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Review Article

Effect of pulmonary rehabilitation training on postoperative recovery in lung cancer patients undergoing thoracoscopic partial pulmonary resection: a meta-analysis

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Abstract: Objective: To systematically analyze the impact of pulmonary rehabilitation (PR) on postoperative recovery of lung cancer patients undergoing thoracoscopic partial pulmonary resection. Methods: This study has been registered with PROSPERO (CRD42024574965). A comprehensive search was conducted in PubMed, The Cochrane Library, Embase, Web of Science and CINAHL for literature on the effects of PR on postoperative rehabilitation in lung cancer patients undergoing thoracoscopic partial pulmonary resection, up to May 2024. Studies meeting the inclusion and exclusion criteria were selected for the meta-analysis. Valid data were extracted, and the integrated analysis was performed using RevMan5.3 and Stata 12.0 software. Results: A total of 10 relevant studies, involving 677 subjects, were included. Of these, 341 patients were in the experimental group, and 336 were in the control group. The meta-analysis showed that PR significantly improved the forced expiratory volume in the first second after surgery (FEV1) [*SMD*=1.73, 95% CI: (0.52-2.94)], peak expiratory flow (PEF) [*SMD*=0.45, 95% CI: (0.12-0.78)], forced vital capacity (FVC) [SMD=4.31, 95% CI: (1.98-6.63)], and 6 min walking distance (6MWD) [*SMD*=1.64, 95% CI: (0.64-2.65)]. PR also reduced the incidence of postoperative complications [*OR*=0.28, 95% CI: (0.18-0.43)] and shortened the duration of postoperative hospitalization [*SMD*=-0.56, 95% CI: (-0.88 - -0.24)] in lung cancer patients undergoing thoracoscopic partial pulmonary resection. There was no significant difference in anxiety [*SMD*=-0.34, 95% CI: (-1.27-0.60)] or depression [*SMD*=-0.15, 95% CI: (-0.48-0.18)] between the two groups. Conclusion: PR improves lung function and exercise tolerance, reduces postoperative complications, and shortens postoperative hospital stays in lung cancer patients undergoing thoracoscopic partial pulmonary resection. However, its effect on reducing negative mood remains unclear. Due to the limitations in the number and quality of included studies, further high-quality studies are needed to validate these findings.

Keywords: Lung rehabilitation training, thoracoscopic pneumonectomy, postoperative rehabilitation, meta-analysis

Introduction

With the introduction and rapid development of video-assisted thoracoscopic surgery (VATS), the use of VATS for partial lung resection has steadily increased. Compared with traditional thoracotomy, VATS offers several advantages such as postoperative pain reduction, shorter hospital stay, faster recovery of respiratory function, and less hospitalization cost. Moreover, VATS provides the same therapeutic effect as traditional surgical methods while promoting better postoperative recovery and functional outcomes for patients [1]. However, many patients who undergo thoracoscopic partial lung resection still experience varying degrees of dyspnea, reduced exercise tolerance, and diminished quality of life due to factors such as underlying disease, surgical stress, anesthesia, and effective volume reduction following resection [2, 3]. Pulmonary rehabilitation (PR), as a non-drug-assisted treatment, is increasingly applied to the clinical settings. PR includes exercise intervention, behavioral intervention, nutritional support, and health education. Exercise intervention is the core of comprehen-

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sive PR, including endurance training, interval training, strength training, and respiratory muscle training [4], all of which can improve lung function, exercise tolerance and quality of life to a certain extent [5, 6]. Currently, PR has been confirmed to have a positive impact on patients with chronic obstructive pulmonary disease (COPD) [7]. Given the considerable overlap between lung cancer and COPD, patients diagnosed with lung cancer may gain greater benefits from PR compared to those with other cancer [8]. While clinical trials have evaluated the effects of PR in lung cancer patients undergoing pulmonary surgery (including partial pneumonectomy and pneumonectomy), there are few studies focused specifically on lung cancer patients undergoing thoracoscopic partial pneumonectomy. Moreover, drawn from different studies [9, 10] regarding the impact of VATS on lung cancer patients vary widely due to small sample sizes and study population limitations. Based on this, we conducted a Meta-analysis of the existing studies on the effect of PR on patients undergoing thoracoscopic partial pneumonectomy during their postoperative rehabilitation, with the goal of providing medical evidence to guide clinical practice and interventions.

Data and methods

Inclusion and exclusion criteria

Inclusion criteria: (1) Type of study: randomized controlled trials (RCTs) with language restriction to English. (2) Study population: lung cancer patients who underwent thoracoscopic partial lung resection. (3) Intervention: the test group underwent pre/postoperative PR, including aerobic exercise (walking, stair climbing, etc.), strength training (upper and lower extremity and respiratory muscle training) and other training (yoga, tai chi, etc.), while the control group underwent conventional treatment. (4) Outcome indicators: ① incidence of postoperative complications; ② exercise tolerance, i.e., 6-min walking distance (6MWD); ③ pulmonary function, including Forced expiratory volume in 1 second (FEV1), Peak expiratory flow (PEF), Forced vital capacity (FVC); ④ postoperative hospitalization time; ⑤ negative emotions, including anxiety and depression.

Exclusion criteria: (1) Systematic reviews, clinical cases, reviews, dissertations, conference papers, animal experiments or other documents; (2) Studies without a control group; (3) Literature with incomplete data, or literature with data that could not be extracted and converted and the authors couldn't be reached; (4) Repeated publications; (5) Literature lacking relevant outcome indicators or imperfect outcome indicators; (6) Non-English literature.

Literature retrieval

All searches followed the principle of a combination of keywords and free words. The Literature search was conducted across PubMed, Web of Science, The Cochrane Library, Embase and CINAHL, covering the entire span of the database's inception until May 2024. The search terms included: "Video-Assisted Thoracic Surgery", "VATS", "Thoracoscopy", "Pleural Endoscopy", "Partial pneumonectomy", "Pulmonary wedge resection", "Pneumonectomy", "inspiratory muscle training", "Breathing Exercises", "pulmonary rehabilitation", "Rehabilitation", "Exercise Training" etc. Taking PubMed database as an example, the specific search strategy is shown as follows:

#1 ((((("Thoracic Surgery, Video-Assisted" [Mesh]) OR ((((((((((((((((Surgeries, Video-Assisted Thoracic[Title/Abstract]) OR (Surgery, Video-Assisted Thoracic[Title/Abstract])) OR (Thoracic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracic Surgery, Video Assisted[Title/Abstract])) OR (Video-Assisted Thoracic Surgeries[Title/Abstract])) OR (Video-Assisted Thoracoscopic Surgery[Title/Abstract])) OR (Surgeries, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Surgery, Video-Assisted Thoracoscopic[Title/Abstract])) OR (Thoracoscopic Surgeries, Video-Assisted[Title/Abstract])) OR (Thoracoscopic Surgery, Video-Assisted[Title/Abstract])) OR (Video Assisted Thoracoscopic Surgery[Title/Abstract])) OR (Video-Assisted Thoracoscopic Surgeries[Title/Abstract])) OR (Video-Assisted Thoracic Surgery[Title/Abstract])) OR (Video Assisted Thoracic Surgery[Title/Abstract])) OR (Surgery, Thoracic, Video-Assisted[Title/Abstract])) OR (VATS[Title/Abstract])) OR (VATSs[Title/Abstract]))) OR ("Thoracoscopy"[Mesh])) OR ((((((((((((((Thoracoscopies[Title/Abstract]) OR (Pleural Endoscopy[Title/

Abstract])) OR (Pleuroscopy[Title/Abstract])) OR (Pleuroscopies[Title/Abstract])) OR (Endoscopy, Pleural[Title/Abstract])) OR (Endoscopies, Pleural[Title/Abstract])) OR (Pleural Endoscopies[Title/Abstract])) OR (Surgical Procedures, Thoracoscopic[Title/Abstract])) OR (Surgical Procedure, Thoracoscopic[Title/Abstract])) OR (Thoracoscopic Surgical Procedure[Title/Abstract])) OR (Thoracoscopic Surgery[Title/Abstract])) OR (Thoracoscopic Surgical Procedures[Title/Abstract])) OR (Surgery, Thoracoscopic[Title/Abstract])) OR (Surgeries, Thoracoscopic[Title/Abstract])) OR (Thoracoscopic Surgeries[Title/Abstract]))) OR ("Thoracoscopes"[Mesh])) OR (((Thoracoscope) OR (Pleuroscopes)) OR (Pleuroscope)).

#2 ("Pneumonectomy"[Mesh]) OR ((((((((((((Pneumonectomies[Title/Abstract]) OR (Endoscopic Lung Volume Reduction[Title/Abstract])) OR (Partial Pneumonectomy[Title/Abstract])) OR (Partial Pneumonectomies[Title/Abstract])) OR (Pneumonectomy, Partial[Title/Abstract])) OR (Bronchoscopic Lung Volume Reduction[Title/Abstract])) OR (Lung Volume Reduction[Title/Abstract])) OR (Reduction, Lung Volume[Title/Abstract])) OR (Volume Reduction, Lung[Title/Abstract])) OR (Lung Volume Reduction Surgery[Title/Abstract])) OR (Pulmonary partial resection[Title/Abstract])) OR (Pulmonary wedge resection[Title/Abstract])).

#3 (((((("Breathing Exercises"[Mesh]) OR ("Breathing Exercises"[Mesh])) OR ((((((((Exercise, Breathing[Title/Abstract]) OR (Respiratory Muscle Training[Title/Abstract])) OR (Muscle Training, Respiratory[Title/Abstract])) OR (Training, Respiratory Muscle[Title/Abstract])) OR (inspiratory muscle training[Title/Abstract])) OR (inspiratory muscle training[Title/Abstract])) OR (pulmonary rehabilitation[Title/Abstract])) OR (lung rehabilitation[Title/Abstract]))) OR ("Rehabilitation"[Mesh])) OR ((Rehabilitation[Title/Abstract]) OR (Habilitation[Title/Abstract]))) OR ("Exercise"[Mesh])) OR (((((((((((((((((((((((((Exercises[Title/Abstract]) OR (Physical Activity[Title/Abstract])) OR (Activities, Physical[Title/Abstract])) OR (Activity, Physical[Title/Abstract])) OR (Physical Activities[Title/Abstract])) OR (Exercise, Physical[Title/Abstract])) OR (Exercises, Physical[Title/Abstract])) OR (Physical Exercise[Title/Abstract])) OR (Physical Exercises[Title/Abstract])) OR (Acute Exercise[Title/Abstract])) OR (Acute Exercises[Title/Abstract])) OR (Exercise, Acute[Title/Abstract])) OR (Exercises, Acute[Title/Abstract])) OR (Exercise, Isometric[Title/Abstract])) OR (Exercises, Isometric[Title/Abstract])) OR (Isometric Exercises[Title/Abstract])) OR (Isometric Exercise[Title/Abstract])) OR (Exercise, Aerobic[Title/Abstract])) OR (Aerobic Exercise[Title/Abstract])) OR (Aerobic Exercises[Title/Abstract])) OR (Exercises, Aerobic[Title/Abstract])) OR (Exercise Training[Title/Abstract])) OR (Exercise Trainings[Title/Abstract])) OR (Training, Exercise [Title/Abstract])) OR (Trainings, Exercise[Title/Abstract])).

#4 #1 AND #2 AND #3.

Literature screening & data extraction

Two researchers (Tianyun Duan and Yinan Guo) independently screened the literature based on the inclusion and exclusion criteria. The screening results were cross-checked, and in cases of disagreement, a third researcher (Hongying Pan) resolved the disputes to determine whether the contentious studies would be included. Data from the final included literature were extracted, including the author, publication data, region, study population, sample size, intervention type, intervention duration, and evaluation tools.

Literature quality evaluation

The quality of the included literature was evaluated using Cochrane Collaboration's risk of bias tool [11], encompassing seven criteria: (1) the method of random sequence generation; (2) allocation concealment; (3) double-blinding of participants and personnel; (4) blinding of outcome assessors; (5) completeness of outcome data; (6) selective reporting or not; (7) other biases. Each study was rated as having a "low", "high", or "uncertain" risk of bias. The assessments were conducted independently by two researchers (Tianyun Duan, Qin Lu). If disagreements arose during the final evaluation, the third researcher (Hongying Pan) facilitated discussions until a consensus was reached on the final quality score for each study.

Statistical methods

The statistical analyses were conducted using RevMan5.3 and Stata 12.0. Continuous data

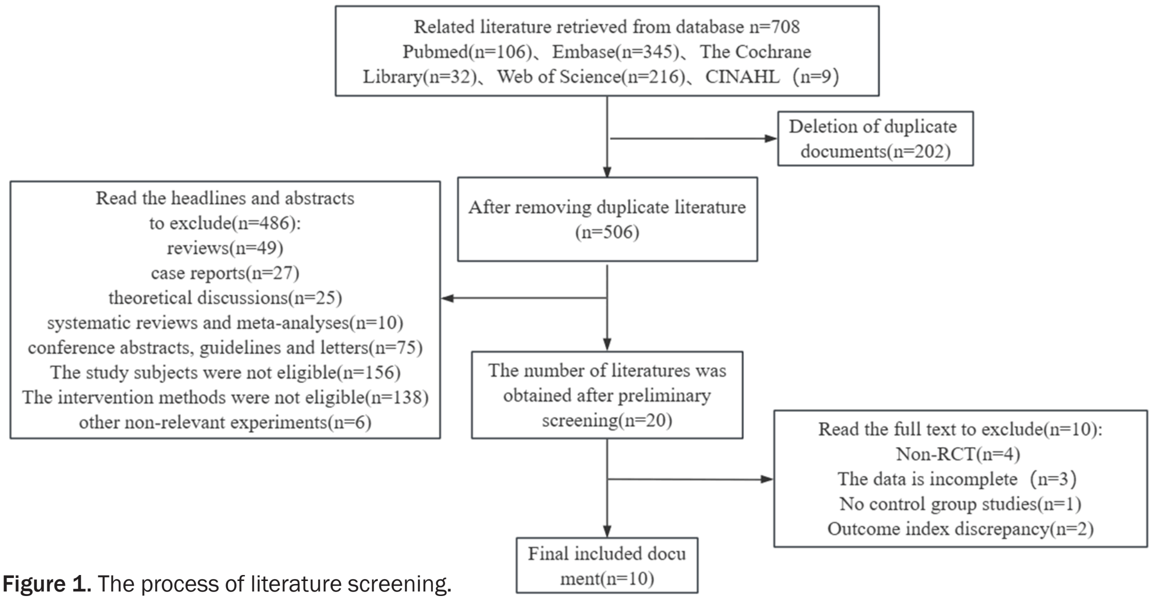

Figure 1. The process of literature screening.

were expressed using the standard mean difference (SMD) and its 95% confidence interval (CI), while categorical variables were reported as the odds ratio (OR) and its 95% CIs. Before meta-analysis, heterogeneity across the included studies was assessed using the chi-square test and the I^2 statistic. When $P>0.10$ or $I^2<50\%$, statistical heterogeneity is deemed absent, allowing the use of a fixed-effects model for the analysis. When $P\leq0.10$ and $I^2\geq50\%$, significant heterogeneity was detected among the included publications, prompting an investigation into its source. In such cases, a random effects model was applied, followed by a sensitivity analysis. The sensitivity analyses were conducted by systematically excluding each study to determine the potential effect of individual studies on overall risk. Egger's linear regression and Begg's test were used to examine the publication bias. Statistics were deemed significant if $P<0.05$.

Results

Results of literature screening

A total of 708 articles were screened through database searches. After screening and elimination based on the inclusion and exclusion criteria, 10 eligible studies were finally selected for the meta-analysis [12-21]. **Figure 1** depicts the process of literature screening.

Basic information of the included studies

The meta-analysis incorporated 10 articles [12-21], including 8 articles from China [12-16, 19-21], 1 from Spain [17], and 1 from France [18]. Collectively, these studies involved 677 subjects, with 341 in the experimental group and 336 in the control group. **Table 1** displays the fundamental features of the included literature.

Literature quality assessment

All the ten included studies were RCTs. The quality evaluation showed that the quality of the ten studies [12-21] was grade B, indicating an acceptable level of quality. All the studies explicitly mentioned their randomization methods: five studies [12, 13, 18, 20, 21] used a random number table for group allocation, and another five [14-17, 19] used a calculator for randomization. Furthermore, five studies [16, 17, 19-21] employed sealed opaque envelopes for allocation concealment, while the remaining five [12-15, 18] did not mention allocation concealment, which may introduce selection bias. Additionally, five studies [14, 16, 17, 19, 21] blinded the outcome evaluators, but none of studies reported blinding of participants or interventions, suggesting the potential for implementation bias. Six studies [12, 14-18] had participant dropouts and described the

Table 1. Basic characteristics of the included studies

Author	Region	Study population	Sample Size (T/C)	Gender [T (Male/Female)/C (Male/Female)]	Age (T/C)	Methods of control	Interventions	Duration of intervention	Outcome measures	Evaluation tools
Yutian Lai 2019 [12]	China	Limited pulmonary function (ppoFEV1%) <60% of patients with lung cancer	34/34	(18/16)/(17/17)	(64.2±6.8)/(63.4±8.2)	Only conventional treatment	Respiratory training and aerobic exercise	1 week	① ② ⑥	Postoperative complications: Assessment was based on American Society of Thoracic Surgeons (STS)/the European Society of Thoracic Surgeons (ESTS) and Clavien-Dindo complication classification. 6-MWD: Assessed according to the American Thoracic Society guidelines.
Pengfei Li 2018 [13]	China	Patients with primary non-small cell lung cancer (NSCLC)	35/34	(17/18)/(17/17)	(58.03±9.56)/(56.47±8.86)	Only conventional treatment	Positive pressure expiratory training	Not stated directly	② ③ ⑤	Postoperative complications: Refer to the joint definition of postoperative complications in Thoracic surgery by the American STS and the ESTS.
Zijia 2020 [14]	China	Patients with NSCLC	37/36	(12/25)/(11/25)	(56.2±10.3)/(56.2±8.7)	Only conventional treatment	Aerobic exercise (jogging, walking, cycling, etc.) and resistance exercise, respiratory training	2 weeks	① ② ③ ④ ⑤ ⑦ ⑧	6MWD: Assessed according to the American Thoracic Society guidelines. Postoperative complications and postoperative hospital stay: Recorded and graded according to the Clavien-Dindo classification. FEV1, FVC and PEF were measured using a portable spirometer. HDAS-A and HDAS-D: the Hospital Anxiety and Depression Scale (HADS; validated Chinese version).
Haoyu 2022 [15]	China	Patients with Lung Cancer	45/45	(18/27)/(26/19)	(60.09±9.61)/(56.84±9.41)	Only conventional treatment	Positive vibration pressure training, breathing training, bicycle training and square dance	Not stated directly	② ③ ④ ⑥	Postoperative complications: Assessment was based on STS/ESTS complication definition and Clavien-Dindo complication classification. postoperative hospital stay: Tracking and recording through the hospital's admission records system.
Han-Bing 2023 [16]	China	Patients with NSCLC	36/34	(19/17)/(13/21)	(56.67±8.21)/(58.38±7.40)	Only conventional treatment	Yoga breathing exercise training	9-14 weeks	⑥ ⑦ ⑧	6MWD: The 6-minute walking test was assessed according to American Thoracic Society guidelines. HDAS-A and HDAS-D: the Hospital Anxiety and Depression Scale (HADS; validated Chinese version).
Sebio Garcia 2017 [17]	Spain	Patients with NSCLC	10/12	(9/1)/(11/1)	(70.9±6.1)/(69.4±9.4)	Only conventional treatment	Endurance training, resistance training and respiratory training	Not stated directly	⑥	6MWD: Tests are repeated according to international recommendations to ensure reliability and the maximum distance is used for analysis.
Laurent 2020 [18]	France	Patients with NSCLC	14/12	(9/5)/(9/3)	(64±7)/(62±9)	Only conventional treatment	Breathing exercises, including load hyper breathing,	3 weeks	① ② ③	FEV1: The test was performed using a Bodybox Jaeger Care Fusion (USA). Postoperative complications: According to literature definition.
Jui-Fang 2020 [19]	China	Patients with Lung Cancer	26/28	(12/14)/(10/18)	(64.2±5.9)/(66.3±7.9)	Only conventional treatment	Inspiratory muscle training and aerobic exercise	6 weeks	⑥	6MWD: According to the American Thoracic Society Clinical Lung Function Laboratory Proficiency Standards Committee's six-minute walk test guidelines.
Jianjun 2024 [20]	China	Patients with Lung Cancer	86/83	(32/54)/(35/48)	(58.26±10.15)/(57.23±8.64)	Only conventional treatment	Breathing training, walk training and nutrition intervention	2 weeks	① ② ③ ④ ⑥	Not mentioned in the text.
Ying Kuo 2022 [21]	China	Patients with Lung Cancer	18/18	(10/8)/(7/11)	(68.33±4.58)/(69.94±5.27)	Only conventional treatment	Respiratory training and aerobic exercise	6 weeks	③ ④ ⑥	FVC and FEV1: Use a spirometer test.

Notes: ① Postoperative complications, ② Postoperative hospital stay, ③ FEV1: Forced Expiratory Volume in 1 second, ④ FVC: Forced Vital Capacity, ⑤ PEF: Peak expiratory flow, ⑥ 6MWD: 6-Minute Walk Distance, ⑦ HDAS-A: Hospital Anxiety and Depression Scale-Anxiety, ⑧ HDAS-D: Hospital Depression and Anxiety Scale-Depression, T: experimental group, C: control group, ppoFEV1%: predicted postoperative forced expiratory volume in one second.

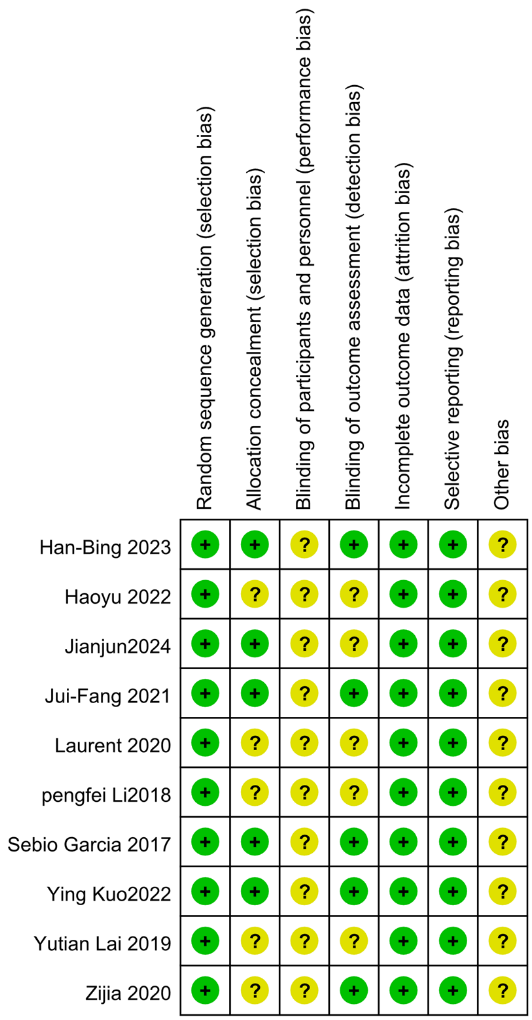

Figure 2. Evaluation of risk of bias in each included studies (Red denotes a high risk of bias, yellow denotes an unknown risk of bias, and green denotes a low risk of bias).

reasons for loss of follow-up, while the other four [13, 19-21] did not report any losses, resulting in a low risk of attrition bias. No other sources of bias were mentioned in any of the included studies, indicating an uncertain risk of bias. The results of bias risk assessment in specific RCTs are shown in **Figures 2**, **3**.

Results from the meta-analysis and the accompanying forest plot

Impact of PR on postoperative complications: Seven studies [12-15, 17, 18, 20], comprising 517 subjects, reported the effect of PR on postoperative complications in lung cancer patients undergoing thoracoscopic partial pulmonary resection. The heterogeneity test showed mild heterogeneity among the studies (P=0.152 and I^2=36.3%), and a fixed-effect model was used to carry out the meta-analysis. The findings indicated that PR significantly reduced the incidence of postoperative complications in patients undergoing thoracoscopic partial pulmonary resection [OR=0.28, 95% CI: (0.18-0.43)], as depicted in **Figure 4**. The sensitivity analysis (**Figure 5**) revealed that excluding any individual study did not alter the overall results, indicating that the outcomes were consistent and reliable.

Effect of PR on postoperative hospitalization time: Six studies [12-15, 18, 20], including 495 subjects, reported the effect of PR on postoperative hospitalization time in lung cancer patients undergoing thoracoscopic partial pulmonary resection. The heterogeneity analysis revealed a high degree of heterogeneity among the studies (P=0.014 and I^2=65.0%), and a random-effects model was used to conduct the meta-analysis. The findings indicate that the experimental group demonstrated a significant reduction in post-surgical hospital stay when compared to the control group [SMD=-0.56, 95% CI: (-0.88 - -0.24)], as depicted in **Figure 6**. Sensitivity analysis (**Figure 7**) indicated that the exclusion of any individual literature did not result in a change in the overall direction of the results, confirming their consistency and reliability. Moreover, the heterogeneity mainly originates from the study by Yutian Lai 2019 [12], which focuses on lung cancer patients with impaired lung function [predicted postoperative forced expiratory volume in one second (ppoFEV1%) <60%], while the other studies did not specify lung function criteria for inclusion.

Effect of PR on postoperative FEV1: Six studies [13-15, 18, 20, 21], involving 463 subjects, reported the effect of PR on FEV1. The heterogeneity test findings revealed significant heterogeneity among studies (P<0.001 & I^2=96.5%), thus a random-effects model was used to conduct the meta-analysis. The results indicated that the experimental group with PR exhibited a significantly higher FEV1 levels than the control group [SMD=1.73, 95% CI: (0.52-2.94)], as depicted in **Figure 8**. Sensitivity analysis (**Figure 9**) indicated that heterogeneity mainly originated from the study of Haoyu 2022

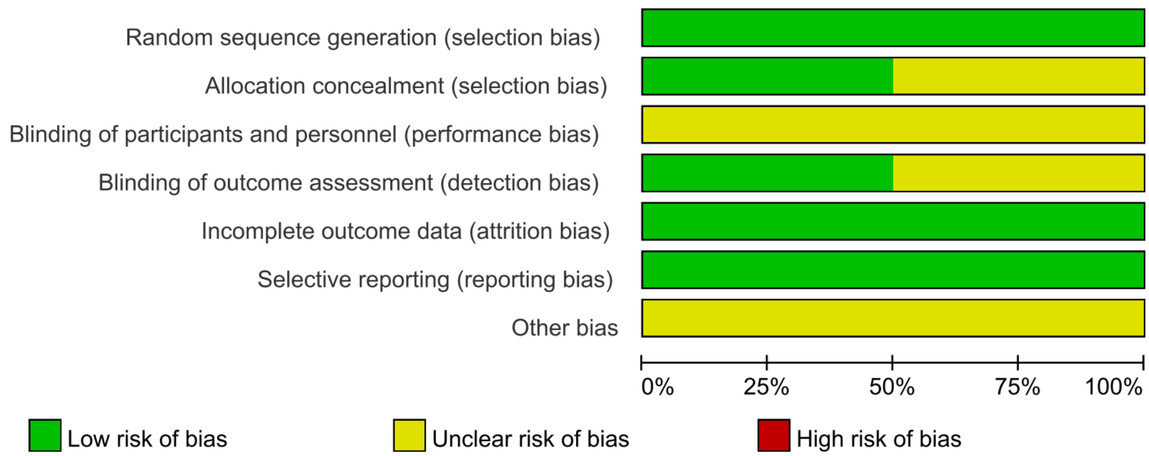

Figure 3. Proportion of total risk of bias.

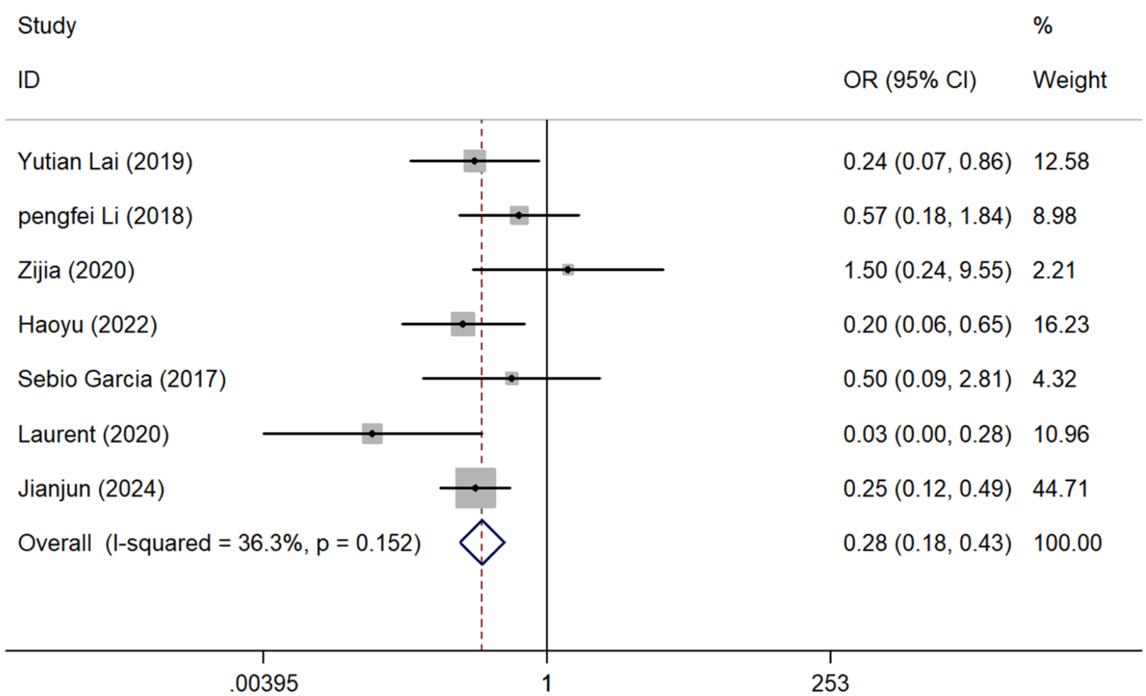

Figure 4. Effect of PR on postoperative complications. PR: Pulmonary rehabilitation.

[15], which used a comprehensive pulmonary rehabilitation training program. This program included Acapella positive-pressure vibration training, respiratory exercises, bicycling training, and square dancing, differing from the simpler rehabilitation programs used in other studies.

Impact of pulmonary rehabilitation on postoperative PEF: Only 2 studies with 142 subjects [13, 14] reported the impact of PR on postoperative PEF among lung cancer patients undergoing thoracoscopic partial lung resection. The heterogeneity test showed no significant inter-study heterogeneity (P=0.578, I^2=0.0%), and thus a fixed-effects model was used. The meta-analysis showed that PR significantly improved the postoperative PEF levels in lung cancer patients undergoing thoracoscopic partial pulmonary resection compared with the control group [SMD=0.45, 95% CI: (0.12-0.78)], as shown in **Figure 10**.

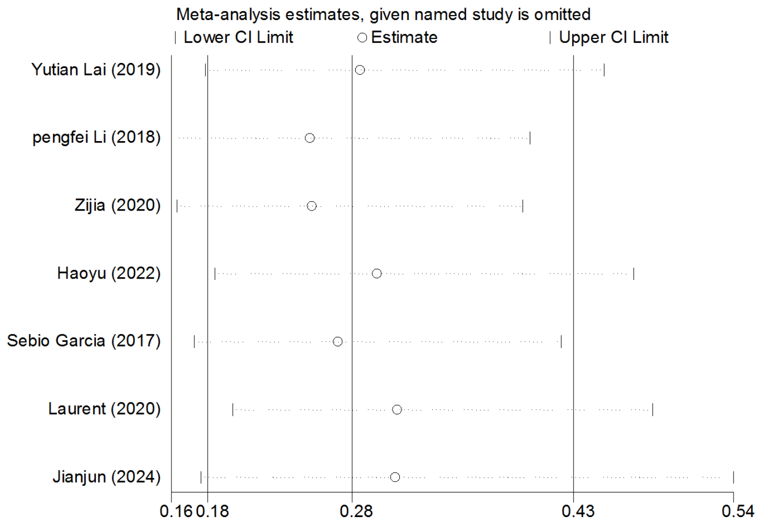

Figure 5. Sensitivity analysis of studies reporting the effect of PR on postoperative complications. PR: Pulmonary rehabilitation.

Effect of PR on postoperative FVC: Four studies (368 samples) [14, 15, 20, 21] reported the effect of PR on postoperative FVC in lung cancer patients undergoing thoracoscopic partial pulmonary resection. The heterogeneity test showed high heterogeneity among studies ($P<0.001$ and $I^2=98.3\%$), and therefore a random-effects model was used to conduct the meta-analysis. The findings indicated that PR significantly improved the postoperative FVC level in lung cancer patients [*SMD*=0.45, 95% CI: (0.12-0.78)], as shown in **Figure 11**. Sensitivity analysis (**Figure 12**) indicated that the exclusion of any individual study didn't result in directional change in the combined results of the remaining studies, demonstrating that the findings are relatively stable and reliable. The heterogeneity was mainly derived from the studies of Haoyu 2022 [15] and Jianjun 2024 [20]. The study of Haoyu 2022 [15] employed a multifaceted rehabilitation approach, including personalized adjustments based on each patient's educational level, disease condition, and psychological state, which differed from the more standardized methods used in other studies. Meanwhile, the study by Jianjun 2024 [20] provided a personalized nutrition plan developed by a dietitian, tailored to meet specific nutritional needs at different stages, unlike the general nutritional advice offered in other studies.

Impact of PR on exercise tolerance: Seven studies (509 samples) [12, 15-17, 19-21] reported the effect of PR on 6MWD in lung cancer patients undergoing thoracoscopic partial pulmonary resection. The heterogeneity test showed high heterogeneity among studies ($P<0.001$ and $I^2=96.5\%$), and thus a random-effects model was used to conduct the meta-analysis. The findings indicated that the experimental group demonstrated a significantly higher 6MWD value compared to the control group [*SMD*=1.64, 95% CI: (0.64-2.65)], as shown in **Figure 13**. The sensitivity analysis (**Figure 14**) indicated that the heterogeneity mainly originated from the study of Haoyu 2022 [15], which used a comprehensive pulmonary rehabilitation training program incorporating acapella positive pressure vibration training, breathing exercises, cycling training, and square dancing, a multimodal intervention that differed from the single- or fewer-modality rehabilitation programs in other studies.

The impact of PR on postoperative negative emotions

Effect of PR on postoperative hospital anxiety and depression scale-anxiety (HADS-A): Two studies (143 samples) [14, 16] reported the effect of PR on HADS-A. Significant heterogeneity was observed among studies with $P=0.005$ and $I^2=87.1\%$, and therefore a random-effects model was applied in the meta-analysis. As shown in **Figure 15**, the experimental group showed a significant reduction in postoperative HADS-A scores as compared to the control group [*SMD*=-0.34, 95% CI: (-1.27-0.60)]. The quality of evidence for this outcome was assessed using the GRADE (Grades of Recommendation, Assessment, Development, and Evaluation) method due to the high heterogeneity between the two studies: (1) Both the two studies were relatively well-designed. However, limitations such as being single-center studies and the inability to blind patients to grouping may have introduced bias. (2) Inconsistency: the two studies had different intervention focuses, yet neither showed a significant difference in HADS-A between the PR

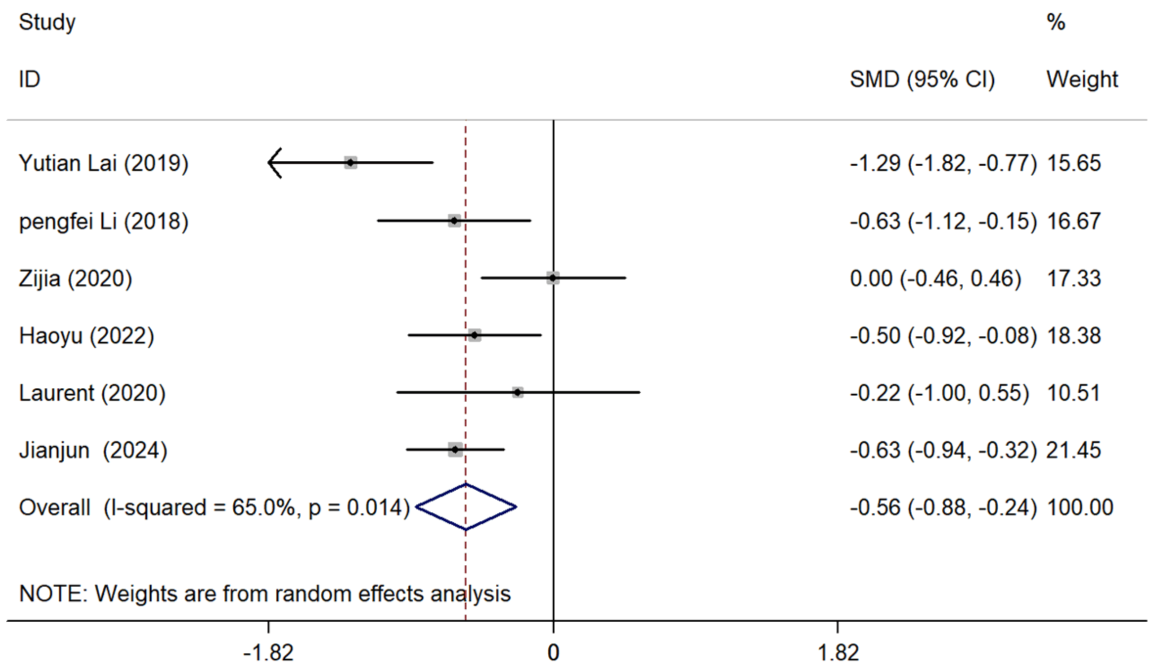

Figure 6. Effect of PR on postoperative hospital stay. PR: Pulmonary rehabilitation.

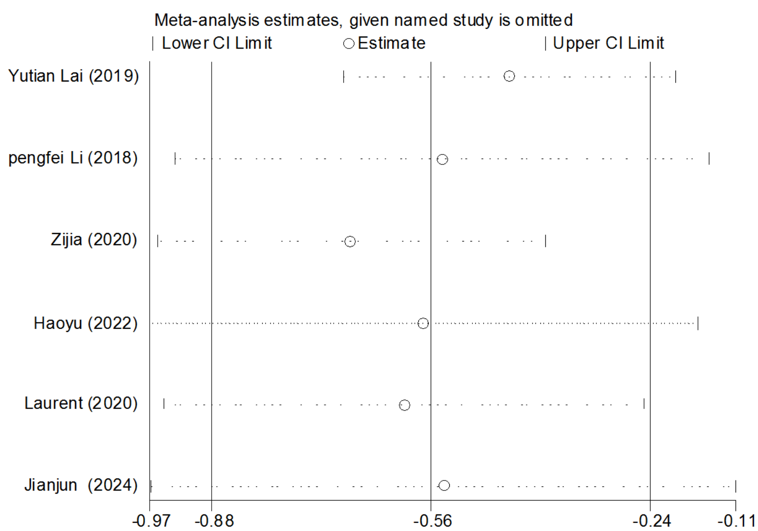

Figure 7. Sensitivity analysis of studies reporting the impact of PR on the length of postoperative hospitalization. PR: Pulmonary rehabilitation.

and control groups, leading to some consistency in the results despite the varying focuses of the interventions. (3) Indirectness: the evidence directly addresses the effect of PR on HADS-A in postoperative lung cancer patients, and no clear indirectness were identified. (4) Precision: the 95% CI of the pooled effect size included 0, with a wide interval, indicating imprecision. This aligns with the finding that there was no statistically significant reduction in HADS-A scores in the PR group compared to the control group. (5) Publication bias: due to the small number of studies (only two), it was difficult to accurately assess the possibility of publication bias, though its presence cannot be ruled out. In summary, the overall quality of evidence was rated as moderate. The reliability of the analysis regarding the effect of PR on postoperative HADS-A scores is limited, and further research is needed to confirm these findings.

Effects of PR on hospital anxiety and depression scale-depression (HADS-D): Two studies (143 samples) [14, 16] reported the effect of PR on postoperative HADS-D in lung cancer patients undergoing thoracoscopic partial lung resection. The heterogeneity test revealed no significant inter-study heterogeneity (P=0.565 and I^2=0.0%), and thus a fixed-effects model was used to conduct the meta-analysis. The findings, as shown in **Figure 16**, revealed no signifi-

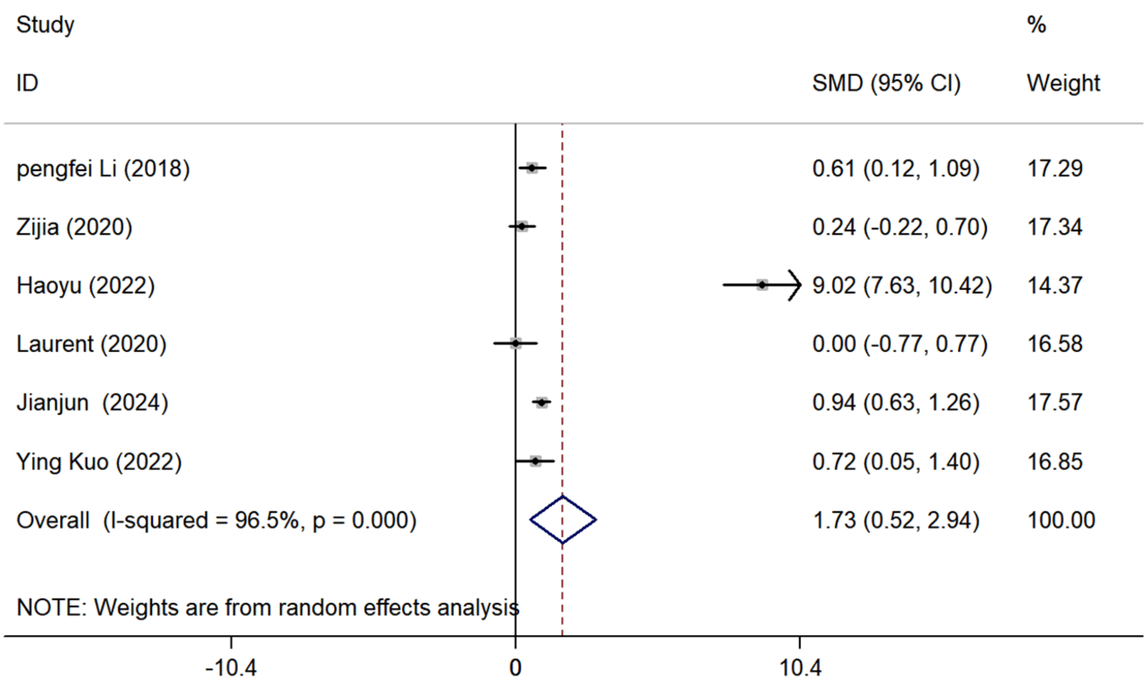

Figure 8. Effect of PR on postoperative FEV1. PR: Pulmonary rehabilitation, FEV1: Forced expiratory volume in 1 second.

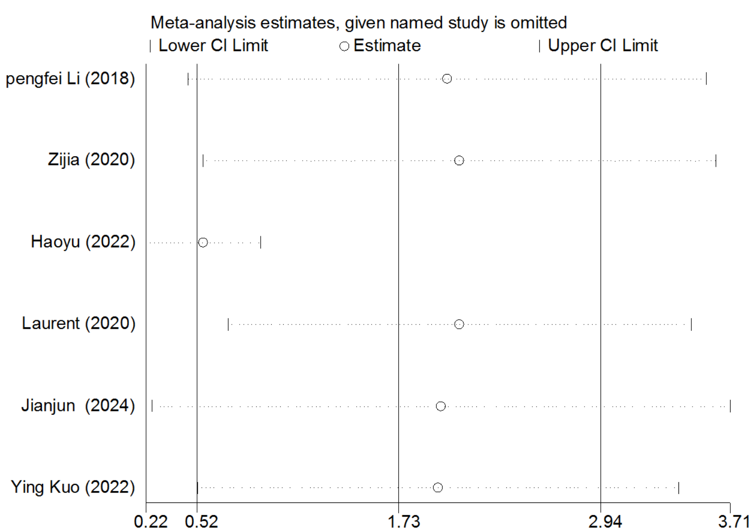

Figure 9. Sensitivity analysis of studies reporting the impact of PR on postoperative FEV1. PR: Pulmonary rehabilitation, FEV1: Forced expiratory volume in 1 second.

cant reduction in postoperative HADS-D scores in the experimental group compared to the control group [SMD=-0.15, 95% CI: (-0.48-0.18)].

Publication bias analysis

Begg's correlation test as well as Egger's linear regression method were used for conducting a publication bias analysis on postoperative rehabilitation in patients undergoing thoracoscopic partial pulmonary resection. The results of both tests showed *P*>0.05 for the outcome indicators, suggesting that the risk of publication bias was relatively low and the outcomes were stable. **Figures 17** and **18** illustrate the results of the Begg's correlation test and Egger's regression test for postoperative complications and 6-minute walking distance (6MWD) as examples for analyzing publication bias. These findings indicate a low likelihood of significant bias in the included studies.

Discussion

In recent years, research on pulmonary rehabilitation (PR) in patients with chronic respiratory diseases has found that PR can effectively enhance patients' quality of life, exercise tolerance, and pulmonary function [22-24]. Therefore, some researchers believe that incorporat-

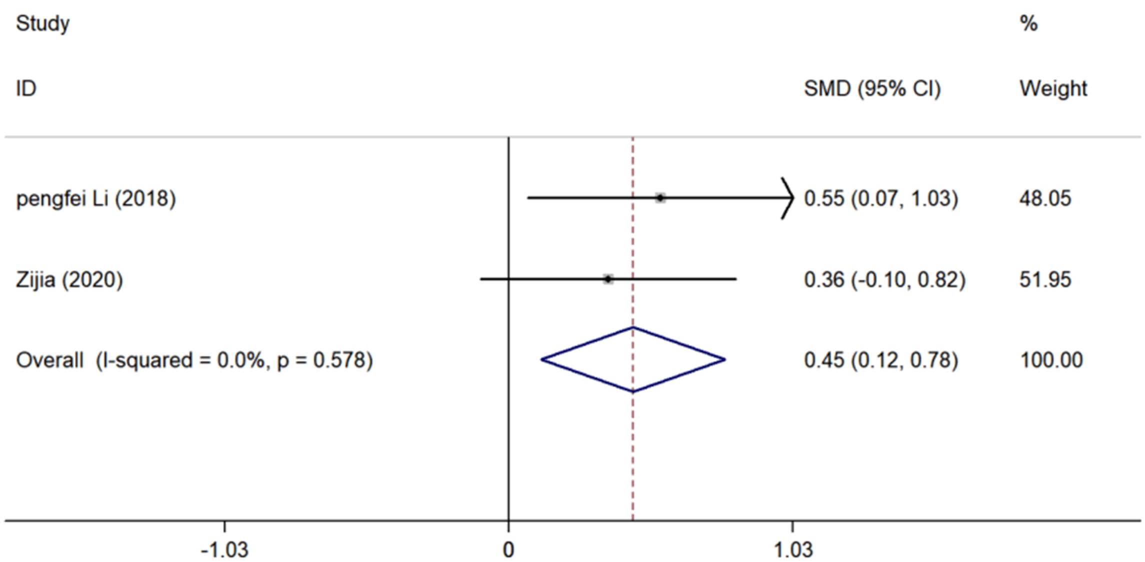

Figure 10. Effect of PR on postoperative PEF. PR: Pulmonary rehabilitation, PEF: Peak expiratory flow.

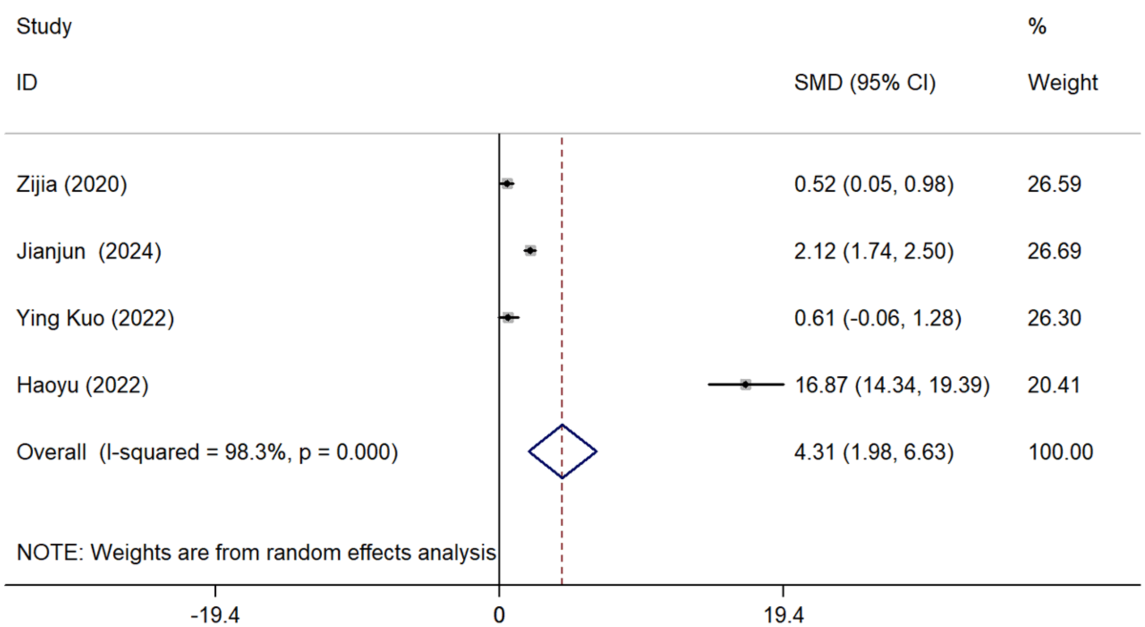

Figure 11. Effects of PR on postoperative FVC. PR: Pulmonary rehabilitation, FVC: Forced vital capacity.

ing PR into conventional surgical treatment may offer clinical benefits for lung cancer patients' postoperative outcomes [25-27]. A systematic evaluation including 7 RCTs showed that preoperative exercise could reduce both the incidence of postoperative complications and the duration of hospitalization in lung cancer patients undergoing surgery [28]. The meta-analysis of Cavalheri and Granger [29] also indicated that preoperative exercise not only reduced postoperative complications but also improved pulmonary respiratory function in patients with lung cancer. However, these comprehensive reviews and other similar studies [30, 31] involve a mix of patients undergoing different surgical procedures, primarily thoracoscope surgery and open surgery, which have varying effects on prognosis. There are differences in how these surgical approaches impact patient outcomes. The available literature

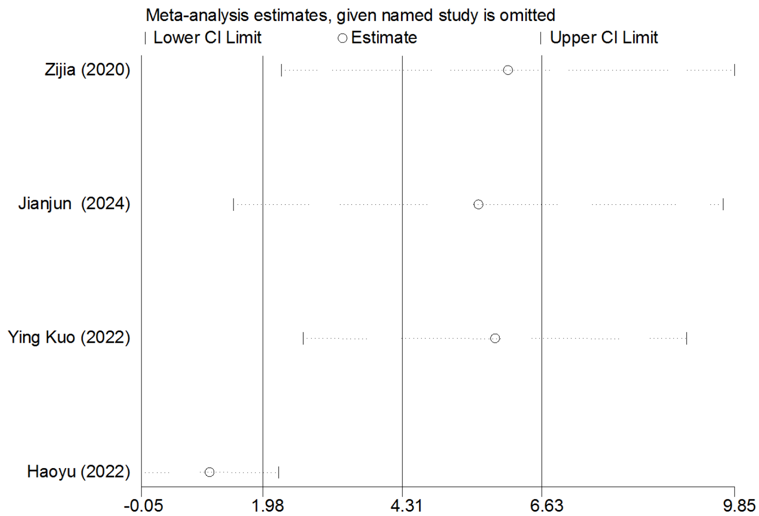

Figure 12. Sensitivity analysis of studies reporting the impact of PR on postoperative FVC. PR: Pulmonary rehabilitation, FVC: Forced vital capacity.

on the use of PR in patients undergoing thoracoscopic lung resection is limited, and studies on PR's effects on postoperative lung function and quality of life in these patients have shown conflicting results. To address this gap, a meta-analysis of all relevant studies was conducted in this study to determine the precise effect of PR on postoperative recovery in patients undergoing thoracoscopic partial pneumonectomy.

Lung cancer patients undergoing thoracoscopic partial pneumonectomy experience different degrees of pulmonary function impairment due to the underlying disease, surgery, and drug treatment. Common indicators used to evaluate pulmonary rehabilitation effects include FEV1, PEF and FVC. FEV1 and PEF are primarily objective measures of obstructive ventilation dysfunction, while FVC reflects restrictive ventilation dysfunction [32, 33]. In this study, six RCTs examining postoperative FEV1 changes, two RCTs assessing postoperative PEF changes, and four RCTs analyzing postoperative FVC changes in lung cancer patients undergoing thoracoscopic partial pulmonary resection were reviewed. The meta-analysis results demonstrated that patients in the experimental PR group showed significantly better PEF, FEV1, and FVC values after the intervention compared to those receiving only conventional treatment. These findings suggest that PR effectively enhances postoperative ventilatory function in patients who undergo thoracoscopic partial pneumonectomy. Stefanelli F et al. [34] conducted a study with 40 patients with non-small cell lung cancer complicated with COPD, who were randomized into a rehabilitation group and a traditional treatment group. The rehabilitation group underwent PR for 3 weeks before operation. The outcomes demonstrated a significant increase in FEV1 in the rehabilitation group compared to the traditional group (1.519±7.70 L vs. 1.728±7.90 L). This finding aligns with the trend observed in this meta-analysis. The potential mechanisms behind PR's benefits may include increased respiratory muscle activity during respiratory training, which prevents excessive gas retention in the lungs, enhances alveolar gas exchange, and improves overall respiratory efficiency. Additionally, exercise and respiratory training activate the entire respiratory muscle system, improving muscle strength and endurance, thereby contributing to better lung function [35, 36]. Different conclusions have also been reached in the literature. Huang J et al. [37] conducted a study on PR in patients with NSCLC and reported no statistically significant differences in FEV1 values before and after training (2.2 L vs. 2.3 L), with no changes observed in PEF and FVC. These discrepancies in findings may be related to differences in measurement methods, baseline lung function characteristics (e.g., histological type, differentiation degree, and disease staging) or variations in follow-up duration.

As a safe and simple method, 6MWD can better reflect the daily exercise tolerance of lung cancer patients and is often used in the evaluation of cardiopulmonary function and cardiopulmonary rehabilitation efficacy [38]. One study [39] found that after a period of PR, the 6MWD of lung cancer patients increased from (524±81) m to (567±78) m, while the control group without PR decreased from (555±113) m to (491±109) m. This confirms PR's role in improving exercise tolerance in postoperative lung cancer patients. This meta-analysis dem-

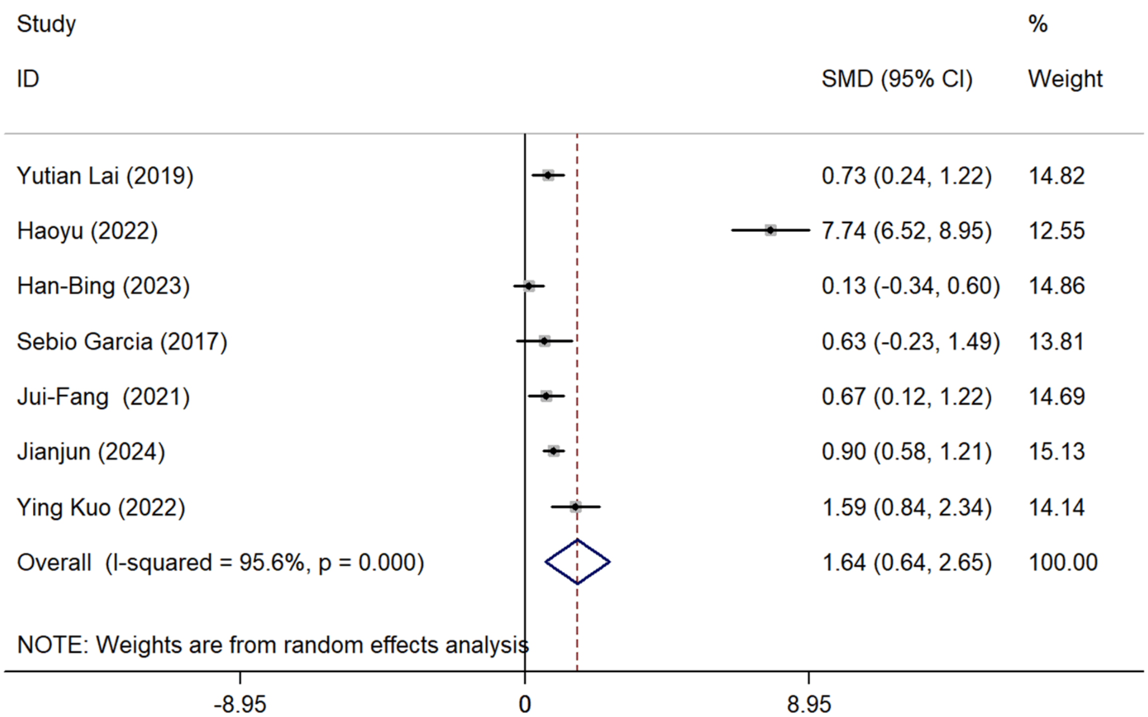

Figure 13. Effects of PR on postoperative 6MWD. PR: Pulmonary rehabilitation, 6MWD: 6-minute walk distance.

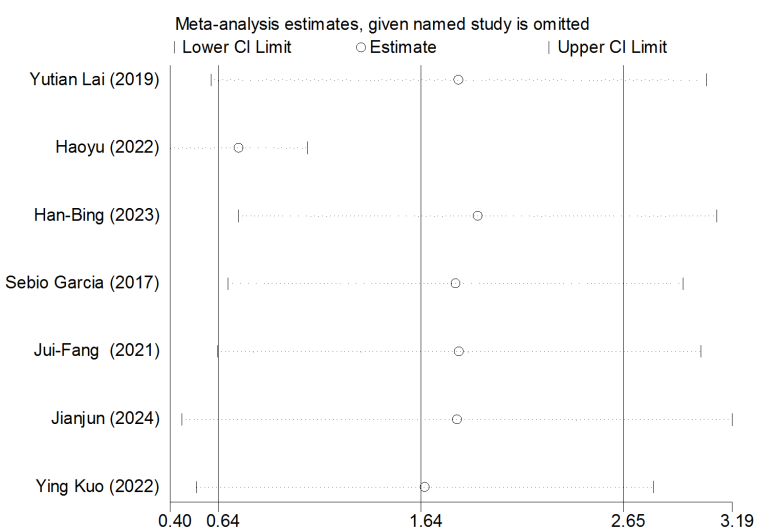

Figure 14. Sensitivity analysis of studies reporting the impact of PR on postoperative 6MWD. PR: Pulmonary rehabilitation, 6MWD: 6-minute walk distance.

onstrated that compared to conventional therapy alone, PR plus conventional therapy significantly improved postoperative 6MWD in lung cancer patients with thoracoscopic partial pneumonectomy [*SMD*=1.64, 95% CI: (0.64-2.65)]. The potential mechanisms for this improvement include the benefits of aerobic and resistance exercise in PR, which can enhance cardiorespiratory endurance, muscle strength, and blood circulation, improving oxygen delivery and carbon dioxide excretion. These factors help alleviate respiratory distress and improve exercise tolerance, thereby increasing 6MWD [40].

In addition, this meta-analysis examined the effect of PR on postoperative complications and hospitalization duration in lung cancer patients undergoing thoracoscopic partial pneumonectomy. The results showed that the experimental group had a significantly shorter postoperative hospital stay than the control group [SMD=-0.56, 95% CI: (-0.88 - -0.24)], and the rate of postoperative complications was only 28% of that in the control group [OR=0.28, 95% CI: (0.18-0.43)]. These results suggest that PR not only reduces the incidence

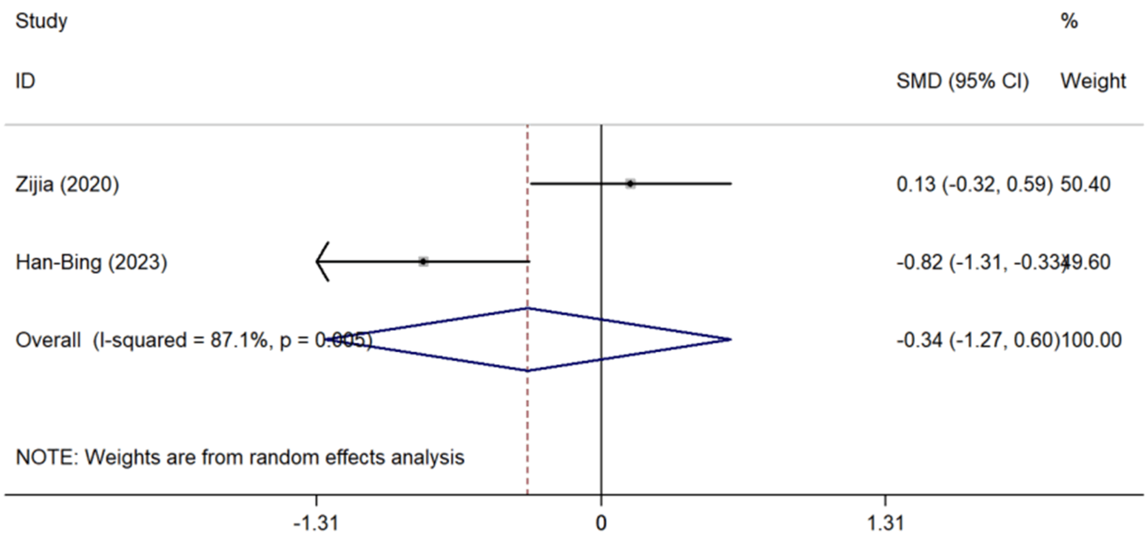

Figure 15. Effects of PR on postoperative HADS-A. PR: Pulmonary rehabilitation, HADS-A: Hospital anxiety and depression scale-anxiety.

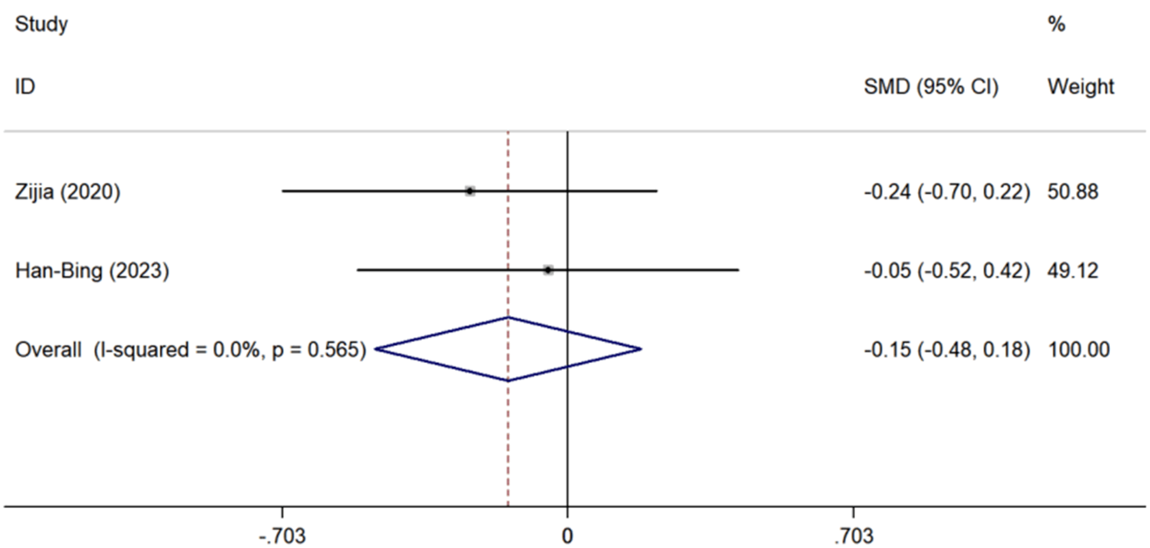

Figure 16. Effects of PR on postoperative HADS-D. PR: Pulmonary rehabilitation, HADS-D: Hospital depression and anxiety scale-depression.

of postoperative complications but also shorten the postoperative hospital stay for lung cancer patients. A retrospective study on perioperative rehabilitation training in pneumonectomy patients also showed that PR significantly reduced postoperative hospital stay, medical costs, and the incidence of postoperative pulmonary complications (PPC) [41]. Lung infection and atelectasis are common complications postoperatively in patients with lung cancer, trauma surgery, anesthesia and endotracheal intubation, which increase lung secretion production and reduce vital capacity. Factors such as diminished ciliary activity, suppressed coughing due to pain, and impaired expiratory flow can lead to secretion retention, airway obstruction, and an increased risk of atelectasis and infection, ultimately affecting alveolar gas exchange. PR, particularly through respiratory training and exercise interventions, can improve cardiopulmonary function, enhance cough efficiency, and reduce the retention of lung secre-

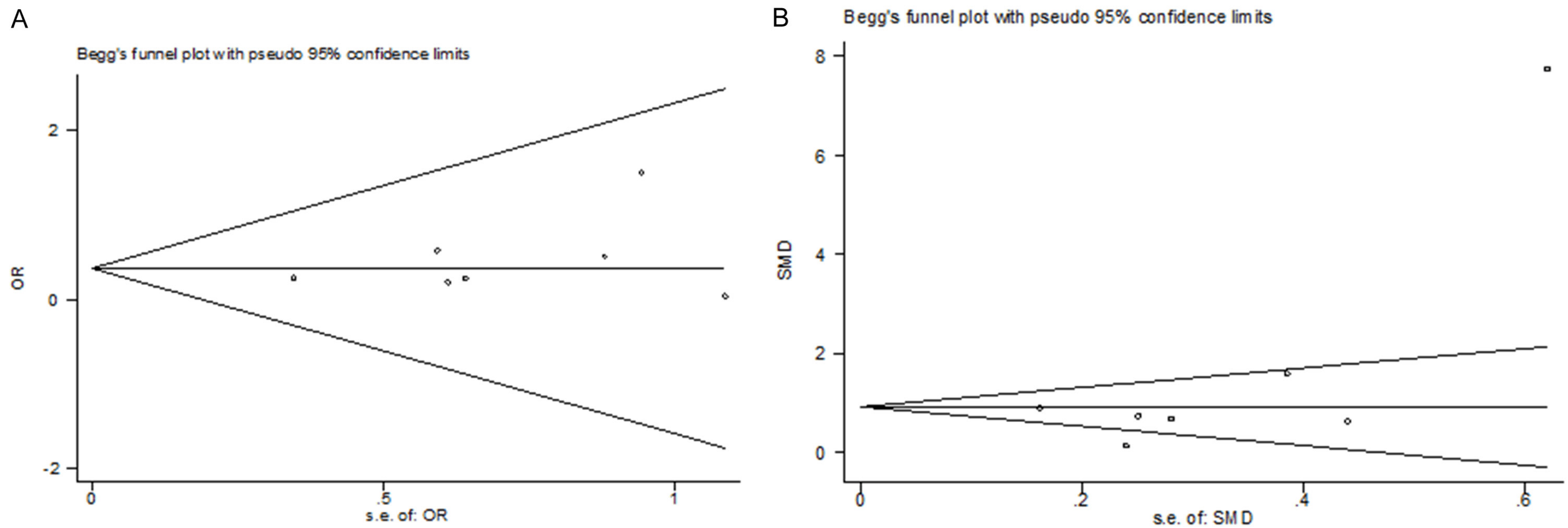

Figure 17. Begg's test on studies reporting postoperative complications (A) and 6MWD (B) in patients undergoing thoracoscopic partial pneumonectomy. PR: Pulmonary rehabilitation, 6MWD: 6-minute walk distance.

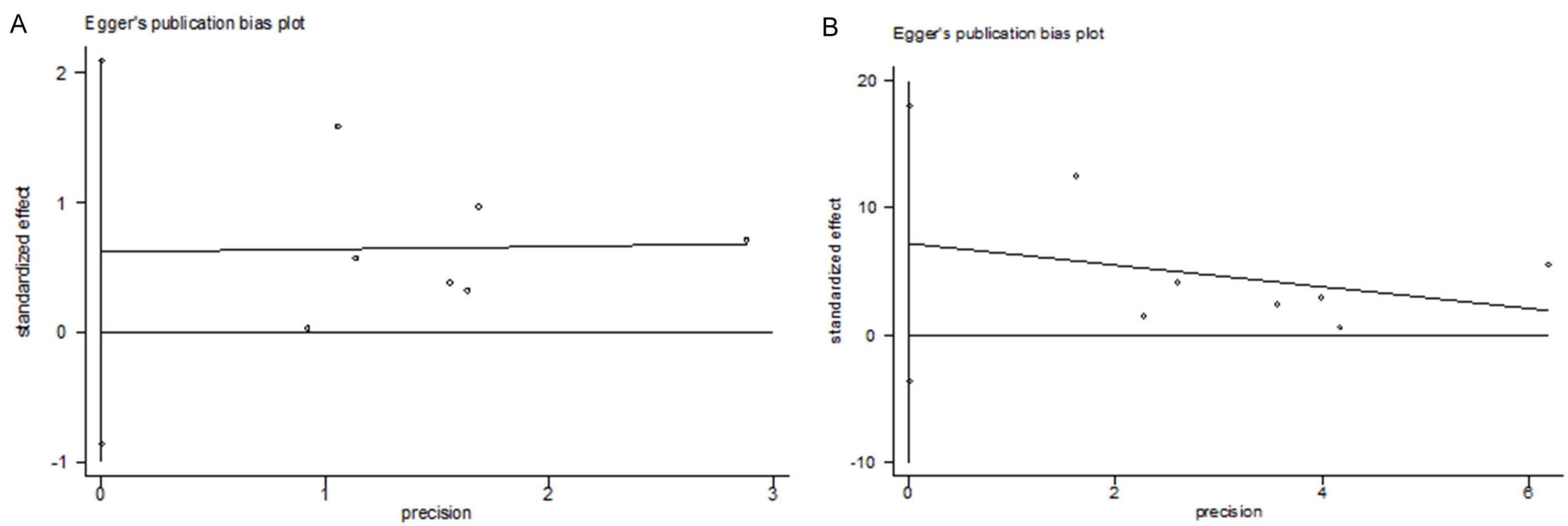

Figure 18. Egger's regression test on studies reporting postoperative complications (A) and 6MWD (B) in patients undergoing thoracoscopic partial pneumonectomy. PR: Pulmonary rehabilitation, 6MWD: 6-minute walk distance.

tions, thereby lowering the risk of these postoperative complications [42].

Some studies have shown that PR can not only improve postoperative complications but also alleviate disease-related psychological anxiety and depression in patients [43]. Anxiety and depression are common in hospitalized patients. Studies have shown that cancer patients tend to have higher HADS scores compared to general population [44]. Negative emotions also affect the overall well-being and prognosis of cancer patients [45]. However, there are limited studies specifically investigating the effects of PR on negative emotions in lung cancer patients undergoing thoracoscopic partial lung resection. Among the literature included in this study, only two studies assessed the impact of PR on post-operative anxiety and depression. The meta-analysis results indicated no significant differences between the experimental group and control group in terms of postoperative HADS-A and HADS-D scores. The possible reasons for the failure of PR to improve postoperative negative emotions are as follows: The development and persistence of negative emotions are influenced by a variety of psychological factors, such as patients' perception of their disease, expectations of treatment, personal personality traits [46]. These factors may extend beyond the scope of PR. In addition, the PR programs in the included literature mainly focused on sports training and didn't fully incorporate psychological interventions, such as psychological counselling and cognitive behavioral therapy, which are often essential for addressing negative emotions. A study on breast cancer patients reported that exercise training of different intensities had different effects on anxiety and depression [47]. This suggests that the intensity of PR exercise may also influence the emotional outcomes of lung cancer patients. More large-scale studies are needed to determine whether PR can effectively reduce negative emotions in patients undergoing thoracoscopic partial pneumonectomy.

The limitations of this study are as follows: (1) Currently, there is no clear, standard protocol for PR in patients undergoing thoracoscopic partial pneumonectomy. The PR interventions in the included studies primarily focused on exercise training, but there were inconsistencies in the form, frequency, duration and time (preoperative/postoperative) of the training across the studies. (2) All of the included studies were randomized controlled trials with small sample sizes. Additionally, none of the studies provided details on sample size estimation, which may affect the robustness and validity of the findings. (3) The studies included in this meta-analysis varied in terms of surgical methods and inclusion criteria, contributing to significant heterogeneity in the results. (4) Due to the limited number of included studies, with each outcome indicator reported in fewer than 10 articles, the publication bias analysis may not be highly meaningful. Therefore, the results of the bias analysis should only be considered as a reference.

In conclusion, pulmonary rehabilitation can reduce postoperative complications, shorten hospital stays, improve exercise tolerance, and enhance postoperative pulmonary function in lung cancer patients undergoing thoracoscopic partial lung resection. However, the effect of PR on patients' postoperative negative emotions requires further investigation in higher-quality studies.

Disclosure of conflict of interest

None.

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References

[1] Hernandez-Vaquero D, Vigil-Escalera C, Pérez-Méndez I, Gutiérrez A, Avanzas P, Wei Y, Diaz R, Silva J, Moris C and Pascual I. Survival after thoracoscopic surgery or open lobectomy: systematic review and meta-analysis. Ann Thorac Surg 2021; 111: 302-313.

[2] Spruit MA, Singh SJ, Garvey C, ZuWallack R, Nici L, Rochester C, Hill K, Holland AE, Lareau SC, Man WD, Pitta F, Sewell L, Raskin J, Bourbeau J, Crouch R, Franssen FM, Casaburi R, Vercoulen JH, Vogiatzis I, Gosselink R, Clini EM, Effing TW, Maltais F, van der Palen J, Troosters T, Janssen DJ, Collins E, Garcia-Aymerich J, Brooks D, Fahy BF, Puhan MA, Hoogendoorn M, Garrod R, Schols AM, Carlin B, Benzo R, Meek P, Morgan M, Rutten-van Mölken MP, Ries AL, Make B, Goldstein RS, Dowson CA, Brozek JL, Donner CF and Wouters EF; ATS/

ERS Task Force on Pulmonary Rehabilitation. An official American Thoracic Society/European Respiratory Society statement: key concepts and advances in pulmonary rehabilitation. Am J Respir Crit Care Med 2013; 188: e13-64.

[3] Silva L, Maricoto T, Mota Â, Lemos L, Santos M, Cunha H, Azevedo I, Berger-Estilita J, Costa P and Padilha JM. Effectiveness of a home-based pulmonary rehabilitation maintenance programme: the Rehab2Life study protocol. BMC Nurs 2024; 23: 338.

[4] Troosters T, Janssens W, Demeyer H and Rabinovich RA. Pulmonary rehabilitation and physical interventions. Eur Respir Rev 2023; 32: 220222.

[5] Xu J, Li X, Zeng J, Zhou Y, Li Q, Bai Z, Zhang Y and Xiao J. Effect of Baduanjin qigong on postoperative pulmonary rehabilitation in patients with non-small cell lung cancer: a randomized controlled trial. Support Care Cancer 2023; 32: 73.

[6] Wang L, Yu M, Ma Y, Tian R and Wang X. Effect of pulmonary rehabilitation on postoperative clinical status in patients with lung cancer and chronic obstructive pulmonary disease: a systematic review and meta-analysis. Evid Based Complement Alternat Med 2022; 2022: 4133237.

[7] Ammous O, Feki W, Lotfi T, Khamis AM, Gosselink R, Rebai A and Kammoun S. Inspiratory muscle training, with or without concomitant pulmonary rehabilitation, for chronic obstructive pulmonary disease (COPD). Cochrane Database Syst Rev 2023; 1: CD013778.

[8] Luo Z, Wan R, Liu S, Feng X, Peng Z, Wang Q, Chen S and Shang X. Mechanisms of exercise in the treatment of lung cancer - a mini-review. Front Immunol 2023; 14: 1244764.

[9] Takamori S, Oizumi H, Suzuki J, Suzuki K and Kabasawa T. Video-assisted thoracoscopic segmentectomy for deep and peripheral small lung cancer. Thorac Cardiovasc Surg 2022; 70: 233-238.

[10] Gabryel P, Piwkowski C, Kasprzyk M, Zieliński P, Roszak M and Dyszkiewicz W. Worse outcomes after conversion of thoracoscopic lobectomy for lung cancer. Interact Cardiovasc Thorac Surg 2021; 32: 356-363.

[11] Crocker TF, Lam N, Jordão M, Brundle C, Prescott M, Forster A, Ensor J, Gladman J and Clegg A. Risk-of-bias assessment using Cochrane's revised tool for randomized trials (RoB 2) was useful but challenging and resource-intensive: observations from a systematic review. J Clin Epidemiol 2023; 161: 39-45.

[12] Lai Y, Wang X, Zhou K, Su J and Che G. Impact of one-week preoperative physical training on clinical outcomes of surgical lung cancer patients with limited lung function: a randomized trial. Ann Transl Med 2019; 7: 544.

[13] Li P, Lai Y, Zhou K, Su J and Che G. Can perioperative oscillating positive expiratory pressure practice enhance recovery in lung cancer patients undergoing thorascopic lobectomy? Zhongguo Fei Ai Za Zhi 2018; 21: 890-895.

[14] Liu Z, Qiu T, Pei L, Zhang Y, Xu L, Cui Y, Liang N, Li S, Chen W and Huang Y. Two-week multimodal prehabilitation program improves perioperative functional capability in patients undergoing thoracoscopic lobectomy for lung cancer: a randomized controlled trial. Anesth Analg 2020; 131: 840-849.

[15] Zou H, Qin Y, Gong F, Liu J, Zhang J and Zhang L. ABCDEF pulmonary rehabilitation program can improve the mid-term lung function of lung cancer patients after thoracoscopic surgery: a randomized controlled study. Geriatr Nurs 2022; 44: 76-83.

[16] Lu HB, Ma RC, Yin YY, Song CY, Yang TT and Xie J. Clinical indicators of effects of yoga breathing exercises on patients with lung cancer after surgical resection: a randomized controlled trial. Cancer Nurs 2023; [Epub ahead of print].

[17] Sebio García R, Yáñez-Brage MI, Giménez Moolhuyzen E, Salorio Riobo M, Lista Paz A and Borro Mate JM. Preoperative exercise training prevents functional decline after lung resection surgery: a randomized, single-blind controlled trial. Clin Rehabil 2017; 31: 1057-1067.

[18] Laurent H, Aubreton S, Galvaing G, Pereira B, Merle P, Richard R, Costes F and Filaire M. Preoperative respiratory muscle endurance training improves ventilatory capacity and prevents pulmonary postoperative complications after lung surgery. Eur J Phys Rehabil Med 2020; 56: 73-81.

[19] Liu JF, Kuo NY, Fang TP, Chen JO, Lu HI and Lin HL. A six-week inspiratory muscle training and aerobic exercise improves respiratory muscle strength and exercise capacity in lung cancer patients after video-assisted thoracoscopic surgery: a randomized controlled trial. Clin Rehabil 2021; 35: 840-850.

[20] Li J and Zheng J. Effect of lung rehabilitation training combined with nutritional intervention on patients after thoracoscopic resection of lung cancer. Oncol Lett 2024; 27: 118.

[21] Kuo NY, Liu JF, Lu HI, Lo CM, Hsien LC, Chang CL and Hsu M. Home-based pulmonary rehabilitation in aged individuals with lung tumor after thoracoscopic surgery. Top Geriatr Rehabil 2022; 38: 110-119.

[22] Kongnakorn T, Sarri G, Freitag A, Marczell K, Kazmierska P, Masters E, Pawar V and Zhang X. Modeling challenges in cost-effectiveness analysis of first-line immuno-oncology thera-

pies in non-small cell lung cancer: a systematic literature review. Pharmacoeconomics 2022; 40: 183-201.
[23] Sanchez-Ramirez DC. Impact of pulmonary rehabilitation services in patients with different lung diseases. J Clin Med 2022; 11: 407.
[24] Devani P, Pinto N, Jain P, Prabhudesai P and Pandey A. Effect of pulmonary rehabilitation (PR) program in patients with interstitial lung disease (ILD)-Indian scenario. J Assoc Physicians India 2019; 67: 28-33.
[25] Fuzhi Y, Dongfang T, Wentao F, Jing W, Yingting W, Nianping M, Wen G and Xiaoyong S. Rapid recovery of postoperative pulmonary function in patients with lung cancer and influencing factors. Front Oncol 2022; 12: 927108.
[26] Yu Z, Xie G, Qin C and Qiu X. Study on the benefit of postoperative exercise rehabilitation in patients with lung cancer complicated with chronic obstructive pulmonary disease. Zhongguo Fei Ai Za Zhi 2022; 25: 14-20.
[27] Scott JM, Thomas SM, Herndon JE 2nd, Douglas PS, Yu AF, Rusch V, Huang J, Capaci C, Harrison JN, Stoeckel KJ, Nilsen T, Edvardsen E, Michalski MG, Eves ND and Jones LW. Effects and tolerability of exercise therapy modality on cardiorespiratory fitness in lung cancer: a randomized controlled trial. J Cachexia Sarcopenia Muscle 2021; 12: 1456-1465.
[28] Li X, Li S, Yan S, Wang Y, Wang X, Sihoe ADL, Yang Y and Wu N. Impact of preoperative exercise therapy on surgical outcomes in lung cancer patients with or without COPD: a systematic review and meta-analysis. Cancer Manag Res 2019; 11: 1765-1777.
[29] Cavalheri V and Granger C. Preoperative exercise training for patients with non-small cell lung cancer. Cochrane Database Syst Rev 2017; 6: CD012020.
[30] Pu CY, Batarseh H, Zafron ML, Mador MJ, Yendamuri S and Ray AD. Effects of preoperative breathing exercise on postoperative outcomes for patients with lung cancer undergoing curative intent lung resection: a meta-analysis. Arch Phys Med Rehabil 2021; 102: 2416-2427, e4.
[31] Wang YQ, Liu X, Jia Y and Xie J. Impact of breathing exercises in subjects with lung cancer undergoing surgical resection: a systematic review and meta-analysis. J Clin Nurs 2019; 28: 717-732.
[32] Young RP, Hopkins R and Eaton TE. Forced expiratory volume in one second: not just a lung function test but a marker of premature death from all causes. Eur Respir J 2007; 30: 616-22.
[33] Chang S, Zhou K, Wang Y, Lai Y and Che G. Prognostic value of preoperative peak expiratory flow to predict postoperative pulmonary complications in surgical lung cancer patients. Front Oncol 2021; 11: 782774.
[34] Stefanelli F, Meoli I, Cobuccio R, Curcio C, Amore D, Casazza D, Tracey M and Rocco G. High-intensity training and cardiopulmonary exercise testing in patients with chronic obstructive pulmonary disease and non-small-cell lung cancer undergoing lobectomy. Eur J Cardiothorac Surg 2013; 44: e260-5.
[35] Ma Y, Chen Y, Zhang N, Xu G, Wang Y, Sun Y, Bai C and Zuo Z. Efficacy and safety of pulmonary rehabilitation training on lung function, quality of life, and T cell immune function in patients with stable chronic obstructive pulmonary disease: a randomized controlled trial. Ann Palliat Med 2022; 11: 1774-1785.
[36] Tao W, Huang J, Jin Y, Peng K and Zhou J. Effect of pulmonary rehabilitation exercise on lung volume and respiratory muscle recovery in lung cancer patients undergoing lobectomy. Altern Ther Health Med 2024; 30: 90-96.
[37] Huang J, Lai Y, Zhou X, Li S, Su J, Yang M and Che G. Short-term high-intensity rehabilitation in radically treated lung cancer: a three-armed randomized controlled trial. J Thorac Dis 2017; 9: 1919-1929.
[38] Wesolowski S, Orlowski TM and Kram M. The 6-min walk test in the functional evaluation of patients with lung cancer qualified for lobectomy. Interact Cardiovasc Thorac Surg 2020; 30: 559-564.
[39] Stigt JA, Uil SM, van Riesen SJ, Simons FJ, Denekamp M, Shahin GM and Groen HJ. A randomized controlled trial of postthoracotomy pulmonary rehabilitation in patients with resectable lung cancer. J Thorac Oncol 2013; 8: 214-21.
[40] Zeng Q, Liao W, Fang W, Liu S, Duan C, Dai Y and Wei C. Clinical effect of aerobic exercise training in chronic obstructive pulmonary disease: a retrospective study. Medicine (Baltimore) 2023; 102: e35573.
[41] Zhou K, Lai Y, Wang Y, Sun X, Mo C, Wang J, Wu Y, Li J, Chang S and Che G. Comprehensive pulmonary rehabilitation is an effective way for better postoperative outcomes in surgical lung cancer patients with risk factors: a propensity score-matched retrospective cohort study. Cancer Manag Res 2020; 12: 8903-8912.
[42] Dwyer TJ, Daviskas E, Zainuldin R, Verschuer J, Eberl S, Bye PTP and Alison JA. Effects of exercise and airway clearance (positive expiratory pressure) on mucus clearance in cystic fibrosis: a randomised crossover trial. Eur Respir J 2019; 53: 1801793.
[43] Gravier FE, Smondack P, Prieur G, Medrinal C, Combret Y, Muir JF, Baste JM, Cuvelier A, Boujibar F and Bonnevie T. Effects of exercise training in people with non-small cell lung cancer

before lung resection: a systematic review and meta-analysis. Thorax 2022; 77: 486-496.
[44] Hinz A, Krauss O, Hauss JP, Höckel M, Kortmann RD, Stolzenburg JU and Schwarz R. Anxiety and depression in cancer patients compared with the general population. Eur J Cancer Care (Engl) 2010; 19: 522-9.
[45] Ni X, Lou Y, Hu W, Wang H, Xu H, Li S, Zhou Y and Ni Y. Development of mobile health-based self-management support for patients with lung cancer: a stepwise approach. Nurs Open 2022; 9: 1612-1624.
[46] Hinz A, Herzberg PY, Lordick F, Weis J, Faller H, Brähler E, Härter M, Wegscheider K, Geue K and Mehnert A. Age and gender differences in anxiety and depression in cancer patients compared with the general population. Eur J Cancer Care (Engl) 2019; 28: e13129.
[47] Blacklock R, Rhodes R, Blanchard C and Gaul C. Effects of exercise intensity and self-efficacy on state anxiety with breast cancer survivors. Oncol Nurs Forum 2010; 37: 206-12.