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Breathing exercises for patients with early-stage lung cancer: a meta-analysis

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Abstract

Background Postoperative pneumonia is a common but serious complication in patients with lung cancer. This meta-analysis aims to evaluate the effect of respiratory exercise on reducing postoperative pneumonia in patients with lung cancer and to provide a reliable basis for clinical treatment and nursing of patients with lung cancer.

Methods Two reviewers searched PubMed, Embase, Web of Science, Cochrane Library, China Knowledge Network, Wanfang, and Weipu databases. We searched for the randomized controlled trials (RCTs) published in Chinese or English on the breathing exercises in patients with lung cancer up to January 30, 2024. The quality of the literature was evaluated with the Cochrane Risk of Bias Tool 2 (ROB 2). RevMan 5.3 software was used for meta-analysis.

Results Eleven RCTs with 1429 patients with lung cancer were included, and 710 patients received breathing exercises. The meta-analysis results showed that breathing exercises could significantly reduce the incidence of postoperative pneumonia [RR = 0.35, 95%CI (0.25, 0.51)], improve the FEV1 [MD = −0.49, 95%CI (−0.73, −0.24)], FVC [MD = −0.59, 95%CI (−0.83, −0.35)] in patients with lung cancer (all $P < 0.05$). There were significant differences in the incidence of pneumonia for patients undergoing breathing exercises with single exercise time ≥ 15 min (RR = 0.37, 95%CI 0.24 ~ 0.62), breathing exercises for 1 week (RR = 0.29, 95%CI 0.16 ~ 0.55) or for 2 weeks (RR = 0.48, 95%CI 0.28 ~ 0.85) and breathing exercises > 4 times (RR = 0.36, 95%CI 0.23 ~ 0.57) per day (all $P < 0.05$).

Conclusion Breathing exercises have shown the capacity to augment pulmonary function in patients with lung cancer, concurrently mitigating the risk of postoperative pneumonia.

Keywords Breathing exercises, Pneumonia, Lung cancer, Pulmonary, Care, Nursing

Introduction

According to data released by the China National Cancer Center, the incidence of lung cancer is 15.4% for women and 24.6% for men in China [1, 2]. Currently, thoracotomy remains the predominant therapeutic approach for the management of early and intermediate-stage lung cancer. This surgical intervention undeniably imposes significant physiological stress on patients. Psychological perturbations, such as emotional instability, can trigger neuroendocrine dysregulation. This, in turn, may manifest as tachycardia, fluctuating blood pressure, and other detrimental physiological responses. In severe cases, it can precipitate bronchospasm, thereby adversely impacting pulmonary ventilation and respiratory function [3, 4]. Therefore, helping patients to skillfully master the basic exercise methods of respiratory exercise is an important means to improve the pulmonary function of perioperative patients with lung cancer [5–7].

Postoperative pneumonia is a new onset of pneumonia in surgical patients within 30 days after operation. It is

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the most common postoperative complication and type of nosocomial infection, accounting for about 50% of all hospital-acquired pneumonia [8, 9]. The incidence of pneumonia after chest surgery is relatively high, mainly in patients undergoing lung cancer surgery. Studies [10, 11] have shown that the incidence of postoperative pneumonia of lung cancer can be as high as 41.06%. It not only seriously affects the prognosis of patients, but also increases the hospital stay and medical expenses [12, 13]. Therefore, it is particularly important to find effective methods to prevent and control postoperative pneumonia of lung cancer. Studies [14, 15] have shown that perioperative respiratory exercise can improve lung function and reduce the incidence of postoperative pneumonia, but the results remain inconsistent or even conflicting, and the best exercise time and frequency are not clear. Previous systematic reviews [16, 17] have addressed the perioperative breathing exercises on postoperative pneumonia in patients with lung cancer, with more related randomized controlled trials (RCTs) published and reported, updated meta-analysis and systematic reviews are needed. Therefore, in order to explore the effect of perioperative respiratory exercise on postoperative pneumonia in patients with lung cancer, a meta-analysis of related RCTs was conducted to provide reliable evidence for the treatment and nursing care of patients with lung cancer.

Methods

This meta-analysis of RCTs was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statements (Supplementary file 1) [18].

Inclusion and exclusion criteria

The literature inclusion criteria of this meta-analysis were as follows: the type of study was RCT on the patients with early-stage lung cancer who received respiratory exercise on the basis of routine nursing during the perioperative period. The study population was patients with lung cancer diagnosed clinically and treated with surgery. The control group was subjected to standard nursing care, whereas the experimental group received an intervention consisting of respiratory exercise in addition to the standard nursing care provided to the control group. The study was reported in English or Chinese. Important related outcome indicators were reported, including the incidence of postoperative pneumonia, the forced vital capacity (FVC), and forced expiratory volume in the first second (FEV1) change between post-operation and pre-operation.

The exclusion criteria for this meta-analysis were as follows: case reports, reviews, unpublished manuscripts, conference abstracts, theses, and dissertations; duplicate publications; and literature that we could not access to full text or incomplete data after contacting the corresponding authors.

Literature search

Two reviewers (Q D, F M) searched the databases of PubMed, Embase, Web of Science, Cochrane Library, China Knowledge Network, Wanfang, and Weipu databases for RCTs on breathing exercises for reducing postoperative pneumonia in patients with lung cancer. The search period was from the establishment of the database to January 30, 2024. The search strategy used in this meta-analysis was as follows: ("breathing [free text]" OR "respiratory [MeSH term]" or OR "exercises [MeSH term]" OR "breath [MeSH term]" OR "breath training [free text]") AND ("lung [MeSH term]" OR "pulmonary [MeSH term]" OR "lung neoplasms [MeSH term]" OR "lung cancer [MeSH term]" OR "pulmonary cancer [free text]" OR "pulmonary neoplasms [free text]"). In addition, we used Scopus and Google Scholar to search gray literature, and we manually searched the reference lists of important relevant reviews and included RCTs to expand the search scope.

Study selection

Two reviewers (Q D, F M) first independently screened the title and abstract of the article read the full text of the literature included after the preliminary screening, and screened out the literature that met the inclusion criteria. When there were disagreements in the inclusion of the literature, a third reviewer (X Z) would read the literature and discuss whether to include the study. We used the Endnote software to manage the references in the process of study selection.

Risk of bias and evidence certainty assessment

Two reviewers (Q D, F M) independently evaluated the quality of included RCTs according to the Cochrane Risk of Bias Tool 2 (ROB 2) [19]. When there were differences in the evaluation results, a third reviewer (X Z) would join the discussion and reach a consensus. The Cochrane risk of bias assessment tool includes the following items: selection (random sequence generation, allocation concealment), performance, detection (blinding of participants and personnel, and outcome assessment), and attrition (incomplete outcome data). Each item was evaluated by "low risk", "unclear", and "high risk".

Grading of Recommendations Assessment, Development, and Evaluation (GRADE) [20] was used to evaluate the certainty of the findings of the review. The GRADE item (research limitations, inconsistencies, indirectness, inaccuracies, and publication biases) considered issues of particular relevance to meta-analysis methods, and the effect of consistency assumptions on the validity of estimates. The GRADE pro online evaluation tool was used to evaluate the certainty grade of each outcome index (https://www.gradepro.org). The final outcome index was divided into four grades: high, moderate, low, and very low certainty.

Data extraction

Two reviewers (Q D, F M) extracted data from the original papers selected for inclusion in the meta-analysis. To facilitate this process, the reviewers utilized Microsoft Excel, a widely recognized and versatile spreadsheet software. Before initiating the full-scale data extraction, two reviewers (Q D, F M) conducted a pilot test using a subset of the included papers. This pilot aimed to assess the functionality of the Excel form, refine the extraction protocol, and ensure inter-rater reliability. Any discrepancies in data interpretation or extraction were discussed and resolved, leading to a consensus on the extraction criteria. The main data extracted in this meta-analysis included first author, year of publication, sample size, age, intervention measures, intervention frequency and duration, outcome indicators, and research conclusions.

Data management and analysis

RevMan 5.3 software was used for data analysis. The continuous outcome measures were reported as mean differences (MDs), while the discrete outcome measures were expressed as relative ratios (RRs). For each effect size, we calculated and reported the 95% confidence intervals (CIs) to provide a measure of precision and statistical uncertainty. To assess the consistency of the effect estimates across the included studies, we tested for heterogeneity using the Chi-square test. The heterogeneity was quantified using the I^2 statistic, which describes the percentage of total variation across studies due to heterogeneity rather than chance. A study was considered homogeneous if the P value was greater than or equal to 0.1 and the I^2 statistic was less than 50%, in which case a fixed-effect model was selected for the meta-analysis. Conversely, when the P value was less than 0.1 and the I^2 statistic was 50% or greater, indicating substantial heterogeneity, a random-effects model was utilized for the meta-analysis to account for the variability between studies. Furthermore, to explore the potential for publication bias, we constructed funnel plots and conducted Egger's regression tests. These methods are sensitive to the presence of asymmetry in the funnel plot, which may suggest selective publication of studies based on their results. Statistical significance was determined using a threshold of $P<0.05$, indicating that there was a significant difference between the compared groups.

Results

RCT selection

A total of 139 reports were initially identified, and 121 reports were included for further screened after duplicate removal. After reading the title and abstracts, 93 reports were excluded, and 28 reports were included for full-text reading. Based on the inclusion and exclusion criteria, a total of 11 RCTs [21–31] were finally included in this meta-analysis (Fig. 1).

Characteristics of RCTs

Of the included 11 RCTs [21–31], a total of 1429 patients with lung cancer were involved, 719 patients received routine care and treatment, and 710 patients received breathing exercises. The improvement in lung function was from breathing exercises alone. The intervention time and frequency of breath exercise were mentioned, and the baseline data of the two groups were comparable. The characteristics of RCTs are presented in Table 1.

Quality of included RCTs

As presented in Figs. 2 and 3, all 11 RCTs have mentioned the randomization, yet 2 RCTs [24, 28] did not report the specific details about the methods to generate the randomization sequence. Four RCTs [21, 22, 25, 26] reported the details of allocation concealments. Due to the nature of the intervention, it was difficult to set a blind design for the participants and researchers. No other biases amongst RCTs were found.

Meta-analysis

All 11 RCTs [21–31] compared the effects of breathing exercises on postoperative pneumonia in patients with lung cancer. There was homogeneity among the studies ($I^2=0\%$, $P=0.87$), and we used the fixed effect model for meta-analysis. The results showed that breathing exercises could significantly reduce the incidence of postoperative pneumonia in patients with lung cancer [RR = 0.35, 95%CI (0.25, 0.51), $P<0.001$, Fig. 4]. The GRADE certainty of the evidence on the incidence of postoperative pneumonia was rated as high (Supplementary file 2).

Five RCTs compared the effects of breathing exercises on FEV1 in patients with lung cancer. There was heterogeneity among the studies ($I^2=98\%$, $P<0.001$), and we used the random effect model for meta-analysis. The results showed that breathing exercises could significantly improve the FEV1 in patients with lung cancer [MD = −0.49, 95%CI (−0.73, −0.24), $P<0.001$, Fig. 5a]. The GRADE certainty of the evidence on the FEV1 change was rated as moderate (Supplementary file 2).

Four RCTs compared the effects of breathing exercises on FVC in patients with lung cancer. There was heterogeneity among the studies ($I^2=97\%$, $P<0.001$),

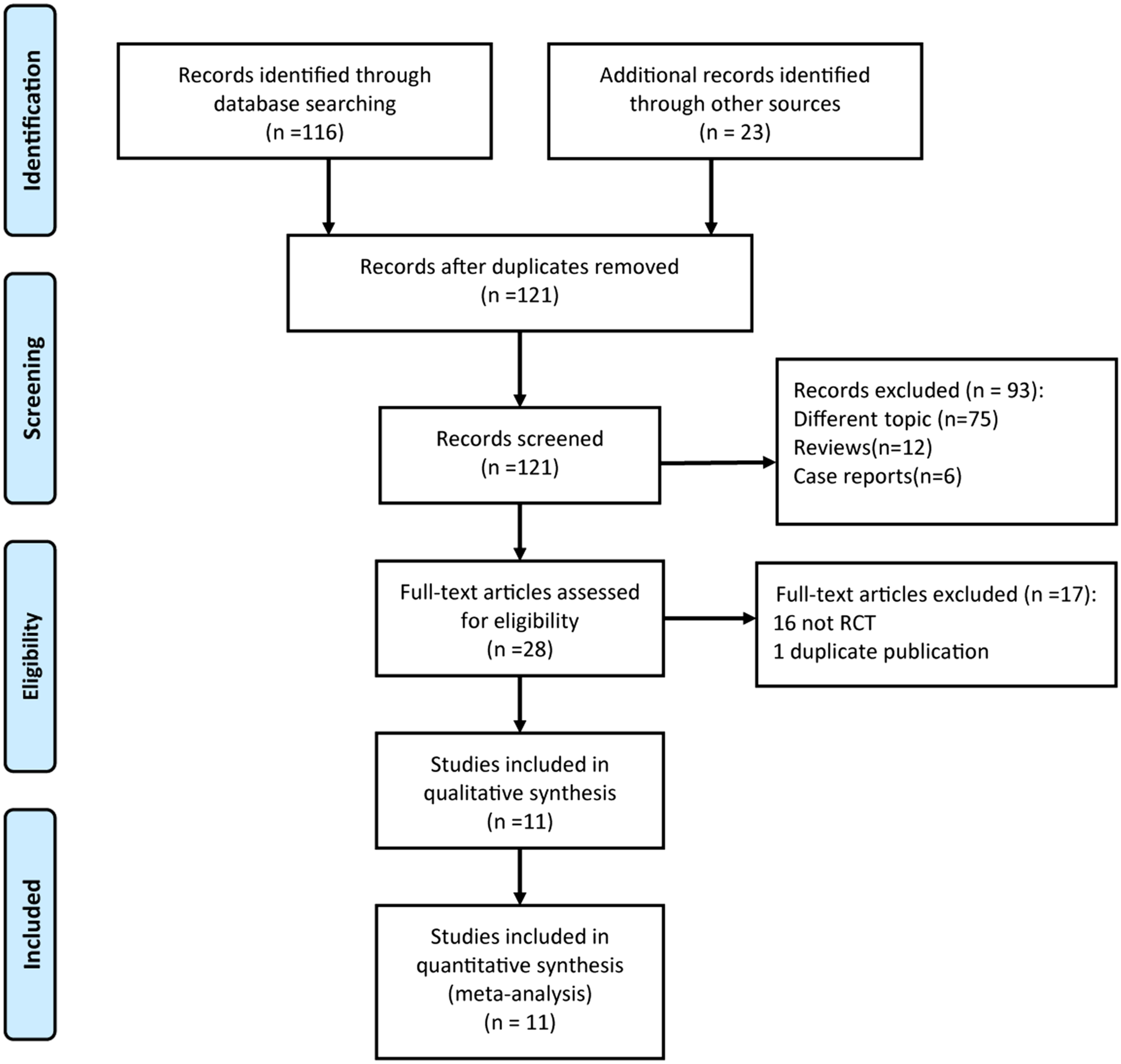

Fig. 1 Flow diagram of RCT selection

and we used the random effect model for meta-analysis. The results showed that breathing exercises could significantly improve the FVC in patients with lung cancer [MD = −0.59, 95%CI (−0.83, −0.35), $P < 0.001$, Fig. 5b]. The GRADE certainty of the evidence on the FVC change was rated as moderate (Supplementary file 2).

We conducted a subgroup analysis on the effects of breathing exercises with different frequencies and durations on the incidence of pneumonia. As indicated in Table 2, there were significant differences in the incidence of pneumonia for patients undergoing breathing exercises with single exercise time ≥ 15 min (RR = 0.37, 95%CI 0.24 ~ 0.62), breathing exercises for 1 week (RR = 0.29, 95%CI 0.16 ~ 0.55) or for 2 weeks (RR = 0.48, 95%CI 0.28 ~ 0.85) and breathing exercises > 4 times (RR = 0.36, 95%CI 0.23 ~ 0.57) per day (all $P < 0.05$).

Publication bias

As shown in Fig. 6, the dots in the funnel plot were evenly distributed. The results of Egger's regression test indicated that there was no publication bias amongst the synthesized outcomes (all $P > 0.05$).

Table 1 The characteristics of included RCTs

RCT ID	Sample size		Age		Intervention		Duration (week)
	Breathing exercise group	Control group	Breathing exercise group	Control group	Breathing exercise group	Control group	
Brocki 2016	34	34	69.7 ± 7.9	70.5 ± 7.5	Breathing trainer 2 times/day	Routine care	2
Li 2015	45	45	NA	NA	Three-ball vital capacity breathing trainer 15 min, 4 ~ 6 times/day	Routine care	1
Li 2018	40	40	56.18 ± 4.62	54.81 ± 4.85	Respiratory booster training for 10 to 15 min/times	Routine care	2
Liu 2016	65	72	56.9 ± 7.9	57.1 ± 8.2	Three-ball vital capacity breathing trainer 20 min, 4 times/day	Routine care	2
Malik 2018	195	192	66.6 ± 2.1	67.5 ± 10.4	Incentive spirometer 10 times/h	Routine care	4
Peng 2011	42	42	59.6 ± 9.1	60.1 ± 8.9	Respiratory booster training 10 ~ 15 min, 6 times per day	Routine care	2
Ran 2019	45	45	57.34 ± 5.73	59.13 ± 5.98	Breathing trainer 10 ~ 15 min, 6 times/day	Routine care	1
Wan 2020	48	48	60.5 ± 6.3		Three-ball vital capacity breathing trainer 20 min, once every 2 h	Routine care	1
Wu 2014	50	50	58.7 ± 9.1	58.9 ± 9.4	Breathing trainer 10 ~ 15 min, 6 times/day	Routine care	2
Xia 2014	100	100	46 ~ 79		Three-ball vital capacity breathing trainer 20 min, 6 times/day	Routine care	1
Zheng 2019	46	51	62.91 ± 9.33	64.84 ± 8.61	Three-ball vital capacity breathing trainer 20 min, 2 times/day	Routine care	2

RCT Randomized controlled trial, *NA* Not available

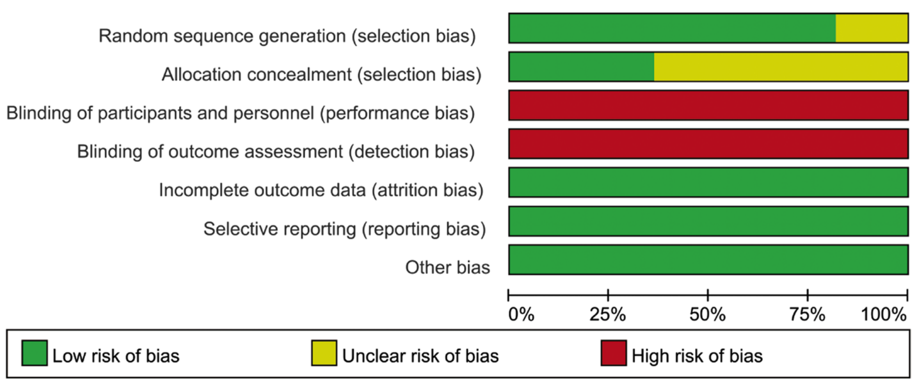

Fig. 2 Risk of bias graph

Discussions

Lung cancer currently ranks as the most prevalent and lethal form of malignant neoplasm. Surgical intervention is recognized as a principal therapeutic modality for this condition. Nevertheless, the surgical procedure can induce a diminution in pulmonary volume and a consequent decline in the mobility of the diaphragm and thoracic wall. This anatomical alteration can precipitate a notable decrement in the efficacious area dedicated to blood oxygenation, the rate of oxygen consumption, the vital capacity, and the maximal pulmonary ventilation. Consequently, these physiological modifications can exert a profound influence on the respiratory function and overall well-being of the patient. This underscores the critical necessity for vigilant postoperative care and supportive measures to ameliorate these adverse outcomes [32, 33]. The findings of this meta-analysis indicate that the implementation of breathing exercises in the perioperative period for patients afflicted with lung cancer significantly enhances pulmonary function and diminishes the prevalence of postoperative pneumonia. The integration of such exercises into the clinical management and nursing protocols for lung cancer patients is deemed not only beneficial but also imperative for

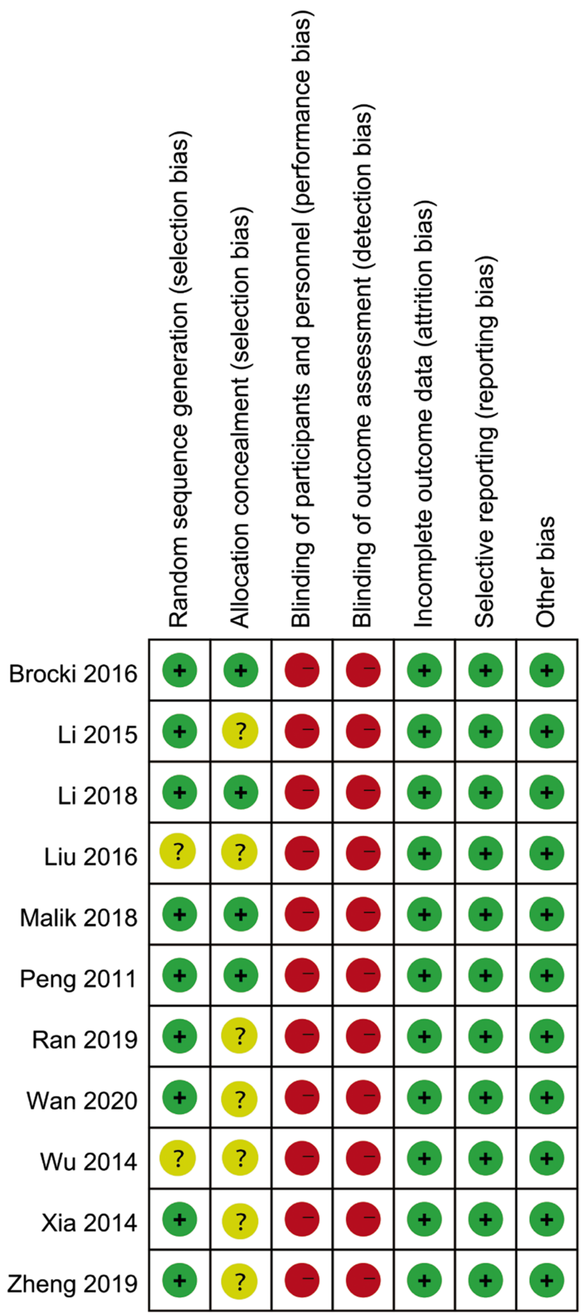

Fig. 3 Risk of bias summary

optimizing their respiratory outcomes and overall clinical care.

Breathing exercises have been demonstrated to augment the muscular strength of the respiratory musculature, thereby enhancing the tidal volume and overall ventilation in patients. These exercises contribute to a reduction in the metabolic expenditure associated with respiratory muscle activity [34, 35]. In contrast to standard nursing practices, the incorporation of breathing exercises has been shown to enhance the inspiratory and expiratory capacities of patients undergoing rehabilitation. Furthermore, the utilization of a breathing trainer, equipped with a graduated scale and adjustable volume settings, enables patients to modulate the intensity of their inhalation and exhalation. This precise control facilitates the achievement of a consistent and deliberate respiratory pattern, characterized by uniformity and slowness, which is integral to the optimization of respiratory function and overall patient recovery [36]. It has been reported that the utilization of a respiratory function exercise as an adjunct to respiratory exercises is particularly efficacious in ameliorating lung function and attenuating the incidence of adverse events [37]. These observations underscore the potential of respiratory function exercise and specialized equipment in the comprehensive care of lung cancer patients following surgical procedures.

Some studies [38, 39] have shown that the optimal intervention period for preoperative respiratory exercises is deemed to be a minimum of 2 weeks, aligning with the current paradigm of accelerated rehabilitation protocols implemented across various healthcare institutions. In the context of lung cancer surgery, thoracoscopic procedures have become prevalent, characterized by abbreviated hospital stays. Consequently, the identification of a rapid and efficacious respiratory exercise regimen is of paramount importance. Such a method could potentially diminish the incidence of postoperative pneumonia, thereby enhancing patient recovery and reducing healthcare-associated complications. This underscores the imperative for innovative and time-efficient respiratory training strategies that can be seamlessly integrated into the preoperative preparation for lung cancer surgery. The results of this study suggest that the incidence of postoperative pneumonia can be effectively reduced by using a breathing exercise apparatus for perioperative patients with lung cancer for 1–2 weeks, which may explain why the respiratory exercise device is used in the perioperative period, which can improve the ventilatory reserve function by guiding the patients to regulate breathing in a short time, which can quickly improve the pulmonary function of patients and reduce the occurrence of postoperative pneumonia [40, 41].

The results of this meta-analysis have shown that different frequencies and durations of single breath exercise will affect the occurrence of postoperative pneumonia in perioperative patients with lung cancer. The incidence of postoperative pneumonia can be effectively reduced if the duration of a single exercise is ≥ 15 min and the exercise time is more than 4 times a day. The relative exercise intensity can be adjusted

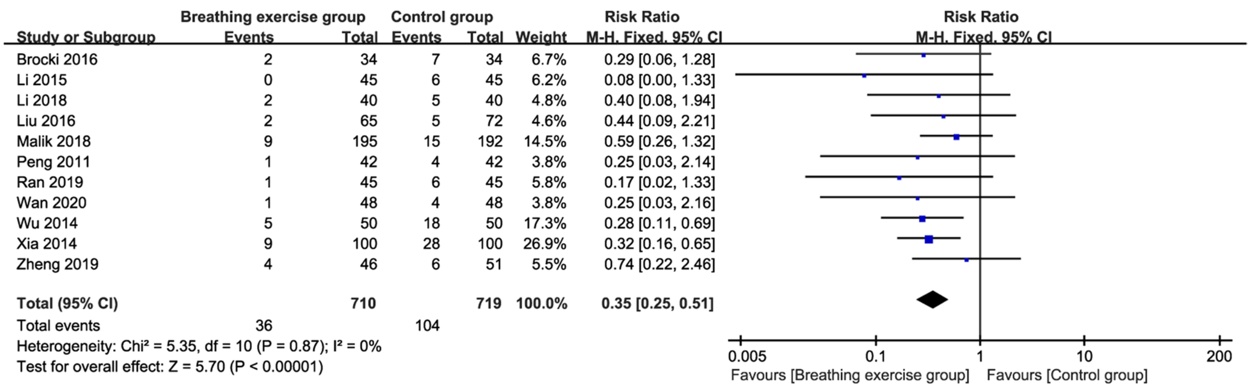

Fig. 4 Forest plot for incidence of pneumonia

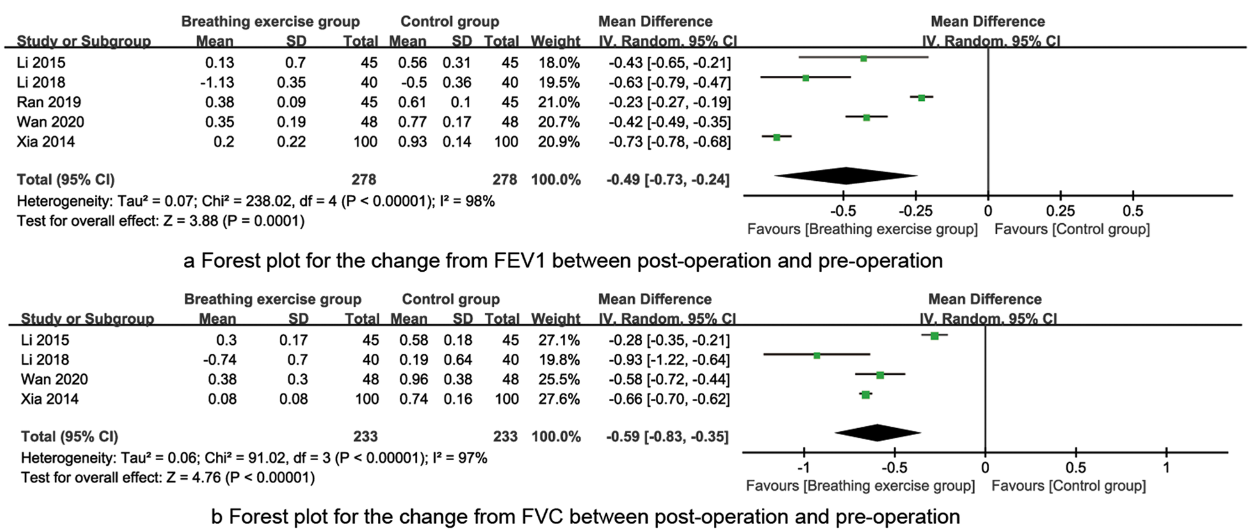

Fig. 5 Forest plot for the change from FEV1 or FVC between post-operation and pre-operation

Table 2 The meta-analysis on the effects of breathing exercises with different frequency and duration on the incidence of pneumonia

Sub-group		Number of included RCTs	Heterogeneity	Model for meta-analysis	RR	95%CI	P
Duration	Single training time ≥ 15 min	8	0%	Fixed	0.37	0.24 ~ 0.62	< 0.001
	Single training time < 15 min	2	0%	Fixed	0.33	0.09 ~ 1.19	0.09
	Breathing exercises for 1 week	4	0%	Fixed	0.29	0.16 ~ 0.55	< 0.001
	Breathing exercises for 2 weeks	6	0%	Fixed	0.48	0.28 ~ 0.85	0.01
Frequency	Breathing exercises > 4 times per day	6	0%	Fixed	0.36	0.23 ~ 0.57	< 0.001
	Breathing exercises ≤ 4 times per day	4	0%	Fixed	0.48	0.22 ~ 1.24	0.07

at 40–80% of the maximum heart rate reserve or reserve oxygen uptake [42]. Breathing exercises play a pivotal role in the swift promotion of lung expansion, effectively engaging the respiratory musculature. They are instrumental in enhancing muscular strength and improving the efficacy of cough mechanisms. Additionally, these exercises are beneficial in mitigating sputum accumulation through expectoration, which exerts a positive influence on the prophylaxis and management of postoperative pneumonia. The integration of such exercises into the preoperative and postoperative care regimen is thus advocated for their potential

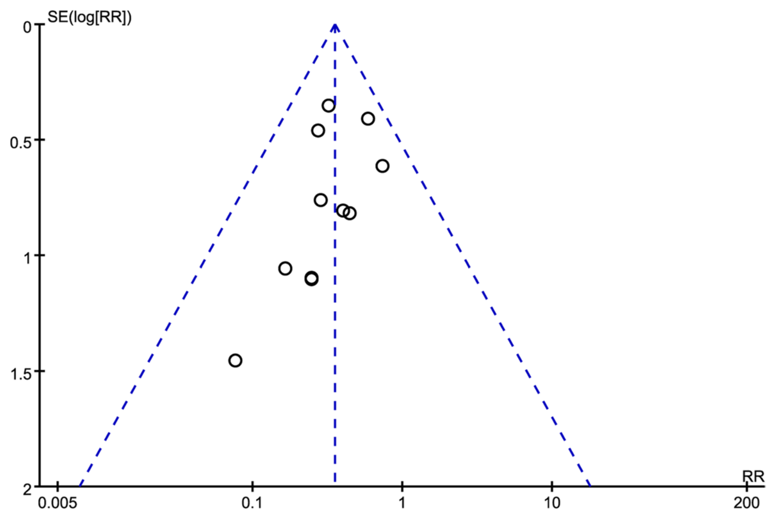

Fig. 6 Funnel plot for incidence of pneumonia

to attenuate respiratory complications and bolster the overall respiratory health of patients undergoing lung cancer surgery [43]. Therefore, perioperative lung cancer patients should strengthen breathing exercises to reduce the incidence of postoperative pneumonia and improve their quality of life.

There are some limitations in this meta-analysis that are worth considering. Firstly, from the study level, the type of respiratory exercise device used in included RCTs in this meta-analysis is inconsistent, the intervention frequency and duration are inconsistent, and the research results may be biased to some extent. Therefore, we have conducted a subgroup analysis of the results in order to increase the credibility of the research results. Secondly, from the outcome level, the diagnosis of pneumonia in these patients is not easily differentiated from post-operative lung atelectasis. We cannot include other more appropriate outcome measures for analysis limited by reported data. Thirdly, from the review level, this study had not been previously registered. And we reported subgroup analysis findings that were not explicitly pre-planned or pre-specified. We understand that this could raise concerns about the transparency and reliability of our results. The decision to perform subgroup analysis was indeed made post-hoc based on emerging patterns and trends observed during the data extraction and analysis phase. We recognize that this approach can introduce bias and affect the interpretability of the results. Finally, the included studies have a limited follow-up duration, which means that the long-term impact of breathing exercises on postoperative complications and pulmonary function in lung cancer patients requires further investigation. Future research should focus on examining the sustained effects of respiratory exercises on the long-term outcomes of lung cancer patients who have undergone surgery.

Conclusions

In conclusion, the results of this meta-analysis have shown that the frequency of intervention in perioperative patients with lung cancer is more than 4 times a day, the duration of each respiratory exercise is more than 15 min, and continuous intervention for 1 week or more can effectively improve the pulmonary function of patients with lung cancer and reduce the incidence of postoperative pneumonia. However, the conclusions drawn from the current body of research are constrained by the limited quantity and variable quality of included RCTs. The findings, while promising, necessitate further validation through more rigorous, high-quality studies with larger sample sizes. Such research is essential to provide robust evidence that can support the development of effective treatment and nursing care protocols for patients with lung cancer.

Abbreviations

RCT	Randomized controlled trial
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
FEV1	Forced expiratory volume in 1 s
FVC	Forced vital capacity
MD	Mean difference
RR	Relative ratio
CI	Confidence interval
NA	Not available

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13643-024-02640-y.

Supplementary Material 1. PRISMA 2020 Checklist.

Supplementary Material 2. GRADE Summary of Findings Table.

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None.

Authors' contributions
Q D and F M designed research. Q D, F M, X M, and X Z conducted the research. Q D, F M, X M, and X Z analyzed the data. Q D wrote the first draft of the manuscript. X Z had primary responsibility for the final content. All authors read and approved the final manuscript.

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Availability of data and materials
All data generated or analyzed during this study are included in this published article. The original data will be available from corresponding authors on reasonable request.

Declarations

Ethics approval and consent to participate
In this study, all methods were performed in accordance with the relevant guidelines and regulations. Ethics approval and consent to participate are not necessary because the study was a meta-analysis.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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