF.

ADMINISTRATIVE INFORMATION

Support - No funding received.

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

Conflicts of interest - None declared.

INPLASY registration number: INPLASY202640044

Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 13 April 2026 and was last updated on 18 May 2026.

INTRODUCTION

Review question / Objective Population (P): Patients diagnosed with non-small cell lung cancer scheduled to undergo lung resection;
Intervention (I): Mobile health-based perioperative pulmonary rehabilitation, including preoperative or postoperative interventions delivered via internet platforms, WeChat groups or public accounts, mobile health APPs, wearable monitoring devices, immersive virtual reality technology, or combined with other interventions;
Comparison (C): Control group receiving conventional perioperative pulmonary rehabilitation, such as oral health education, printed health education manuals, or post-discharge telephone follow-up;
Outcomes (O): Primary outcome: 6-minute walk distance; Secondary outcomes: Anxiety, depression, quality of life (functional status, global health status, symptoms);
Study Type (S): Randomized Controlled Trial (RCT) or Quasi-Experimental Design (QED).

Rationale Lung cancer is one of the most common malignancies worldwide and ranks first in both mortality and incidence among cancers in China, accounting for 23.8% of cancer-related deaths [1,2]. Minimally invasive video-assisted thoracoscopic surgery is the preferred treatment. Despite advances in surgical techniques, the incidence of postoperative complications such as reduced pulmonary function, chronic cough, and pulmonary infection remains as high as 30%, prolonging hospital stays and increasing socioeconomic burden [3]. Perioperative pulmonary rehabilitation has been widely recognized for improving postoperative recovery in lung cancer patients [4]. However, traditional pulmonary rehabilitation education is often limited in format, lacks continuity and effective supervision, and frequently leads to rehabilitation discontinuation [5]. Mobile health (mHealth)—including applications, WeChat platforms, virtual reality, and wearable devices [6]—offers a new approach to address these challenges.

Several randomized controlled trials have explored mHealth-based perioperative pulmonary rehabilitation in lung cancer patients, but findings remain inconsistent [7,8]. Some studies confirm significant improvements in exercise capacity and anxiety, while others report limited effects on quality of life and depression. This inconsistency may stem from heterogeneity in intervention formats, intensity, follow-up duration, and outcome measures.

A more fundamental issue is that existing studies focus on whether mHealth is "generally effective," overlooking the possibility that its effects may differ fundamentally across outcome dimensions. The mechanisms through which mHealth affects physical function, psychological symptoms, and overall health may follow entirely different logics. Pooling these heterogeneous effects under a binary label obscures the true pattern of intervention effects and hinders clinical optimization.

No systematic review or meta-analysis has specifically evaluated the effectiveness of mHealth-supported perioperative pulmonary rehabilitation in lung cancer patients [9]. Previous meta-analyses by Lu et al. [10] and Guo et al. [11] did not distinguish pre-discharge from post-discharge time points nor assess dimension-specific effects on quality of life. Thus, whether mHealth produces time-dependent effects on depression or dimension-selective effects on quality of life remains unknown. This evidence gap undermines clinical decision-making regarding the appropriate scope of mHealth use, obscures the dynamic patterns of depression improvement in intervention optimization, and hinders the identification of specific intervention modules for quality of life in research design.

First, a clinical decision-making dilemma. Faced with contradictory primary studies, clinicians cannot confidently answer: "In which specific aspects is mHealth definitely effective?" Indiscriminate recommendation may delay access to better interventions, while outright rejection may overlook its value in exercise and anxiety management.

Second, an intervention optimization dilemma. For time-dependent effects (e.g., potential delayed improvement in depression), individual studies with limited follow-up cannot capture dynamic patterns. Meta-analysis with subgroup analyses or meta-regression can systematically test whether follow-up duration acts as an effect modifier.

Third, a research design dilemma. Insufficient evidence on quality of life is itself an important signal—it suggests that existing mHealth interventions may lack specific components targeting quality of life, or that current measurement tools are insensitive. This finding will guide future research toward mechanism-driven intervention development rather than replicative validation.

Condition being studied Lung cancer is one of the most common malignancies worldwide and ranks first in both mortality and incidence among cancers in China, accounting for 23.8% of cancer-related deaths. Minimally invasive video-assisted thoracoscopic surgery (VATS) is the preferred treatment for lung cancer. Despite advances in surgical techniques, the incidence of postoperative complications such as reduced pulmonary function, chronic cough, and pulmonary infection remains as high as 30%, which prolongs hospital stays and increases socioeconomic burden. Perioperative pulmonary rehabilitation has been widely recognized for improving postoperative recovery and promoting health outcomes in patients with lung cancer. However, traditional pulmonary rehabilitation education is often limited in format, lacks continuity and effective supervision, and frequently leads to rehabilitation discontinuation. Mobile health (mHealth) technologies offer a new approach to address these challenges, but evidence on their effectiveness remains inconsistent and has not been systematically synthesized.

METHODS

Search strategy Databases and Search Period
The following electronic databases will be searched from their inception to March 20, 2026: PubMed, Web of Science, Embase, Cochrane Library, CINAHL, China National Knowledge Infrastructure (CNKI), Wanfang Data, VIP (Chinese Science and Technology Periodical Database), and CBM (Chinese Biomedical Literature Database).
Language and Publication Type
The search will be limited to articles published in Chinese or English. Grey literature will also be included.
Reference Tracing
The reference lists of included studies and relevant reviews will be manually screened to identify additional eligible studies.
Search Strategy Design
The search strategy will combine subject headings (MeSH/Emtree terms) with free-text words and synonyms. The Boolean operators "AND" and "OR" will be used to combine search terms.

English Search Terms
Population (Lung Cancer):
("Lung Neoplasms"[Mesh] OR "Carcinoma, Non-Small-Cell Lung"[Mesh] OR "lung neoplasms"[tiab] OR "lung neoplasm"[tiab] OR "pulmonary neoplasm"[tiab] OR "pulmonary neoplasms"[tiab] OR "lung cancer"[tiab] OR "lung cancers"[tiab] OR "pulmonary cancer"[tiab] OR "pulmonary cancers"[tiab] OR "cancer of the lung"[tiab] OR "cancer of lung"[tiab] OR "lung carcinoma"[tiab] OR "lung tumor"[tiab] OR "adenocarcinoma of lung"[tiab] OR "bronchial neoplasms"[tiab] OR "pulmonary tumor"[tiab] OR "pulmonary carcinoma"[tiab])
Intervention (mHealth/Digital Health):
("Internet"[Mesh] OR "Social Media"[Mesh] OR "Mobile Applications"[Mesh] OR "Telemedicine"[Mesh] OR "Internet"[tiab] OR "Social Media"[tiab] OR "Online"[tiab] OR "Web Browser"[tiab] OR "Software"[tiab] OR "Mobile Applications"[tiab] OR "Smartphone"[tiab] OR "Cell Phone"[tiab] OR "informatization"[tiab] OR "WeChat"[tiab] OR "cloud platform"[tiab] OR "informationization"[tiab] OR "information-based"[tiab] OR "App"[tiab] OR "video"[tiab] OR "micro-lecture"[tiab] OR "mobile"[tiab] OR "telemedicine"[tiab] OR "network"[tiab] OR "visualization"[tiab] OR "digital"[tiab] OR "remote"[tiab] OR "distance education"[tiab] OR "Telerehabilitation"[tiab] OR "virtual visit"[tiab] OR "virtual appointment"[tiab] OR "video visit"[tiab] OR "online visit"[tiab] OR "online appointment"[tiab] OR "e-consultation"[tiab] OR "remote consultation"[tiab] OR "remote consult"[tiab] OR "teleconsultation"[tiab] OR "teleconsult"[tiab] OR "videoconference"[tiab] OR "wearables"[tiab] OR "mobile sensing"[tiab] OR "mobile health"[tiab] OR "smartwatch"[tiab] OR "eHealth"[tiab] OR "mHealth"[tiab] OR "telephone"[tiab] OR "technolog"[tiab] OR "telenursing"[tiab] OR "technology-based"[tiab] OR "text message"[tiab])
Intervention (Pulmonary Rehabilitation):
("Pulmonary Rehabilitation"[Mesh] OR "Exercise Therapy"[Mesh] OR "Physical Therapy Modalities"[Mesh] OR "Respiratory Therapy"[Mesh] OR "Pulmonary rehabilitation"[tiab] OR "Lung rehabilitation"[tiab] OR "exercise training"[tiab] OR "exercise therapy"[tiab] OR "physical therapy"[tiab] OR "Rehabilitation"[tiab] OR "Respiratory Therapy"[tiab] OR "physiotherapy"[tiab] OR "Pulmonary exercise"[tiab] OR "breathing exercise"[tiab] OR "respiratory rehabilitation"[tiab] OR "fast-track surgery"[tiab] OR "accelerated rehabilitation"[tiab] OR "ERAS"[tiab] OR "Exercise endurance"[tiab] OR "Postoperative rehabilitation"[tiab] OR "multimodal rehabilitation"[tiab] OR "FTS"[tiab] OR "enhanced recovery"[tiab] OR "ERAS program"[tiab])
Context (Perioperative Period):
("Perioperative Period"[Mesh] OR "Perioperative Period*"[tiab] OR "Period, Perioperative"[tiab] OR "Periods, Perioperative"[tiab] OR "pneumonectomy"[tiab] OR "lobectomy"[tiab] OR "postoperative"[tiab] OR "preoperative"[tiab] OR "pulmonary lobectomy"[tiab] OR "thoracic surgery"[tiab] OR "multimodal perioperative care"[tiab] OR "bilobectomy"[tiab] OR "pulmonary resection"[tiab] OR "Radical operation"[tiab] OR "pulmonary wedge resection"[tiab] OR "sleeve lobectomy"[tiab] OR "VATS"[tiab])
Chinese Search Terms
Population: (肺癌 OR 肺肿瘤 OR 肺腺癌 OR 非小细胞肺癌 OR 肺恶性肿瘤 OR 支气管肺癌 OR 原发性支气管癌 OR 鳞状细胞癌)
Intervention (mHealth): (信息化 OR 大数据 OR Web OR 虚拟现实技术 OR 视频 OR 远程医疗 OR 互联网 OR App OR 微信 OR 可穿戴设备)
Intervention (Pulmonary Rehabilitation): (肺康复 OR 呼吸操 OR 呼吸康复 OR 肺功能锻炼 OR 运动训练 OR 呼吸训练 OR 肺功能训练 OR 加速康复外科 OR 快速康复 OR ERAS)
Context (Perioperative): (围术期 OR 围手术期 OR 肺切除 OR 肺癌根治术 OR 肺叶切除 OR 肺楔形切除 OR 全肺切除 OR 肺动脉袖式切除 OR 肺段切除 OR 胸腔镜手术 OR 开胸手术)
Final Search Combination
The final search will combine the four sets of terms using "AND":
(Lung Cancer Terms) AND (mHealth Terms) AND (Pulmonary Rehabilitation Terms) AND (Perioperative Terms).

Participant or population Patients diagnosed with non-small cell lung cancer scheduled to undergo lung resection.

Intervention Mobile health-based perioperative pulmonary rehabilitation, including preoperative or postoperative interventions delivered via internet platforms, WeChat groups or public accounts, mobile health APPs, wearable monitoring devices, immersive virtual reality technology, or combined with other interventions.

Comparator Control group receiving conventional perioperative pulmonary rehabilitation, such as oral health education, printed health education manuals, or post-discharge telephone follow-up.

Study designs to be included Study designs to be included: Randomized Controlled Trial (RCT) or quasi-experimental design (QED).

Eligibility criteria (1) Non-Chinese or non-English publications
(2) Duplicate publications
(3) Conference abstracts, comments, letters, case reports
(4) Animal studies or in vitro studies
(5) Full text unavailable or data could not be pooled
(6) No control group or self-controlled before-after studies
(7) Non-randomised controlled trials
(8) Small-sample feasibility studies.

Information sources Electronic Databases
The following electronic databases will be searched from inception to March 20, 2026:
English databases: PubMed, Web of Science, Embase, Cochrane Library, CINAHL
Chinese databases: China National Knowledge Infrastructure (CNKI), Wanfang Data, VIP, CBM (Chinese Biomedical Literature Database)
Search Strategy
The search will combine subject headings with free-text words and synonyms using Boolean operators "AND" and "OR".
English search terms:
Population: "Lung Neoplasms" OR "lung cancer" OR "pulmonary neoplasm" OR "non-small cell lung cancer" OR "lung carcinoma" OR "lung tumor" OR "bronchial neoplasms" OR "pulmonary tumor" OR "pulmonary carcinoma"
Intervention (mHealth): "Information Technology" OR "Big Data" OR "Internet" OR "Social Media" OR Online OR Software OR "Mobile Applications" OR Smartphone OR WeChat OR App OR video OR telemedicine OR digital OR remote OR Telerehabilitation OR "mobile health" OR "eHealth" OR "mHealth" OR telephone* OR technolog* OR "text message*"
Intervention (Pulmonary rehabilitation): "Pulmonary rehabilitation" OR "Lung rehabilitation" OR "exercise training" OR "exercise therapy" OR "physical therapy" OR Rehabilitation OR "Respiratory Therapy" OR physiotherapy OR "breathing exercise" OR "respiratory rehabilitation" OR "fast-track surgery" OR "ERAS" OR "enhanced recovery"
Context (Perioperative): "Perioperative Period*" OR pneumonectomy OR lobectomy OR postoperative OR preoperative OR "pulmonary lobectomy" OR "thoracic surgery" OR "pulmonary resection" OR VATS
Chinese search terms:
Population: 肺癌 OR 肺肿瘤 OR 肺腺癌 OR 非小细胞肺癌 OR 肺恶性肿瘤 OR 支气管肺癌患者
Intervention (mHealth): 信息化 OR 大数据 OR 互联网 OR App OR 微信 OR 可穿戴设备 OR 远程医疗 OR 视频
Intervention (Pulmonary rehabilitation): 肺康复 OR 呼吸锻炼 OR 呼吸康复 OR 肺功能锻炼 OR 运动训练 OR 加速康复外科 OR ERAS
Context (Perioperative): 围手术期 OR 肺切除术 OR 肺癌根治术 OR 肺叶切除 OR 胸腔镜手术 OR 开胸手术
Grey Literature and Reference Tracing
Grey literature will be searched. Reference lists of relevant studies and reviews will be traced to identify additional eligible studies.

Main outcome(s) The primary outcome was exercise capacity measured by the 6-Minute Walk Test (6MWT) distance (meters).
Timing of outcome measurement: Outcomes were extracted at two time points: (1) pre-discharge (immediately before hospital discharge); (2) post-discharge (follow-up after discharge).
Effect measures: Standardized mean difference (SMD) with 95% confidence intervals (CIs) was calculated using random-effects models due to expected clinical and methodological heterogeneity across studies.
Main findings: Compared with control groups, mHealth-based perioperative pulmonary rehabilitation significantly improved 6MWT distance both pre-discharge (SMD=1.32, 95% CI: 0.38–2.27, P=0.006) and post-discharge (SMD=1.04, 95% CI: 0.86–1.23, P<0.001).
Subgroup considerations: The effect size for 6MWT was larger at pre-discharge (SMD=1.32) than post-discharge (SMD=1.04), suggesting potential attenuation over time but sustained benefit.

Additional outcome(s) Secondary outcomes included:
1. Anxiety: Measured by Hospital Anxiety and Depression Scale-Anxiety (HADS-A) and Self-Rating Anxiety Scale (SAS).
2. Depression: Measured by Hospital Anxiety and Depression Scale-Depression (HADS-D) and Self-Rating Depression Scale (SDS).
3. Functional status: Measured by functional status scales (e.g., Karnofsky Performance Status or similar tools).
4. Health-related quality of life: Measured by overall health status scales (e.g., EORTC QLQ-C30 global health status) and symptom scales.
Main findings – Pre-discharge:
HADS-A: SMD=-0.34 (95% CI: -0.55 to -0.14, P=0.0008) – significant improvement

SAS: SMD=-1.40 (95% CI: -1.66 to -1.15, P<0.001) – significant improvement
SDS: SMD=-0.71 (95% CI: -0.94 to -0.47, P<0.001) – significant improvement
Functional status: SMD=0.36 (95% CI: 0.03 to 0.69, P=0.03) – significant improvement
HADS-D: SMD=-0.23 (95% CI: -0.48 to 0.02, P=0.07) – not significant
Main findings – Post-discharge:
HADS-A: SMD=-0.44 (95% CI: -0.63 to -0.24, P<0.001) – significant
SAS: SMD=-1.38 (95% CI: -1.68 to -1.08, P<0.001) – significant
HADS-D: SMD=-0.38 (95% CI: -0.63 to -0.13, P=0.003) – significant
SDS: SMD=-1.29 (95% CI: -1.85 to -0.74, P<0.001) – significant
Functional status: SMD=0.54 (95% CI: 0.36 to 0.72, P<0.001) – significant
Overall health status: SMD=0.24 (95% CI: 0.09 to 0.39, P=0.002) – significant
Symptom scale: SMD=-0.42 (95% CI: -0.83 to -0.00, P=0.05) – not significant.

Data management Screening and data management tools: Retrieved records were imported into EndNote for duplicate removal, then transferred to Rayyan for title/abstract and full-text screening.
Screening process: Two independent reviewers conducted the screening based on eligibility criteria. Disagreements were resolved through discussion or consultation with a third reviewer. The PRISMA flow diagram was used to document the screening process.
Data extraction: A standardized data extraction form was developed in Microsoft Excel and piloted on three randomly selected studies. Two reviewers independently extracted data. Discrepancies were resolved by consensus or by consulting a third reviewer.
Data extracted included: (1) Study characteristics (first author, year, country, sample size); (2) Participant characteristics (age, sex, cancer stage, surgery type); (3) Intervention details (mHealth format, duration, frequency); (4) Comparator description; (5) Outcome data (means, SDs, sample sizes); (6) Follow-up duration (pre-discharge and post-discharge).
Handling missing data: Corresponding authors were contacted via email for missing or unclear data. Two follow-up emails were sent within three weeks. If data remained unavailable, the study was included only in qualitative synthesis, and missing data were reported as a limitation.
Data storage: All extracted data were stored in a password-protected Excel file on a secure institutional server.

Quality assessment / Risk of bias analysis A total of 10 randomized controlled trials and 5 quasi-experimental studies involving 1,948 patients were included. The Cochrane Risk of Bias tool (version 5.1.0) was used to assess the methodological quality of included RCTs, and the JBI critical appraisal tool was used for quasi-experimental studies. RCT quality assessment: Two independent reviewers assessed each RCT across six domains: (1) random sequence generation; (2) allocation concealment; (3) blinding of participants and personnel; (4) blinding of outcome assessment; (5) incomplete outcome data; (6) selective reporting. Disagreements were resolved through discussion or consultation with a third reviewer. Each study was rated as: Low risk of bias – all domains adequately addressed; High risk of bias – one or more domains inadequately addressed; Unclear risk – insufficient information to judge. QED quality assessment: Two independent reviewers assessed each quasi-experimental study using the JBI critical appraisal tool across nine items: (1) clear cause-and-effect relationship; (2) comparability of baseline; (3) same other interventions across groups; (4) control group; (5) multi-dimensional outcome measurement; (6) completeness of follow-up; (7) same method for outcome measurement; (8) credibility of outcome measurement method; (9) appropriateness of analysis method. Each item was rated as Yes (Y), No (N), or Unclear (U). Quality grades: A – all criteria met; B – partial criteria met; C – no criteria met. Results: The quality ratings of the 10 RCTs were all Grade B; among the 5 quasi-experimental studies, 2 were rated Grade A and 3 were rated Grade B. Limitations: Common methodological limitations in RCTs included lack of blinding of participants and personnel (due to the nature of behavioral interventions), as well as unclear random sequence generation and allocation concealment in some studies. Among the quasi-experimental studies rated Grade B, the main limitation was the lack of multi-dimensional outcome measurement. Graphical presentation: Risk of bias summaries were presented as percentage bar charts and summary figures following Cochrane Handbook guidelines.

Strategy of data synthesis Software: Statistical analyses were performed using Stata (version 17.0) and Review Manager (RevMan, version 5.4).
Effect measures: All outcome variables were continuous, and the standardized mean difference (SMD) with 95% confidence intervals (CI) was calculated as the effect measure. The significance level was set at $\alpha = 0.05$.
Heterogeneity assessment: Statistical heterogeneity was assessed using the I^2 statistic

and the Chi² test (significance level set at P < 0.10 for Chi²).
Model selection:
If P > 0.1 and I² < 50%, studies were considered homogeneous, and a fixed-effect model (FEM) was used for meta-analysis.
If P < 0.1 and I² ≥ 50%, significant heterogeneity was considered present. Sources of heterogeneity were explored through sensitivity analysis, subgroup analysis, and meta-regression. After analyzing clinical heterogeneity, a random-effect model (REM) was applied.
Publication bias: Publication bias was tested using Begg's or Egger's test, with P < 0.05 indicating potential publication bias.
Specific outcomes analysis:
6-Minute Walk Distance (6MWD): Eight studies (n=807 patients) reported 6MWD. Pre-discharge: significant heterogeneity (I²=96%), REM was used (SMD=1.32, 95% CI: 0.38–2.27, P=0.006). Meta-regression with intervention format as covariate showed no significant moderating effect (P=0.14). Post-discharge: low heterogeneity (I²=48%), FEM was used (SMD=1.04, 95% CI: 0.86–1.23, P<0.001).
Anxiety: Nine studies (n=1,097 patients) reported anxiety. Pre-discharge HADS: low heterogeneity (I²=3%), FEM (SMD=-0.34, 95% CI: -0.55 to -0.14, P=0.0008). Pre-discharge SAS: single study, FEM (SMD=-1.40, 95% CI: -1.66 to -1.15, P<0.001). Post-discharge HADS: I²=0%, FEM (SMD=-0.44, 95% CI: -0.63 to -0.24, P<0.001). Post-discharge SAS: I²=22%, FEM (SMD=-1.38, 95% CI: -1.68 to -1.08, P<0.001).
Depression: Eight studies (n=1,023 patients) reported depression. Pre-discharge HADS: significant heterogeneity (I²=70.9%); after removing Liu [15], heterogeneity decreased to I²=0%, FEM showed no significant difference (SMD=-0.23, 95% CI: -0.48 to 0.02, P=0.07). Post-discharge HADS: I²=34%, FEM (SMD=-0.38, 95% CI: -0.63 to -0.13, P=0.003). Post-discharge SDS: two studies, I²=71%, REM (SMD=-1.29, 95% CI: -1.85 to -0.74, P<0.001).
Functional status: Four studies (n=493 patients). Pre-discharge: I²=0%, FEM (SMD=0.36, 95% CI: 0.03–0.69, P=0.03). Post-discharge: I²=32%, FEM (SMD=0.82, 95% CI: 0.49–1.15, P<0.001). Results were stable in leave-one-out analysis.
Symptoms (post-discharge): Four studies, I²=79%, REM (SMD=-0.86, 95% CI: -1.19 to -0.53, P=0.05). Results were unstable when Sui [11] or Wang [20] was removed.
Overall health status (post-discharge): Five studies (n=709 patients), I²=13%, FEM (SMD=0.45, 95% CI: 0.13–0.78, P=0.002). Results were stable in leave-one-out analysis.

Subgroup analysis Pre-planned subgroup analyses were conducted based on follow-up time points (pre-discharge vs. post-discharge) for all outcomes. To explore the sources of heterogeneity for outcomes with substantial heterogeneity (pre-discharge 6MWD: I² = 96%; post-discharge symptoms: I² = 79%), additional exploratory subgroup analyses were performed based on follow-up duration. However, no clear sources of heterogeneity were identified through these analyses. Due to the large number of tables, subgroup results are presented as text descriptions.
Exploratory subgroup analyses: To explore the sources of heterogeneity for outcomes with substantial heterogeneity (pre-discharge 6MWD: I²=96%; post-discharge symptoms: I²=79%), additional exploratory analyses were conducted based on follow-up duration. However, no clear sources of heterogeneity were identified through these analyses.
Meta-regression analysis: To further investigate whether mHealth intervention format contributed to heterogeneity, meta-regression was performed with intervention format as a covariate (categorized as: wearable devices vs. WeChat groups vs. internet-based platforms vs. WeChat official accounts vs. virtual reality technology).
Results of meta-regression:
For pre-discharge 6MWD (I²=96%): The intervention format had no significant moderating effect on effect size (β=0.83, 95% CI: -0.44 to 2.09, P=0.14).
For post-discharge symptom outcomes (I²=79%): The intervention format had no significant moderating effect on effect size (β=0.19, 95% CI: -2.51 to 2.12, P=0.75).
Conclusion from meta-regression: Different mHealth platform types were not the primary source of heterogeneity in this review.
Heterogeneity reduction through study removal: For pre-discharge HADS depression (I²=70%), heterogeneity significantly decreased after removing Liu 2025 (I² decreased to 0%), suggesting that this study was a major source of heterogeneity. After removal, funnel plot showed no publication bias, and the result remained stable.
Limitations: Subgroup analyses and meta-regression should be interpreted cautiously given the limited number of included studies (n=15) and potential confounding variables not measured (e.g., intervention intensity, duration, patient adherence).

Sensitivity analysis Methods: Sensitivity analyses were conducted to assess the robustness of the pooled effect estimates using the following approaches:

Leave-one-out analysis: Each study was sequentially removed in RevMan 5.4 to assess whether any single study disproportionately influenced the overall effect estimate.
Stata sensitivity analysis: Performed to identify potential sources of heterogeneity.
Publication bias assessment: Egger's test was used to assess publication bias, with P>0.05 indicating no significant publication bias.
Results of sensitivity analyses:
Stable results (P values did not change qualitatively after removing any single study):
Pre-discharge and post-discharge 6MWD
Pre-discharge and post-discharge HADS anxiety
Pre-discharge and post-discharge SAS anxiety
Pre-discharge and post-discharge HADS depression (after removal of Liu 2025)
Pre-discharge and post-discharge functional status
Post-discharge overall health status
Unstable results (P value changed qualitatively after removing specific studies):
Post-discharge symptom outcome (4 studies, I^2=79%): After sequentially removing Sui 2020 or Wang Ziyu 2025, the P value changed qualitatively, indicating that the result was not robust.
Heterogeneity investigation:
For pre-discharge 6MWD (I^2=96%): Stata sensitivity analysis indicated no clear source of heterogeneity. Meta-regression with intervention format as covariate showed no significant moderating effect (P=0.14).
For pre-discharge HADS depression (I^2=70%): Funnel plot suggested publication bias. After removing Liu 2025, heterogeneity decreased to I^2=0%, and funnel plot showed no publication bias. The result remained stable.
For post-discharge symptom outcome (I^2=79%): Stata sensitivity analysis indicated no clear source of heterogeneity. Meta-regression showed no significant moderating effect of intervention format (P=0.75).
Publication bias assessment: Egger's tests for all outcomes showed P>0.05, indicating no significant publication bias.
Conclusion: Most primary findings were robust, except for the post-discharge symptom outcome, which should be interpreted with caution.

Language restriction Chinese and English.

Country(ies) involved China.

Other relevant information Study characteristics: This systematic review and meta-analysis included 15 randomized controlled trials (RCTs) involving a total of 1,948 patients (955 in the intervention group, 993 in the control group).
Summary of main findings:
Exercise capacity (6MWD):
Pre-discharge: Significant improvement (SMD=1.32, 95% CI: 0.38–2.27, P=0.006), substantial heterogeneity (I^2=96%)
Post-discharge: Significant improvement (SMD=1.04, 95% CI: 0.86–1.23, P<0.001), low heterogeneity (I^2=48%)
Anxiety:
Both pre-discharge and post-discharge showed significant improvement across HADS and SAS measures (all P<0.001), with low heterogeneity (I^2=0%-22%)
Depression:
Pre-discharge HADS: No significant difference (SMD=-0.23, 95% CI: -0.48 to 0.02, P=0.07), heterogeneity reduced from I^2=70% to 0% after removing Liu 2025
Post-discharge HADS: Significant improvement (SMD=-0.38, 95% CI: -0.63 to -0.13, P=0.003), low heterogeneity (I^2=34%)
Functional status:
Pre-discharge: SMD=0.36 (95% CI: 0.03–0.69, P=0.03), I^2=0%
Post-discharge: SMD=0.54 (95% CI: 0.36–0.72, P.

Keywords Mobile health; Lung cancer; Perioperative pulmonary rehabilitation; Systematic review/Meta-analysis.

Dissemination plans Publication plan: The results of this systematic review and meta-analysis will be submitted for publication in a peer-reviewed SCI-indexed journal in the field of oncology, respiratory medicine, or digital health.
Data sharing: The complete dataset extracted from included studies, along with the standardized data extraction form and statistical analysis code, will be made available as supplementary files upon publication.
Protocol availability: The full protocol for this review has been registered with INPLASY (retrospective registration). The protocol is available through the INPLASY platform or upon request from the corresponding author.
Conference presentation: Findings will be presented at relevant national or international conferences (e.g., Chinese Thoracic Society Annual Meeting, World Conference on Lung Cancer, or Chinese Society of Clinical Oncology annual meeting) to reach a wider clinical and research audience.
Stakeholder dissemination: A plain language summary will be prepared for dissemination to patients, caregivers, and healthcare providers through hospital-based patient education channels, clinical rehabilitation departments, and social media platforms (e.g., WeChat official accounts).

Open access: The final manuscript will be published in an open-access journal whenever possible to maximize accessibility and readership.
Clinical practice implications: The findings will be used to inform evidence-based recommendations for mHealth-based perioperative pulmonary rehabilitation in lung cancer patients.

Contributions of each author

Author 1 - Xueling Fang - Study conceptualization and design, data curation and analysis, manuscript drafting and revision.
Email: 2207601920@qq.com
Author 2 - Jiefen Ou - Data curation and organization.
Email: nhyyojf@126.com
Author 3 - Meifen Dai - Data curation and organization.
Email: 63015911@qq.com
Author 4 - Yanhuan Li - Data curation and organization.
Email: 13902896765@139.com
Author 5 - Mingzhu Wang - Data verification and validation.
Email: mingzhu0217@126.com
Author 6 - Dan Yang - Data verification and validation.
Email: 184440208@qq.com
Author 7 - Shaofang LUO - Quality control of the article, overall supervision throughout the entire process.
Email: 191297335@qq.com

Update note

Table 1 – Summary of Protocol Amendments (Item-by-item)
1. Literature search date: 2026.1.20 → 2026.3.20. Reason: forgot to update.
2. Pre-discharge SDS: Not reported → Added: 1 QED, SMD = -0.71, 95% CI: -0.94 to -0.47, $P < 0.001$. Reason: previously omitted.
3. Post-discharge SDS: Original: 2 RCTs, $I^2 = 71\%$, SMD = -1.29, 95% CI: -1.85 to -0.74, $P < 0.001$, stability not reported → Added: results stable. Reason: added missing sensitivity analysis.
4. Pre-discharge functional status: Original: 2 RCTs, $I^2 = 0\%$, SMD = 0.36, 95% CI: 0.03 to 0.69, $P = 0.03$, results stable → New finding: after excluding Li-2024, results become unstable ($P = 0.36$). Reason: completed stability assessment.
5. Post-discharge functional status: Original: 4 RCTs, $I^2 = 32\%$, SMD = 0.82, 95% CI: 0.49 to 1.15, $P < 0.001$, results stable → Corrected to: $I^2 = 32\%$, SMD = 0.54, 95% CI: 0.36 to 0.72, $P < 0.001$. Reason: original misread SMD from forest plot.
6. Post-discharge symptom dimension: Original: 4 RCTs, $I^2 = 79\%$, SMD = -0.86, 95% CI: -1.19 to -0.53, $P = 0.05$; after excluding Sui-2020 or Wang-2025 one by one, $P < 0.05$ in all cases; results unstable → Corrected to: $I^2 = 79\%$, SMD = -0.42, 95% CI: -0.83 to -0.00, $P = 0.05$; after excluding Wang-2025, $P = 0.08$ (no substantial change); after excluding Sui-2020, results unstable. Reason: original report misread SMD value from forest plot; re-analysis confirmed correct effect size and sensitivity analysis results.
7. Post-discharge general health status: Original: 4 RCTs + 1 QED (QED control n = 100), $I^2 = 13\%$, SMD = 0.45, 95% CI: 0.13 to 0.78, $P = 0.002$, results stable → Revised to report only 4 RCTs: $I^2 = 0\%$, SMD = 0.30, 95% CI: 0.13 to 0.47, $P = 0.0006$, results stable; QED control n corrected to 120. Reason: methodological separation; sample size correction.
8. HADS-A: Original (mixed RCTs + QEDs): Pre-discharge (3 RCTs + 2 QEDs): $I^2 = 3\%$, SMD = -0.34, 95% CI: -0.55 to -0.14, $P = 0.008$; Post-discharge (3 RCTs + 1 QED): $I^2 = 0\%$, SMD = -0.44, 95% CI: -0.63 to -0.24, $P < 0.001$ → Revised to report only RCT results: Pre-discharge (3 RCTs): $I^2 = 0\%$, SMD = -0.46, 95% CI: -0.74 to -0.18, $P = 0.001$; Post-discharge (3 RCTs): $I^2 = 0\%$, SMD = -0.47, 95% CI: -0.69 to -0.25, $P < 0.001$. Reason: methodological separation.
9. Post-discharge HADS-D: Original: 3 RCTs + 1 QED, $I^2 = 34\%$, SMD = -0.38, 95% CI: -0.63 to -0.13, $P = 0.003$ → After excluding Wang-2025: I^2 decreased from 34% to 0%, SMD = -0.47, 95% CI: -0.68 to -0.26, $P < 0.001$. Reason: Wang-2025 was the source of heterogeneity; results remain stable after exclusion.

Table 2 – Types of Changes and Outcomes Affected
Effect size correction: Post-discharge functional status, post-discharge symptom dimension
Methodological separation (RCTs only): HADS-A (pre- and post-discharge), post-discharge general health status
Added missing data: Pre-discharge SDS, post-discharge SDS sensitivity analysis
Sample size correction: Post-discharge general health status (QED control: 100 → 120)
Heterogeneity clarification: Pre-discharge functional status (Li-2024), post-discharge HADS-D (Wang-2025), post-discharge symptom dimension (Sui-2020)
Please attach the original Tables 1 and 2 to this protocol update for full clarity.