# Effect of lung rehabilitation training combined with nutritional intervention on patients after thoracoscopic resection of lung cancer

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Received June 28, 2023; Accepted January 11, 2024

DOI: 10.3892/ol.2024.14251

**Abstract.** Thoracoscopic lobectomy is the main type of surgical treatment for lung cancer. Postoperative patients have complications and decreased pulmonary function, which affects their discharge time and quality of life. Lung ventilator training has been shown to promote the postoperative recovery of patients; however, no specific treatment plan has been approved to enhance lung rehabilitation. Therefore, it is necessary to explore methods to promote the postoperative rehabilitation of patients with lung cancer. The patients with lung cancer who were admitted to Banan Hospital Affiliated to Chongqing Medical University (Chongqing, China) between January 2022 and January 2023, and who planned to undergo a thoracoscopic lobectomy, were randomly categorized into two groups. The experimental group began lung rehabilitation training 2 weeks before the operation and received individualized nutrition programs. The control group did not receive lung rehabilitation training and nutrition programs. The quality of life, lung function, 6-min walking distance (6MWD), nutritional status, postoperative complications, hospital expenses and hospital stay between the two groups were compared. Finally, 86 and 83 patients were included in the test and control groups, respectively. Regarding the postoperative indicators, the patients in the test group scored higher in all areas of quality of life, exhibited higher lung function and 6MWD, and had significantly higher serum total protein, albumin and hemoglobin levels, and body mass index, compared with the control group. Furthermore, the incidence of postoperative pulmonary complications, the duration of hospitalization and the hospitalization costs were lower in the experimental group. In conclusion, lung rehabilitation training combined with nutritional intervention can promote the postoperative rehabilitation of patients with lung cancer. The research has been duly registered in the Chinese Clinical Trial Register platform (registration no. ChiCTR2300078681; registered Dec 15, 2023).

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*Key words:* lung cancer, lung rehabilitation training, nutrition intervention, quality of life, lung function, nutritional status

## Introduction

According to the global cancer statistics of 2020, lung cancer is still the main cause of cancer-associated death, with an estimated 1.8 million people dying of the disease every year (1). Non-small cell lung cancer (NSCLC) is the most common pathological type of lung cancer, representing 85% of all cases (2). Early stage NSCLC is typically treated using surgery (3). However, patients with lung cancer experience decreased respiratory area, decreased lung function and pulmonary complications after surgery (4).

In recent years, promoting the rapid recovery of patients after surgery has become a key issue. Lung rehabilitation training is a comprehensive intervention designed to improve the functional capacity and quality of life of individuals with respiratory diseases (5). The mechanism of action of lung rehabilitation training is multifaceted. Exercise therapy enhances the efficiency of the cardiovascular and respiratory systems, leading to an improvement in oxygen utilization and exercise tolerance. Respiratory therapy focuses on teaching patients various breathing techniques and strategies to optimize their respiratory function. Educational components equip patients with the knowledge and skills necessary to manage their conditions effectively (6). Comprehensive nutritional support plays a vital role in enhancing the overall health and well-being of patients, particularly those undergoing treatment or recovery from various illnesses. In addition to improving a patient's nutritional status, appropriate nutritional intervention can significantly reduce the risk of complications, promote wound healing and boost the immune system (7). This, in turn, contributes to a better quality of life for patients and supports their faster recovery. Currently, there is little research on lung rehabilitation training combined with individualized nutrition support (8). Therefore, the present prospective randomized controlled study aimed to explore the effect of postoperative

lung rehabilitation training combined with individualized nutrition intervention on patients treated for lung cancer, and provide a basis in clinical practice for accelerated rehabilitation methods after lung cancer surgery.

## Patients and methods

*Research object*. All participants in the present study were selected from Banan Hospital Affiliated to Chongqing Medical University (Chongqing, China) where they underwent surgical treatment for lung cancer. The patients who needed surgical treatment between January 2022 and January 2023 were included. These individuals were diagnosed with NSCLC in accordance with Oncology Society of Chinese Medical Association guidelines for the clinical diagnosis and treatment of lung cancer (2021 edition) (9), and subsequently underwent thoracoscopic lobectomy. The patients were diagnosed through careful evaluation of clinical manifestations, comprehensive analysis of imaging studies and employment of histological or cytological examination techniques. Inclusion criteria were as follows: i) Patients with primary NSCLC confirmed by pathological diagnosis before operation; ii) those suspected of having lung cancer underwent a pathological analysis of a biopsy during the operation, and the results confirmed the diagnosis of NSCLC.; iii) patients in whom thoracoscopic lobectomy or partial wedge lobectomy was indicated; and iv) patients who agreed to participate in the study and provided written informed consent. The exclusion criteria were as follows: i) The results of intraoperative rapid freezing or postoperative paraffin pathological examination did not conform to the diagnosis of primary NSCLC; ii) patients who were not suitable for thoracoscopic surgery; iii) patients who underwent a pulmonary bilobectomy and total pneumonectomy; iv) patients with massive bleeding during the operation; v) patients who required an unplanned reoperation; vi) those who did not cooperate with lung rehabilitation training or refused to implement a nutrition plan; vii) patients with severe hepatic and renal insufficiency, intestinal obstruction and gastrointestinal bleeding; viii) patients who were participating in other clinical research projects; and ix) patients who refused to provide informed consent.

*Randomization method*. The research has been duly registered in the Chinese Clinical Trial Register platform (registration no. ChiCTR2300078681; registered, Dec 15, 2023), marking it as a randomized controlled study. Random numbers were generated according to a random number table, and a number plate was prepared and sealed in envelopes. Patients randomly selected envelopes after admission. If the number plate in the envelope was odd, they were included in the test group, while patients with even numbers were included in the control group.

*Planning scheme*. Rehabilitation physicians were invited to provide comprehensive explanations on the intricacies of pulmonary rehabilitation training in the form of instructional videos. Subsequently, upon patient enrollment, the attending physicians deftly integrated these videos into their guidance on pulmonary rehabilitation training. In the test group, lung rehabilitation training commenced 2 weeks prior to the operation, accompanied by individually tailored nutrition intervention prescribed by dietitians. Conversely, the control group did not receive lung rehabilitation training or special nutrition intervention. Following routine preoperative preparation, both groups underwent the planned operation and received customary postoperative treatment. Once their condition stabilized, they were discharged. In the test group, lung rehabilitation training commenced 2 weeks after the operation, accompanied by personalized nutrition intervention prescribed by a nutritionist throughout the entire process. Both groups of patients were followed up at the 4th, 8th and 12th weeks after the operation. Generally, the medical staff maintained follow-up communication with patients 2-3 times per week. Patients were provided with detailed instructions on the rehabilitation program, including exercises, frequency, duration and any specific guidelines. Regular communication with the patients was maintained through phone or text messages to provide support, answer any questions and address concerns they may have had. Automated reminders and motivational messages sent via phone or text message were utilized to remind patients about their scheduled exercises and encourage them to stay committed to the program. The objective of this monitoring process was to ensure that patients adhered to the treatment plan and medical directives, while also providing essential support and guidance. Additionally, the medical staff diligently recorded the patient's feedback and monitored any changes in their condition, making necessary adjustments or recommendations accordingly. Fig. 1 presents the project flow chart.

*Preoperative preparation*. At 3 days before the operation, expectorant (ambroxol hydrochloride syrup, oral, twice a day, 10 ml each time), antiasthmatic (salbutamol, high-frequency atomization inhalation, twice a day, 2.5 mg each time) and anti-inflammatory (budesonide, high-frequency atomization inhalation, twice a day, 1 mg each time) drugs were administered. Anti-infection treatment was administered to patients with a definite infection before the operation. The treatment plan was formulated according to the microbial drug sensitivity test, clinical pharmacy or respiratory consultation. When the two groups of patients entered the research, all smoking patients were advised to give up smoking in order to facilitate their postoperative recovery.

*Lung rehabilitation training plan*. The lung rehabilitation training included breathing training combined with walking training.

*Breathing training*. A breathing trainer (Leventon S.A.U.) was used. The respirator was connected correctly, and deep and even inhalations were drawn through the mouthpiece, ensuring that the yellow buoy ball was kept raised to the preset mark for as long as possible. Next, the patient removed the breathing trainer and exhaled slowly. These steps were repeated. The training time was between 10 and 15 min, following which a normal breath rest was taken. During waking hours, breathing training was performed every 2 h. It was ensured that patients were able to tolerate subjective feelings and that the training did not cause fatigue (10).

*Walking training*. Patients performed stretching exercises for the muscles in their legs, waist, shoulders, chest and arms, before walking. The total duration of the stretching

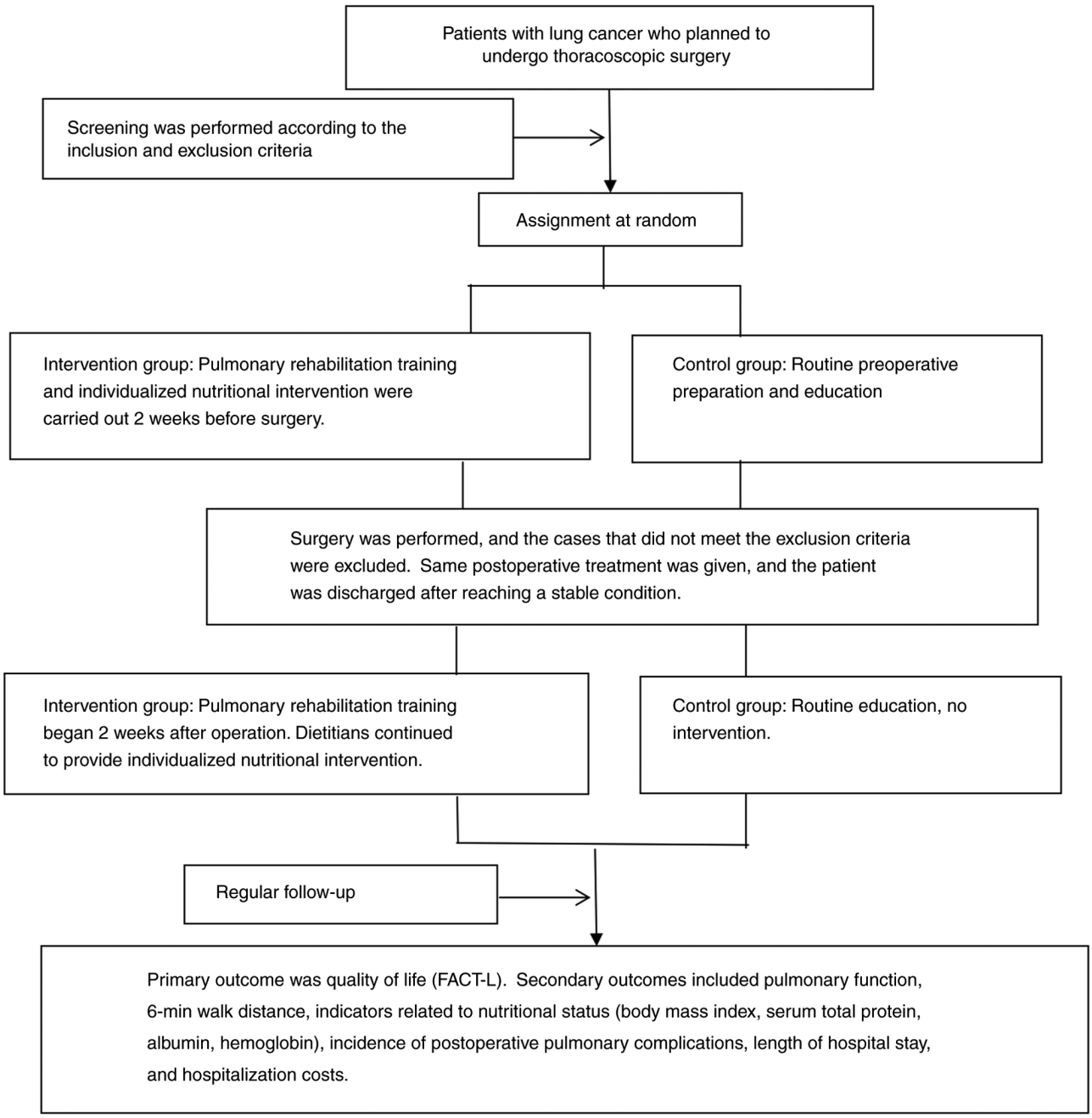


Figure 1. Project flow chart.

exercises was 5 min. Next, the patient walked at a slower speed (1.98 km/h as the initial speed) on a treadmill. Gradually, the patients increased their running speed within 5 min, and then walked at a suitable speed. Each walking training session lasted between 20 and 40 min. Alternatively, walking training was performed on a flat road and involved walking slowly for an initial 5 min, followed by gradually increasing the walking speed and maintaining a faster walking speed for 20-40 min.

*Principles of individualized nutrition support program*. The nutritionist provided one-to-one nutrition consultation and dietary guidance for each patient, and calculated the daily total energy and nutrient intake of the patient according to the dietary survey, based on the nutritional support requirements of patients with malignant tumors (11). The daily intake of patients reached 70% of the target value, the total energy requirement was 25-30 kcal/kg/day and the protein requirement was 1.5-2.0 g/kg/day [body weight was calculated according to ideal body weight; ideal body weight (kg)=height (cm)-105]. Oral nutrition support (ONS) was given to patients with an insufficient independent diet. If the implementation of ONS was poor, and the dietary survey showed that the dietary intake did not reach 60% of the energy intake standard for 7 consecutive days, the clinician and dietitian discussed the nutrition support plan and decided whether to provide tube feeding enteral nutrition or parenteral nutrition support based on patients' choice.

*Operation type*. Intraoperative general anesthesia was administered intravenously. Both groups of patients underwent

Table I. Basic patient data.

| Variable | Test group (n=86) | Control group (n=83) | $t/\chi^2$ | P-value |
|---|---|---|---|---|
| Age | 58.26±10.15 | 57.23±8.64 | 0.707 | 0.481 |
| Sex, n (%) | | | | |
| Male | 32 (47.8) | 35 (52.2) | 0.434 | 0.510 |
| Female | 54 (52.9) | 48 (47.1) | | |
| Smoking, n (%) | | | | |
| Yes | 47 (48.0) | 51 (52.0) | 0.800 | 0.374 |
| No | 39 (54.9) | 32 (45.1) | | |
| COPD, n (%) | | | | |
| Yes | 54 (52.4) | 49 (47.6) | 0.250 | 0.617 |
| No | 32 (48.5) | 34 (51.5) | | |
| Operation type, n (%) | | | | |
| Superior lobectomy | 19 (52.8) | 17 (47.2) | 0.802 | 0.849 |
| Middle lobectomy | 16 (44.4) | 20 (55.6) | | |
| Inferior lobectomy | 21 (53.8) | 18 (46.2) | | |
| Wedge resection | 30 (51.7) | 28 (48.3) | | |
| Pathological type, n (%) | | | | |
| Squamous cell carcinoma | 24 (48.0) | 26 (52.0) | 0.237 | 0.626 |
| Adenocarcinoma | 62 (52.1) | 57 (47.9) | | |
| TNM classification, n (%) | | | | |
| Stage I | 38 (49.4) | 39 (50.6) | 0.199 | 0.905 |
| Stage II | 26 (51.0) | 25 (49.0) | | |
| Stage III | 22 (53.7) | 19 (46.3) | | |
| Chemotherapy, n (%) | | | | |
| Yes | 57 (47.9) | 62 (52.1) | 1.437 | 0.231 |
| No | 29 (58.0) | 21 (42.0) | | |

COPD, chronic obstructive pulmonary disease; TNM, Tumor-Node-Metastasis; stage I, T1a-2aN0M0; stage II, T2b-T3N0-1M0; stage III, T3N1M0 and T4N0-1M0.

thoracoscopic lobectomy + systematic lymph node dissection (the left side was cleared of the 4L, 5, 6, 7, 8, 9 and 10 groups of lymph nodes, and the right side was cleared of the 2R, 3, 4R, 7, 8, 9 and 10 groups of lymph nodes) (12).

*Postoperative treatment*. Expectorant, antiasthmatic and anti-inflammatory treatments were administered 3-7 days after the operation. If a pulmonary infection was present, antibiotics were administered according to microbial drug sensitivity tests, and clinical pharmacy or respiratory consultations. Postoperative epidural analgesia was administered. A patient-controlled analgesia (PCA) pump is a fluid infusion device that can automatically administer medication. Sufentanil, an analgesic drug, was continuously and slowly injected into the epidural space through a PCA pump, and the drug infusion concentration was maintained at 2 $\mu$g/ml/h to relieve the pain of the patients. The PCA pump was used for 2 consecutive days. After the pump was removed, oral ibuprofen sustained release capsules were provided for pain relief if the patient still felt significant pain. According to the results of the chest X-ray, the thoracic drainage tube was removed as soon as possible at the appropriate time. Patients were encouraged to perform early passive activities, gradual bedside sitting and standing, and slow walking after surgery.

*Observation indicators*. Five observation indicators were used. i) Quality of life: The fourth version of the Functional Assessment of Cancer Therapy-Lung (FACT-L) in Chinese was used for assessing the quality of life (13). The scale was categorized into five areas, namely, physiological status, social/family status, emotional status, functional status and additional lung cancer concerns. The higher the score, the better the quality of life (14). ii) Lung function: The forced expiratory volume in 1 sec (FEV1), the forced vital capacity (FVC) and the FEV1/predicted value ratio (FEV1% pred) were evaluated. iii) Nutritional status: Body mass index (BMI), and total protein (TP), albumin (Alb) and hemoglobin (Hb) levels were measured. iv) Exercise endurance: A 6-min walk distance (6MWD) test was used to assess endurance (15). v) Postoperative pulmonary complications: Pulmonary infection, pneumothorax (air entering the pleural cavity, with a lung compression area of ≥30%), pleural effusion, subcutaneous emphysema and respiratory failure were recorded.

Table II. Comparison of FACT-L scores.

| FACT-L | Test group (n=86) | Control group (n=83) | t | P-value |
|---|---|---|---|---|
| Physiological condition | | | | |
| Before treatment | 18.91±1.30 | 19.05±1.94 | -0.553 | 0.581 |
| At 12 weeks post-operation | 21.06±1.66 | 19.20±1.86 | 6.837 | <0.001 |
| Social/family status | | | | |
| Before treatment | 18.42±1.99 | 18.55±2.27 | -0.413 | 0.680 |
| At 12 weeks post-operation | 20.65±1.90 | 18.51±1.79 | 7.544 | <0.001 |
| Emotional status | | | | |
| Before treatment | 17.26±1.42 | 16.88±1.89 | 1.461 | 0.146 |
| At 12 weeks post-operation | 18.90±1.87 | 16.86±2.55 | 5.914 | <0.001 |
| Functional status | | | | |
| Before treatment | 16.05±1.12 | 15.98±1.27 | 0.385 | 0.701 |
| At 12 weeks post-operation | 18.28±1.47 | 16.24±1.54 | 8.798 | <0.001 |
| Additional concerns about lung cancer | | | | |
| Before treatment | 24.23±1.40 | 24.40±1.79 | -0.666 | 0.506 |
| At 12 weeks post-operation | 26.65±1.44 | 23.69±2.04 | 10.901 | <0.001 |

FACT-L, Functional Assessment of Cancer Therapy-Lung.

Table III. Comparison of 6MWD and lung function.

| Pulmonary function | Test group (n=86) | Control group (n=83) | t | P-value |
|---|---|---|---|---|
| FEV1, liters | | | | |
| Before treatment | 2.23±0.26 | 2.29±0.25 | -1.531 | 0.128 |
| At 4 weeks post-operation | 1.82±0.24 | 1.60±0.16 | 6.652 | <0.001 |
| At 8 weeks post-operation | 2.11±0.22 | 1.81±0.19 | 9.693 | <0.001 |
| At 12 weeks post-operation | 2.19±0.22 | 2.00±0.18 | 6.073 | <0.001 |
| FVC, liters | | | | |
| Before treatment | 3.04±0.23 | 3.09±0.21 | -1.440 | 0.152 |
| At 4 weeks post-operation | 2.51±0.17 | 2.21±0.20 | 10.425 | <0.001 |
| At 8 weeks post-operation | 2.66±0.18 | 2.41±0.19 | 8.755 | <0.001 |
| At 12 weeks post-operation | 2.91±0.23 | 2.48±0.17 | 13.952 | <0.001 |
| FEV1% pred, % | | | | |
| Before treatment | 97.37±12.47 | 94.26±10.06 | 1.779 | 0.077 |
| At 4 weeks post-operation | 76.69±9.91 | 65.67±5.83 | 8.855 | <0.001 |
| At 8 weeks post-operation | 85.18±8.32 | 74.83±4.96 | 9.858 | <0.001 |
| At 12 weeks post-operation | 91.72±9.40 | 84.71±9.79 | 4.747 | <0.001 |
| 6MWD, meters | | | | |
| Before treatment | 453.28±20.12 | 457.89±18.46 | -1.552 | 0.123 |
| At 4 weeks post-operation | 425.07±18.97 | 411.35±18.25 | 4.791 | <0.001 |
| At 8 weeks post-operation | 450.81±26.05 | 437.25±21.04 | 3.727 | <0.001 |
| At 12 weeks post-operation | 470.02±24.05 | 448.96±22.95 | 5.818 | <0.001 |

6MWD, 6-min walk distance; FEV1, forced expiratory volume in 1 sec; FVC, forced vital capacity; FEV1% pred, FEV1/predicted value ratio.

*Statistical analysis*. SPSS 23.0 (IBM Corp.) was used for the statistical analysis. The measurement data conformed to the normal distribution and are expressed as the mean ± standard deviation. The inter-group comparisons were conducted using the independent sample t-test. Count data are expressed as n (%) and were analyzed using the $\chi^2$ test when the expected frequency was ≥5. When the total sample size was <40 or the expected frequency was <5, Fisher's exact test was used.

Table IV. Comparison of relevant indicators of nutritional status.

| Nutrition-related indicators | Test group (n=86) | Control group (n=83) | t | P-value |
|---|---|---|---|---|
| BMI, kg/m$^2$ | | | | |
| Before treatment | 21.47±1.52 | 21.55±2.01 | -0.297 | 0.767 |
| At 4 weeks post-operation | 21.68±1.59 | 20.38±1.28 | 5.848 | <0.001 |
| At 8 weeks post-operation | 21.98±2.07 | 21.24±1.58 | 2.608 | 0.010 |
| At 12 weeks post-operation | 22.41±1.75 | 21.19±1.12 | 5.432 | <0.001 |
| TP, g/l | | | | |
| Before treatment | 65.89±6.42 | 66.91±6.06 | -1.057 | 0.292 |
| At 4 weeks post-operation | 69.36±7.15 | 64.85±8.43 | 3.749 | <0.001 |
| At 8 weeks post-operation | 71.19±8.65 | 66.20±5.89 | 4.389 | <0.001 |
| At 12 weeks post-operation | 72.52±7.22 | 67.78±5.09 | 4.946 | <0.001 |
| Alb, g/l | | | | |
| Before treatment | 40.60±3.61 | 39.76±4.25 | 1.399 | 0.164 |
| At 4 weeks post-operation | 43.01±4.59 | 39.64±3.89 | 5.129 | <0.001 |
| At 8 weeks post-operation | 43.85±4.06 | 41.54±3.48 | 3.962 | <0.001 |
| At 12 weeks post-operation | 46.02±3.86 | 42.03±3.17 | 7.312 | <0.001 |
| Hb, g/l | | | | |
| Before treatment | 112.74±15.18 | 114.08±14.99 | -0.576 | 0.565 |
| At 4 weeks post-operation | 117.14±12.71 | 108.92±9.87 | 4.703 | <0.001 |
| At 8 weeks post-operation | 120.01±11.67 | 112.28±11.18 | 4.394 | <0.001 |
| At 12 weeks post-operation | 121.32±11.24 | 114.83±11.34 | 3.737 | <0.001 |

BMI, body mass index; TP, total protein; Alb, albumin; Hb, hemoglobin.

P<0.05 was considered to indicate a statistically significant difference.

## Results

*Basic data*. During the preliminary phase, an estimation of the requisite sample size was conducted. Considering post-operative quality of life as the pivotal evaluative criterion for patients with lung cancer, the study placed particular emphasis on the FACT-L as the primary outcome measure. Based on an ANOVA F-Test, considering a significance level of 0.05 for two-sided tests, an 80% power and an anticipated standard deviation of 20 points, it was determined that a minimum of 64 cases per group was required. Accounting for an expected dropout rate of 20%, a total enrollment of 155 cases was targeted, thus yielding an initial sample size estimate of 160 cases. Ultimately, this study successfully enrolled a robust cohort of 169 patients, ensuring an ample sample size. A total of 169 patients (86 in the test group and 83 in the control group) were included in the study. Throughout the study duration, there were no instances of mortality related to lung cancer among the patients. The experimental group consisted of a total of 86 patients, with a mean age of 58.26±10.15 years. This group included 32 males with a mean age of 59.28±7.49 years and 54 females with a mean age of 57.65±11.46 years. The control group consisted of a total of 83 patients, with a mean age of 57.23±8.64 years. Among them, there were 35 males with a mean age of 56.14±9.64 years and 48 females with a mean age of 58.02±7.84 years. Table I shows that there no statistically significant disparity (P>0.05) existed between the two groups in terms of variables such as sex, age, smoking status, presence of chronic obstructive pulmonary disease (COPD), operation type and pathological type. Stages I and II represent the early stage of NSCLCs, encompassing the T1a-2aN0M0 and T2b-T3N0-1M0 classifications. By contrast, stage III represents locally advanced NSCLCs, which include the T3N1M0 and T4N0-1M0 classifications (16). Given the lack of statistically significant differences in Tumor-Node-Metastasis classification between the two patient groups, it can be concluded that this particular factor would not affect the research results.

*Comparison of FACT-L scores*. There was no significant difference in FACT-L quality of life scores between the two groups before treatment (P>0.05). At 12 weeks after the operation, the scores of patients in the test group in terms of physical status, social/family status, emotional status, functional status and additional concerns about lung cancer were all significantly higher than those in the control group (P<0.05), as shown in Table II.

*Comparison of 6MWD and lung function*. There was no significant difference in lung function and 6MWD between the test group and the control group before treatment (P>0.05). After the operation, at 4, 8 and 12/weeks, the indexes related to lung function (FEV1, FVC and FEV1% pred) in the test group were significantly higher than those in the control group (P<0.05). The 6MWD of the experimental group was also significantly longer than that of the control group (P<0.05) (Table III).

Table V. Comparison of clinical outcomes.

| Outcome | Test group (n=86) | Control group (n=83) | $t/\chi^2$ | P-value |
|---|---|---|---|---|
| Hospitalization time, days | 5.59±1.14 | 6.43±1.52 | -4.048 | <0.001 |
| Hospitalization expenses x ¥10,000 | 4.58±1.13 | 5.84±1.12 | -7.227 | <0.001 |
| Pulmonary infection, n (%) | | | | |
| Yes | 2 (18.2) | 9 (81.8) | 5.036 | 0.025 |
| No | 84 (53.2) | 74 (46.8) | | |
| Pneumothorax, n (%) | | | | |
| Yes | 2 (16.7) | 10 (83.3) | 6.053 | 0.017 |
| No | 84 (53.5) | 73 (46.5) | | |
| Pleural effusion, n (%) | | | | |
| Yes | 3 (21.4) | 11 (78.6) | 5.300 | 0.021 |
| No | 83 (53.5) | 72 (46.5) | | |
| Subcutaneous pneumatosis, n (%) | | | | |
| Yes | 5 (27.8) | 13 (72.2) | 4.305 | 0.038 |
| No | 81 (53.6) | 70 (46.4) | | |
| Respiratory failure, n (%) | | | | |
| Yes | 1 (11.1) | 8 (88.9) | 4.454 | 0.035 |
| No | 85 (53.1) | 75 (46.9) | | |

*Comparison of nutritional status-related indicators*. There was no statistically significant difference in the nutritional status of the two groups before treatment (P>0.05). At 4, 8 and 12 weeks after the operation, the BMI, and TP, Alb and Hb levels of the test group were significantly improved compared with those of the control group (P<0.05) (Table IV).

*Comparison of clinical outcomes*. In contrast to the control group, patients in the experimental group experienced significantly reduced hospitalization times and incurred fewer expenses (P<0.05). Furthermore, when comparing postoperative complications between the two groups, the test group exhibited significantly lower rates of pulmonary infection, pleural effusion, subcutaneous pneumatosis and respiratory failure (P<0.05) (Table V).

## Discussion

Lung cancer is a malignant tumor with the highest incidence rate and mortality in the world, and that has serious effects on people's health (1). As medicine continues to develop, lung cancer screening is steadily promoted and improvements are made in health awareness, early stage lung cancer is being detected more often. Presently, the treatment of lung cancer is mainly surgical. Video-assisted thoracoscopic surgery is the main thoracic surgical procedure used, where a small camera is used to investigate inside the chest of a patient through a small incision (17). Compared with open lobectomy, thoracoscopic lobectomy has more advantages in terms of reducing duration of hospital stay and chest tube use (18).

With the lobectomy of lung cancer, patients will have a decreased respiratory area, decreased lung function and decreased activity tolerance (19). The present study revealed a notable decline in pulmonary function and 6MWD post-operation, which was evident in both the experimental and control groups. Pulmonary rehabilitation is defined as a comprehensive intervention based on a thorough patient assessment after patient-tailored treatment, including but not limited to exercise training, education and behavioral modification (20). Pulmonary rehabilitation training aims to improve lung function, enhance physical fitness and optimize respiratory health. Through a tailored exercise program, patients engage in activities such as breathing exercises, aerobic exercises and strength training. These exercises help to strengthen respiratory muscles, increase lung capacity, improve oxygen uptake and enhance overall physical endurance. By participating in pulmonary rehabilitation training, patients can regain their respiratory function more efficiently, reduce postoperative complications, such as pneumonia, and enhance their quality of life (21). Brocki *et al* (22) showed that pulmonary resection has significant short-term and long-term effects on lung function and oxygenation, and that the manner in which postoperative lung function is improved in patients is important. Respiratory muscle strength training, especially strength training for the inspiratory muscles, has been indicated to significantly enhance exercise capacity, improve respiratory function and reduce dyspnea (23). A study by Su *et al* (24) also highlighted the crucial role of pulmonary rehabilitation in diverse clinical scenarios. This comprehensive approach has been shown to effectively decrease the occurrence of pulmonary complications, enhance lung function and ultimately enhance the overall quality of life. By the 12th week of the present study, the 6MWD revealed noteworthy disparities between the experimental and control groups. Specifically, the experimental group achieved a distance of 470.02±24.05 meters, while the control group recorded a lower distance of 448.96±22.95 meters. This discrepancy signifies a significantly superior exercise capacity within the experimental group.

Furthermore, in terms of lung function, the indexes of FEV1, FVC and FEV1% pred exhibited higher values in the experimental group at 4, 8 and 12 weeks post-operation, in contrast to the control group. This indicates a favorable recovery trajectory in lung function among the experimental group. Additionally, when evaluating quality of life, the scores pertaining to physical status, social/family status, emotional status, functional status and concerns regarding lung cancer were significantly elevated in the experimental group compared with those in the control group. When scrutinizing postoperative complications, the test group showcased a notable reduction in the incidence of pulmonary infection, pleural effusion, subcutaneous pneumatosis and respiratory failure, in contrast with the control group. For individuals necessitating thoracoscopic lung cancer resection, the implementation of rehabilitation training has the potential to ameliorate their pulmonary function status, bolster their cardiopulmonary endurance, enhance the efficacy of expectoration, mitigate the risk of thrombosis and ameliorate their psychological well-being (25). In the present study, the experimental group exhibited a mean hospitalization time of 5.59±1.14 days, accompanied by a modest hospitalization cost of 4.58±1.13 thousand yuan. By contrast, the control group endured a significantly longer mean hospitalization time of 6.43±1.52 days, coupled with a significantly higher hospitalization cost of 5.84±11.2 thousand yuan. Overall, this comprehensive approach facilitates the rehabilitation process, reduces the hospitalization duration and ultimately alleviates the burden of medical expenses.

After surgery, patients often experience a decrease in appetite and a reduced ability to consume sufficient nutrients. In a cross-sectional study, the incidence of malnutrition in patients with lung cancer in stages I-IV was 17.39, 15.00, 22.00 and 36.86%, respectively (26). In the present study, the assessment of nutritional status was conducted at 4, 8 and 12 weeks after the surgical procedure in both groups. The experimental group exhibited superior measurements in terms of BMI, and TP, Alb and Hb levels when compared with the control group at each respective time point. Surgical procedures can create significant stress on the body, and proper nutrition plays a critical role in promoting the healing process (27). By providing essential nutrients, such as proteins, vitamins and minerals, nutritional support helps to optimize the body's ability to heal and regenerate damaged tissues. Furthermore, lung cancer surgery can lead to changes in the digestive system, resulting in difficulties with swallowing or absorbing nutrients. Nutritional interventions, such as enteral or parenteral nutrition, can be implemented to ensure that patients receive the necessary nutrients directly into their bloodstream or digestive system. This helps to prevent malnutrition, maintain muscle mass and support the immune system, reducing the risk of complications (28). Additionally, nutritional support can help manage treatment-related side effects, such as nausea, vomiting or taste changes, which can affect a patient's appetite and food intake (29). Nutritionists can work with patients to develop personalized dietary plans that address their specific needs and preferences. This may include modifying the texture or consistency of food, providing oral nutritional supplements or recommending alternative food choices that are easier to tolerate. By optimizing nutritional intake, postoperative patients with lung cancer can experience improved wound healing, faster recovery, enhanced immune function and an overall improvement in their quality of life (30). Patients with lung cancer have large nutritional needs after surgery, and standardized nutritional intervention can reduce the degree of protein decomposition in patients, avoid the deterioration of nutritional status, and maintain and gradually improve their nutritional status (31,32).

Currently, there is a prevailing lack of awareness among some doctors in China regarding the principles of Enhanced Recovery After Surgery medicine. The primary objective of the present study is to ascertain the positive impact of combining pulmonary rehabilitation training with nutritional intervention on the postoperative recovery of patients with lung cancer. By doing so, it aims to garner increased attention and subsequent efforts from medical professionals towards advancing the swift recuperation of these patients. The results showed that the experimental group who underwent lung rehabilitation training and individualized nutrition intervention had higher quality of life, faster recovery of lung function and exercise ability, better nutritional status, lower incidence of pulmonary complications, and reduced hospital stay and hospitalization costs. The results of this study can provide a basis in clinical practice to support the accelerated rehabilitation method for patients with lung cancer after surgery. Simultaneously, the pulmonary rehabilitation exercises employed in this study can serve as a valuable reference for establishing standardized and effective protocols for pulmonary rehabilitation training. Lung rehabilitation training and nutrition intervention can benefit patients with lung cancer. With the strengthening of awareness in all medical staff with regard to the concept of accelerating rehabilitation, the use of a multidisciplinary cooperation model to promote the rehabilitation of patients has become inevitable in anti-tumor treatment (33). The integration of pulmonary rehabilitation training with nutritional intervention holds great promise and merits widespread promotion and application.

The present study implemented various measures to enhance patient compliance throughout the research. While these efforts facilitated adherence to the rehabilitation program, we recognize that relying solely on phone or text communication has limitations in detecting non-compliance. For future studies, the integration of additional monitoring methods, such as wearable devices or telehealth platforms will be explored, to improve the ability to detect and address non-compliance more effectively. In the study's design, two distinct cohorts, the experimental group and the control group, were established. The experimental group underwent a comprehensive approach involving pulmonary rehabilitation training combined with nutritional intervention. However, we did not include a comparative analysis between patients who exclusively received pulmonary rehabilitation training and those who solely received nutritional intervention. In future investigations, one goal is to conduct a comprehensive comparative analysis among four groups to determine whether patients undergoing a synergistic combination of pulmonary rehabilitation and nutritional intervention experience greater benefits compared with those who exclusively receive pulmonary rehabilitation or nutritional intervention alone.

In conclusion, for patients with lung cancer undergoing thoracoscopic surgery, the lung rehabilitation training method

used in the present study can be combined with nutritional intervention in a multidisciplinary collaborative treatment model to promote better recovery and higher quality of life after surgery.

**Acknowledgements**

Not applicable.

**Funding**

This study was partly supported by Chongqing Banan Science and Technology Bureau (grant. no. 2021-45).

**Availability of data and materials**

The datasets used and/or analyzed during the current study are not publicly available due to individual participants' privacy but are available from the corresponding author on reasonable request.

**Authors' contributions**

JL and JZ contributed to the conception and design of the study, jointly collected and organized the data, conducted the data analysis and interpreted the findings and confirm the authenticity of all the raw data. In addition, JL led the drafting of the manuscript, and JZ contributed to the manuscript review. Both authors read and approved the final manuscript.

**Ethics approval and consent to participate**

The protocol of this study was approved by the Ethics Committee of the Banan Hospital Affiliated to Chongqing Medical University (approval no. R2022003) and written informed consent was obtained from all participants.

**Patient consent for publication**

The patients all provided written informed consent for publication of the data in this manuscript.

**Competing interests**

The authors declare that they have no competing interests.

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