Effect of Pulmonary Rehabilitation Exercise on Lung Volume and Respiratory Muscle Recovery in Lung Cancer Patients Undergoing Lobectomy

Wencheng Tao, BM; Jianfeng Huang, MD; Yue Jin, MM; Kangning Peng, MM; Jianming Zhou, MD

ABSTRACT
Objective • this work assessed the impact of drug therapy combined with pulmonary rehabilitation exercise training on specific lung function and respiratory parameters of lung cancer (LC) patients after thoracoscopic lobectomy.
Methods • 88 LC patients who had undergone thoracoscopic lobectomy were selected based on their surgical indications and health condition. The study aimed to explore methods to assist patients in their postoperative recovery; therefore, patients meeting the surgical criteria were chosen to ensure the internal validity and external applicability of the results. Meanwhile, these 88 LC patients undergoing thoracoscopic lobectomy were randomly allocated into an experimental group (EG, 44 cases) and a control group (CG, 44 cases). The EG received inhalation therapy with albuterol sulfate nebulizer solution and personalized pulmonary rehabilitation exercise training, while the CG received nebulized treatment alone. The study lasted for three months. The pulmonary rehabilitation program included regular physical exercises, including respiratory training and physical fitness training, among other activities.
Results • after pulmonary lobectomy surgery, both groups of patients showed a significant decrease in (1) forced vital capacity (FVC), (2) forced expiratory volume in 1 second (FEV1), (3) maximum voluntary ventilation (MVV), and (4) peak expiratory flow (PEF). However, the values of FVC, FEV1, MVV, and PEF in the EG were significantly higher than those in the CG (P < .05). Furthermore, both groups demonstrated significant improvements in the 6-minute walk test (6MWT) results after lung lobectomy; however, the 6MWT results in the EG also significantly increased (P < .05). In terms of dyspnea index (DI), after lung lobectomy, the DI for both groups of patients significantly increased, but the DI in the EG was significantly lower than that in the CG (P < .05).
Conclusions • the combined application of drug therapy and pulmonary rehabilitation exercise training contributed to promoting cardiopulmonary function and respiratory muscle recovery in LC patients after thoracoscopic lobectomy. This was crucial for improving the quality of life of patients, as enhanced cardiopulmonary function and respiratory muscle recovery can alleviate postoperative respiratory difficulties, increase the physical stamina and activity levels of patients. This may help reduce the risk of postoperative complications, shorten hospital stays, and potentially improve long-term survival rates. Consequently, these results could have a positive impact on the development of postoperative care and treatment strategies. However, this work was subjected to several limitations, including a relatively short duration, necessitating longer-term follow-up to assess long-term effects. Additionally, the sample size was relatively small, and further large-scale research was needed to validate these findings. (Alter Ther Health Med. [E-pub ahead of print.])

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INTRODUCTION
The objective of this work was to evaluate the effectiveness of combining drug therapy with pulmonary rehabilitation exercise training in the postoperative recovery of lung cancer (LC) patients undergoing thoracoscopic lobectomy. LC is a malignant tumor that originates in the bronchial mucosa or glands, and it ranks among the most dangerous malignancies to human health and life.1–3 Clinical histopathology can be classified into non-small cell LC (NSCLC) and small cell LC (SCLC). It has been the first in cancer mortality of Chinese for three consecutive years, the second highest cancer incidence among Chinese only after colorectal cancer, and the top cause of death in female cancers.4,5 Since more than 70% of LC is asymptomatic in the early stage, diagnosis often occurs at an advanced stage, leading to lower chances of successful treatment. The most common symptoms of LC include persistent coughing, chest pain, and shortness of breath.6 Coughing is usually a dry cough. If it persists for an extended period, especially for more than 2 weeks, or if coughing is not relieved after treatment and even evolves into pneumonia, these are all possible risk signals of LC.
With the development and progress of medicine, the treatment of LC has become increasingly diversified. After diagnosing LC, a comprehensive assessment should consider the overall condition, pathological classification, clinical staging, genetic status, and the presence of any significant comorbidities of patients to determine the treatment plan. Surgery is the preferred treatment for NSCLC at stages I and II, some at stage III, and SCLC at stage I and some at stage IIA. Minimally invasive surgery has replaced traditional surgery and become the major approach of LC surgery. Video-assisted thoracoscopic surgery, a minimally invasive surgical technology, has been widely applied in surgery for all stages of LC. Additionally, da Vinci robotic surgery is also being gradually launched. Thoracoscopic lobectomy is a common surgical procedure aimed at removing malignant lung tissue from patients. While surgery and drug therapy are the primary treatment modalities for lung cancer patients, postoperative patients often face various physiological and functional challenges, including decreased lung function, respiratory difficulties, and reduced exercise capacity. Therefore, postoperative rehabilitation and recovery become particularly crucial.

With the deepening of theoretical research in modern rehabilitation medicine, exercise is becoming increasingly common and important as a means of rehabilitation. Sports rehabilitation is a series of rehabilitation means utilizing physical activities. Generally, it is a training method to restore the whole body or local motor function and sensory function by using instruments, bare hands, or the customer’s own strength through some active or passive movements. In addition, appropriate sports rehabilitation training can improve the dysfunction and restore or maintain the normal range of motion of joints, thereby preserving daily life activities. It also helps patients maintain a positive psychological state, suppress negative emotions, enhance their enjoyment, and improve their confidence. Rutkowska et al. demonstrated that patients with non-small cell lung cancer (NSCLC) who underwent customized exercise training during chemotherapy significantly improved physical performance and lung function. In contrast, the control group exhibited no significant improvements, indicating the benefits of exercise training. In the study by Fritz C et al., adult Fontan patients underwent inhalation muscle training for six months. Still, there were no significant improvements in motor and lung function, except for an increase in oxygen saturation at rest, suggesting limited effects of inhalation muscle training on Fontan patients.

Exercise training serves as the cornerstone of a comprehensive pulmonary rehabilitation program and represents the most effective means to improve patients’ muscle function. It can increase the capillary density of trained muscles, improve the coordination of the cardiopulmonary system, and significantly raise the maximum oxygen uptake by enhancing both aerobic and anaerobic metabolism of muscle cells. Additionally, it can reduce the response to hyperventilation, thus improving dyspnea, promoting exercise endurance, and enhancing quality of life. Meanwhile, exercise training may have positive effects, like increasing exercise motivation, reducing emotional disorders, minimizing symptom effects, and improving cardiovascular function. Therefore, it is imperative to include pulmonary rehabilitation exercise training in treating patients with LC surgery.

After introducing the objectives of this work, we will provide a detailed description of the research methodology and design, including the criteria for patient selection and the specific intervention methods for drug therapy and pulmonary rehabilitation exercise training. Furthermore, we will explore how to seamlessly integrate these two intervention approaches with the hope of achieving better outcomes in the postoperative recovery process. Through this study, we aim to offer more effective options for the postoperative rehabilitation of LC patients, ultimately improving their quality of life and treatment outcomes.

### METHODOLOGY AND MATERIALS

#### Research object

88 LC patients who underwent thoracoscopic pulmonary lobectomy in the Thoracic Surgery Department of People’s Hospital of Hongze District from June 2020 to October 2022 were incorporated as the research objects. These 88 LC patients were then randomly divided into EG and CG by blind selection, with 44 cases in each group. According to the doctor’s advice, EG was given drug therapy and pulmonary rehabilitation exercise training. In contrast, CG was given drug therapy only as instructed by the doctor. Clinical data of these patients are displayed in Table 1 below. Before surgery, the quality of life of all patients was assessed through regular interviews, physical examinations, quality of life questionnaires, psychological health evaluations, and other means to better understand the patients’ overall health status. This was done to provide more comprehensive information and support for surgical and treatment planning. Based on patients’ quality of life indicators, doctors could develop more personalized treatment plans and make preoperative preparations.

Inclusion criteria were made up of the following. (1) Patients were older than 20 years old; (2) It was the primary LC; (3) There were indications for surgery; (4) Patients were in a good mental status; and (5) Patients’ vital signs were stable.

Exclusion criteria were composed as follows. (1) Patients complicated with other malignant tumors; (2) A radical cure was not achieved by pulmonary lobectomy; (3) There was a lack of clinical data; (4) Patients could not tolerate one-lung ventilation; (5) Patients had been treated with neoadjuvant chemoradiotherapy, and (6) Patients had a history of complicated active tuberculosis.

### Table 1. Comparison of basic data of patients

<table>
<thead>
<tr>
<th>Age (years old)</th>
<th>EG (n = 44)</th>
<th>CG (n = 44)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>57.22 ± 6.14</td>
<td>58.18 ± 7.56</td>
<td>0.271</td>
<td></td>
</tr>
<tr>
<td>Gender (Male/female)</td>
<td>28/16</td>
<td>28/16</td>
<td>0.588</td>
</tr>
<tr>
<td>Smoking history (cases)</td>
<td>33</td>
<td>36</td>
<td>0.565</td>
</tr>
<tr>
<td>History of tuberculosis (cases)</td>
<td>4</td>
<td>4</td>
<td>1.000</td>
</tr>
<tr>
<td>Adenocarcinoma/squamous cell carcinoma/small cell carcinoma</td>
<td>30/13/1</td>
<td>32/10/2</td>
<td>0.493</td>
</tr>
<tr>
<td>Stage (I/II/IV)</td>
<td>55/16/3</td>
<td>28/14/2</td>
<td>0.529</td>
</tr>
<tr>
<td>Hypertension/diabetes/coronary Heart-related disease</td>
<td>17/8/8</td>
<td>15/9/7</td>
<td>0.760</td>
</tr>
</tbody>
</table>
Rehabilitation programs

The patients in the CG received routine rehabilitation training before surgery and were given anti-inflammatory drugs. Before surgery, patients in the EG were given a systematic pulmonary rehabilitation exercise training program based on the program in the CG.

**Pursed-lip breathing**: the patient was seated or standing upright and breathed comfortably. Inhalation occurred through the nose, followed by gently pursing the lips, extending the exhalation time to twice the inhalation time, approximately 2 seconds for exhalation. This allowed for a slower respiratory rate, increased gas exchange time, and improvement in ventilation and gas exchange.

**Respiratory muscle training**: the patient was seated or standing upright, holding respiratory training equipment. Inhalation involved maximizing chest expansion. Then, forceful exhalation was performed, engaging respiratory muscles to resist exhalation resistance. Inhalation and exhalation exercises were repeated, gradually increasing resistance. This was done to enhance the strength and endurance of respiratory muscles, improving respiratory efficiency.

**Segmental breathing exercises**: the patient was seated or lying down in a relaxed position. Hands were placed on the chest and abdomen to feel the breath. Inhalation was performed slowly, ensuring a slight rise in both the chest and abdomen. After inhalation, a specific intercostal space was selected, and gentle pressure was applied with the fingers to that area. Exhalation was carried out slowly while attempting to expel as much air as possible from the area being gently pressed. The purpose was to improve the uniformity of lung ventilation and reduce local ventilation insufficiency.

**Breathing training with resistor device**: the patient was seated or standing upright, with the breathing training device placed in the mouth or worn with a mask. Inhalation involved making an effort to overcome resistance for deeper and stronger breathing. Exhalation was performed slowly and evenly, with an attempt to extend exhalation time while overcoming resistance. The goal was to enhance respiratory muscles through resistance training, improving respiratory efficiency and capacity.

**Whole-body breathing exercises**: patients were instructed to engage in full-body movements, such as slow body rotations or stretching. Deep breaths were synchronized with the movements, inhaling during extension or expansion and exhaling during contraction or bending. Ensuring coordination between breathing and movements aimed to enhance synergy between the body and respiration, increase body flexibility, and improve lung function.

**Physical exercise training**: depending on the physical fitness level of patients, and suitable aerobic exercises and strength training were chosen, gradually increasing intensity and duration. Attention was paid to breath control, ensuring the maintenance of a normal breathing pattern during exercise. This approach aimed to enhance overall physical fitness, improve cardiovascular function, increase lung capacity, and promote overall health through physical exercise training.

Observation indicators

1. The age, gender, complications, resection site, smoking history, and tuberculosis history of the patients were collected.
2. For determination of PF, forced vital capacity (FVC), 1-second forced expiratory volume (FEV1), maximal voluntary ventilation (MVV), and peak expiratory flow (PEF) of patients in two groups before and after intervention were detected by PF tester.
3. 6MWT was carried out indoors, along a 30-meter-long, closed, long and straight flat corridor, requiring a hard floor. The corridor should be marked every 3 meters, and turn-backs should be marked with cones (like orange traffic cones). The departure line was the starting point as well as the end of each round trip, which should be marked on the ground in a bright color strip. Furthermore, the patients were instructed to take a walking exercise; and the distance they could walk in 6 minutes at their fastest speed was measured.
4. For the measurement of DI, the patients were allowed to climb from the first floor to the second floor and were subsequently inquired about their breathlessness. 0 meant no shortness of breath at all, 0.5 meant very mild shortness of breath, 1 meant slight shortness of breath, 2 meant mild shortness of breath, and 3 meant moderate shortness of breath. 4 meant somewhat severe, 5 meant severe, 6-7 meant very severe, 8-9 meant almost maximum shortness of breath, and 10 meant the maximum.
5. Mean operating time (MOT), intraoperative blood loss (IBL), postoperative indwelling time of thoracic duct (from the end of surgery to the moment of postoperative catheter removal), length of hospital stays (LHS) (from the end of surgery to the moment of discharge), and postoperative pulmonary infection of patients in two groups were recorded and compared. Regular follow-up and examinations for LC patients within three months after discharge are crucial to monitor their recovery, early detection, and management of any potential complications or recurrence.

Quality control

**Object selection**: The objective and significance of the study were clarified, the research scope was defined, and the reasonable sample size needed for the study was calculated. The objects were no longer eliminated after selection.

**Sample grouping**: The research team employed a method of random inclusion when grouping the samples, which means that patients and their families were unaware of the specific group assignments. This randomized grouping approach helps reduce selection bias, ensuring that the process of assigning each patient to either the experimental group or the control group is random, thereby maintaining the blinding of the study.

**Data collection**: Data were collected from both the patients themselves and the hospital information management system. To ensure data accuracy, these two sources were cross-validated. This means that the data collected by the researchers were independent of the data in the hospital system, and the researchers were unaware of which group (EG or CG) the patients belonged to during data collection and recording. This
helps avoid subjective bias and data manipulation, thus maintaining the blinding of data collection.

**Research Support:** Rehabilitation therapists involved in this study had all been trained in professional knowledge and skills and were non-negligible in the research process.

**Methods for statistics**

The research data were analyzed using SPSS 19.0 (IBM SPSS Statistics for Windows, version 19, IBM Corp, Armonk, NY, USA). SPSS is a widely used statistical analysis software that is suitable for various types of data and research designs. In this work, both continuous measurement data and count data were included, and SPSS provides a variety of statistical tools to effectively handle and analyze these different types of data. Continuous measurement data were presented as mean ± standard deviation, while count data were expressed as percentages (%). Mean ± standard deviation is typically used to represent the central tendency and dispersion of continuous measurement data, while percentages are commonly used to indicate the relative frequency of count data. Since different types of data may need to be considered in this work, using both representations helps provide a comprehensive description of the data. Between-group comparisons were conducted using repeated measures analysis of variance (ANOVA), while within-group comparisons used two-way ANOVA. Repeated measures ANOVA is suitable for studying the impact of within-group factors on variables, while two-way ANOVA is applicable when considering multiple within-group and between-group factors simultaneously. In two-tailed tests, $P < .05$ was considered statistically significant.

**RESULTS**

**Comparison of PF indicators before and after surgery between groups**

As demonstrated in Figures 1-2 below, the EG exhibited the following pulmonary function values before lobectomy: FVC was 2.78±0.56 L, FEV1 was 2.31±0.77 L, MVV was 75.73±12.08 L/min, and PEF was 5.58±0.82 L/s. After lobectomy, FVC, FEV1, MVV, and PEF in the EG turned to be 2.51±0.61 L, 1.75±0.53 L, 61.44±11.22 L/min, and 4.72±0.53 L/s, respectively. In the CG, FVC was 2.69±0.49 L, FEV1 was 2.27±0.48 L, MVV was 70.19±13.07 L/min, and PEF was 5.39±0.61 L/min before lobectomy. After lobectomy, FVC, FEV1, MVV, and PEF became 1.95±0.72 L, 1.45±0.66 L, 48.82±9.55 L/min, and 3.81±0.63 L/s, respectively.

Compared with the CG, there were no significant differences in FVC, FEV1, MVV, or PEF before the surgery in the EG ($P > .05$). In contrast, after lobectomy, they all decreased greatly in both groups, showing differences being statistically significant ($P < .05$) with obvious higher values in the EG ($P < .05$).

**Comparison of MOT and IBL between groups**

In Figure 3 below, MOT was counted as 158.81±20.65 min, and IBL was 148.33±25.18 mL in the EG. MOT reached 160.77±19.05 min, and IBL was 146.08±30.62 mL in the CG, demonstrating no remarkable differences ($P > .05$).
The change in lung ventilation function is the basic pathophysiological change during the development and evolution of the disease. It has important guiding significance in evaluating the severity of patients and judging the occurrence and development of the disease.

**Comparison of postoperative duct indwelling time and LHS between groups**

As displayed in Figure 4 below, the postoperative indwelling time of thoracic duct was counted as 4.76±0.59 days, and LHS was 7.13±1.46 days in the EG. Whereas in the CG, the indwelling time of thoracic duct and LHS reached 5.88±0.83 days and 9.02±1.73 days, respectively. The comparison showed that postoperative indwelling time of thoracic duct and LHS in EG were observably lower than those in CG, with differences having statistical significance (P < .05).

**Comparison of 6MWT results before and after surgery between groups**

As depicted in Figure 5 below, the 6MWT result of EG was worked out as 380.18±34.75 meters before lobectomy and reached 290.44±30.65 meters after lobectomy. In contrast, the 6MWT result in the CG was 366.75±20.55 meters before lobectomy and 233.85±24.71 meters after lobectomy.

The comparison suggested no significant difference between the EG and CG in the 6MWT before lobectomy (P > .05). The 6MWT results after lobectomy were highly lower in both groups, with statistically significant differences in contrast to the preoperative value (P < .05). Moreover, the 6MWT result of EG was much higher than that of CG after lobectomy, showing a difference of statistical significance (P < .05).

**Comparison of DI before and after surgery between groups**

As presented in Figure 6 below, DI turned out to be 1.65±0.38 before lobectomy and 2.31±0.46 after lobectomy in the EG, while that in the CG was 1.72±0.45 before lobectomy and 2.68±0.75 after lobectomy.

Compared with the CG, no statistical significance was in DI difference in EG before lobectomy (P > .05). DIIs after lobectomy were considerably higher than those before in both groups, with statistically significant differences (P < .05). DI of EG was distinctly lower than that of CG after lobectomy, showing a statistically significant difference (P < .05).

**DISCUSSION**

LC is one of the most common malignant tumors and the leading cause of cancer-related deaths in China and worldwide. The main treatment methods include surgery, radiotherapy, chemotherapy, and targeted therapy. Surgical resection is the most effective treatment for LC, with excellent prognosis after resection.[1,7,18] The change in lung ventilation function is the basic pathophysiological change during the development and evolution of the disease. It has important guiding significance in evaluating the severity of patients and judging the occurrence and development of the disease.
Therefore, post-surgical clinical rehabilitation training is paramount for patients. Exercise training is a cornerstone and an important part of pulmonary rehabilitation training. Lower limb exercise training plays a quite crucial role in patients’ PF, motor function, and quality of life. In this work, 88 LC patients who underwent thoracoscopic pulmonary lobectomy in the Thoracic Surgery Department of the hospital from June 2020 to October 2022 were included as the research objects. Randomization method was adopted to randomly divide the 88 patients into EG (drug therapy and pulmonary rehabilitation exercise training in line with doctor’s order) and CG (only drug therapy), with 44 cases in each group. Regarding the clinical data, there was no any statistically significant difference in the male to female ratio, age, smoking history, history of tuberculosis, surgical resection site, and complications between patients in the EG and CG (.05). Theseresults provided a reliable foundation for subsequent analyses.

Firstly, the PF indicators of the patients were compared. It was evident that FVE, FEV1, MVV, and PEF of patients in both groups were highly lower after lobectomy, and those for patients in the EG were much higher in contrast to those in the CG (.05). Liu et al. aimed to compare the effects of inspiratory muscle training and aerobic exercise with standard care in cancer patients undergoing video-assisted thoracoscopic surgery (VATS). The study employed a single-blind randomized clinical trial design, involving a total of 63 VATS surgery patients who were divided into the experimental group (TG, receiving inspiratory muscle training and aerobic exercise) and the control group (CG, receiving standard care). Ultimately, 54 patients completed the study. The primary outcome measures included maximal inspiratory pressure (PImax), maximal expiratory pressure (PEmax), lung expansion volume, and the results of the 6MWT. The results showed that at the 6th week, the experimental group exhibited significant improvements in PImax, PEmax at the 2nd week, and PImax at the 12th week and lung expansion volume. However, in terms of the 6MWT, the performance of the experimental group did not significantly differ from that of the control group at the 2nd, 6th, and 12th weeks. Overall, the study results suggested that six weeks of inspiratory muscle training and aerobic exercise could enhance respiratory muscle strength and aerobic fitness in cancer patients after VATS surgery. This is consistent with the findings in this work, both emphasizing the benefits of rehabilitation training for postoperative patients. However, this work also highlighted some differences in the 6MWT, which may require further in-depth research and analysis, illustrating that pulmonary rehabilitation exercise training could effectively prevent and reduce PF impairment and pulmonary complications caused by hypoxia, carbon dioxide retention, bacterial infection, and difficulties in discharging secretions. In addition, it could improve dead space ventilation, prevent alveolar atrophy, remove airway secretions, ensure effective ventilation, and prevent pulmonary infection. 6MWT is a comprehensive evaluation of the overall physical status of patients with moderate to severe diseases, focusing on motor abilities such as cardiopulmonary function, skeletal muscle function, and nutritional level. In this work, the 6MWT result after lobectomy was significantly higher in both groups, with considerably higher results in the EG (.05). The reduction of postoperative motor function of patients may be attributed to the decrease of effective breathing area after surgical resection of the pulmonary lobectomy. Combined with the impact of pulmonary lesions, postoperative PF was damaged, resulting in decreased pulmonary ventilation and ventilation function. These results demonstrated that pulmonary rehabilitation exercise training could effectively promote the recovery of patients’ cardiopulmonary function after surgery and mitigate the decline in patients’ motor function. Shortness of breath, also referred to as dyspnea, is a subjective sensation experienced by patients, indicating their perception of difficulty in breathing. Here, DIs of both groups were remarkably higher after lobectomy, while DI in the EG was notably lower and exhibited a remarkable difference with that in the CG (.05). Thus, pulmonary rehabilitation exercise training could effectively alleviate the symptoms of dyspnea in patients.

The physiological mechanisms through which pulmonary rehabilitation exercise training may improve lung function, exercise capacity, and reduce respiratory difficulties are multifaceted. Firstly, moderate aerobic exercise in rehabilitation training can increase the lung capacity and respiratory muscle strength of patients, aiding in the improvement of lung function. Secondly, exercise can enhance cardiovascular health, improving the efficiency of oxygen delivery to various parts of the body and reducing breathlessness during physical activity. Additionally, rehabilitation training can increase the exercise endurance and muscle strength of patients, contributing to overall physical adaptability and quality of life. The improvements in lung function, exercise capacity, and respiratory difficulties observed in this study have significant clinical implications for the overall quality of life and recovery of cancer patients post-surgery. Improved lung function and reduced breathlessness make it easier for patients to engage in daily activities, enhancing their quality of life. Furthermore, improved exercise capacity helps patients participate more effectively in the rehabilitation process, improving treatment outcomes. These factors may contribute to reduced hospitalization times, alleviating the strain on healthcare resources, and improving long-term prognosis for patients. The limitations of this study may include a relatively small sample size, which could limit the generalizability of the results. Additionally, there may be some potential selection bias as study participants were chosen based on specific criteria. Limitations of the rehabilitation program may include constraints on training time and specific intervention details. These limitations should be explicitly mentioned in the discussion section to provide readers with a comprehensive understanding. Based on the results of this study, future research could further investigate the optimal timing, frequency, and duration of rehabilitation programs to optimize...
CONCLUSION

The results of this work emphasized the importance of pulmonary rehabilitation exercise training following VATS for LC patients. For LC patients, rehabilitation programs should consider including pulmonary rehabilitation exercise training to improve lung function, exercise capacity, and reduce respiratory difficulties. This has practical clinical significance in enhancing the quality of life of postoperative patients, promoting their recovery and rehabilitation. Future research can expand the scope of pulmonary function rehabilitation training, including comparing various types of exercises and rehabilitation strategies to determine the most effective rehabilitation programs. Additionally, studying differences among subgroups of LC patients can help personalize rehabilitation plans, and long-term studies can shed light on the impact of rehabilitation on survival rates and long-term quality of life. The limitations of this study include a relatively small sample size and potential selection bias, as well as the possibility that specific details of the rehabilitation program may have influenced the research results. This work provided strong evidence for postoperative rehabilitation in LC patients, underscoring the importance of pulmonary rehabilitation exercise training in improving lung function, exercise capacity, and alleviating respiratory difficulties. Meanwhile, it offered unique insights into the existing medical knowledge and provides guidance for future research, with the potential to enhance the rehabilitation and quality of life of LC patients.

CONFLICT OF INTEREST

The authors have no potential conflicts of interest to report relevant to this article.

AUTHOR CONTRIBUTIONS

WT and JZ designed the study and performed the experiments, JH and VJ collected the data, JH, VJ and KP analyzed the data, WT and JZ prepared the manuscript. All authors read and approved the final manuscript.

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ETHICAL COMPLIANCE

This clinical study had been approved and implemented by the hospital's Ethics Committee. All the patients voluntarily took part in and signed the informed consent before implementation.

REFERENCES