Xu *et al. Journal of Cardiothoracic Surgery* (2025) 20:179
https://doi.org/10.1186/s13019-025-03343-8

Journal of Cardiothoracic Surgery

RESEARCH Open Access

Feasibility of postoperative home-based pulmonary function training for lung cancer patients: a real-world study

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Abstract

Background Pulmonary surgery can significantly impact patients' respiratory function and reduce their quality of life. Previous studies have shown that perioperative breathing exercises (BE) can facilitate the recovery of lung function and improve patients' quality of life after surgery. However, due to the lack of supervision and awareness, patients often struggle to adhere to the prescribed exercise regimen. This study statistics and analyzes the effect of postoperative respiratory function training on postoperative recovery of patients undergoing pneumonectomy in a realistic environment, in order to provide a basis for optimizing postoperative rehabilitation strategies.

Methods Patients undergoing surgical treatment for pulmonary nodules received standardized education upon admission, including guidance on performing breathing exercises. Preoperative pulmonary function tests (PFT) and arterial oxygen saturation measurements were conducted, and patients were instructed to return for follow-up pulmonary function and arterial oxygen saturation assessments at 1 month, 3 months, and 6 months post-surgery. In addition, patients were asked to complete online questionnaires at these time points. Oxygen saturation levels were also re-assessed before discharge, and patients were encouraged to complete a discharge questionnaire. Weekly phone calls were made to remind patients to continue their breathing exercises. The study analyzed 12 potential factors that might affect the outcomes, including preoperative nebulization use, surgical method, and patient age. The primary outcome measures were the effects of postoperative breathing exercises on FEV1, FVC, DLCO, and SPO2 at 1 month (T1), 3 months (T2), and 6 months (T3) post-surgery. Secondary outcomes included LCQ cough assessment, FACT-L quality of life assessment, evaluations of pain and appetite, SAS anxiety level, SDS depression level, AIS sleep quality, and the modified MRAC assessment of dyspnea symptoms.

Results The study initially enrolled 296 patients (T0), including 233 patients who underwent sublobar resection (SRP) and 63 patients who underwent lobectomy (LBP). Between T0 and T1, 203 patients remained in the SRP group and 47 in the LBP group. Between T0 and T2, 36 patients remained in the SRP group and 9 in the LBP group. By T3, the SRP group had 14 patients, and the LBP group had 5 patients remaining. Due to incomplete data, SPO2 measurements were excluded from the analysis. Additionally, the SRP group at T3 and the LBP group at T2 and T3 were not included in the analysis.In the SRP group, at T1, the BE group showed significantly better recovery in FEV1 and FVC compared to the control group. By T2, the BE group had a significantly improved sleep quality compared to the control group

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($P < 0.05$). In the LBP group, at T1, the BE group demonstrated a significant advantage in alleviating anxiety symptoms compared to the control group ($P < 0.05$). No significant differences were observed in other outcomes.

Keywords Pulmonary function training, Lung cancer, Pulmonary surgery

Introduction

With the increasing awareness of health and the advancement of thoracoscopic techniques, an increasing number of small pulmonary nodules are being detected early and surgically removed, leading to a younger demographic of patients undergoing surgical treatment. Many of these patients are asymptomatic prior to surgery. Compared to elderly patients, younger patients—especially asymptomatic ones—tend to be more concerned about the impact of surgery on their postoperative quality of life. Pulmonary surgery significantly affects respiratory function.According to the British thoracic society (BTS), patients should have an FEV1 of more than 1.5 L before lobectomy and more than 2 L before pneumonectomy [1]. At the same time, PFT is also an indicator of the degree of dyspnea. It is more intuitive to evaluate the impact of surgery on patients by PFT. According to reports [2], both FEV1 and FVC sharply decline by the second week post-surgery, followed by gradual recovery. At six months postoperatively, patients who underwent sublobar resection (SRP) regained approximately 93% of their preoperative FEV1 and FVC, whereas those who underwent lobectomy (LBP) regained 87% and 86%, respectively. In addition, postoperative symptoms such as cough, dyspnea, and anxiety or depression are common burdens for lung cancer patients [3]. Therefore, improving patients' quality of life after surgery has become a pressing issue. Pulmonary rehabilitation is commonly used to improve the quality of life in patients with chronic obstructive pulmonary disease (COPD), effectively enhancing respiratory muscle function and alleviating dyspnea symptoms [4]. Studies have shown that preoperative respiratory muscle training, such as respiratory muscle endurance training, can significantly improve the endurance of respiratory muscles in patients with non-small cell lung cancer (NSCLC) postoperatively and reduce the incidence of postoperative complications [5–7]. H.A. Шефер et al. reported that 2 weeks of preoperative pulmonary rehabilitation training can significantly improve the cardiopulmonary function of patients with moderate to severe chronic obstructive pulmonary disease, and thus prepare the patients for further surgical treatment [8]. Additionally, there is evidence that preoperative home-based exercise training can significantly improve patients' postoperative quality of life [9]. However, despite the potential benefits of postoperative pulmonary rehabilitation training for improving the quality of life in lung cancer patients, adherence remains poor, particularly after discharge, with most patients struggling to follow the prescribed training regimen.Therefore, we designed a study to evaluate the effects of postoperative respiratory training on postoperative lung function recovery and quality of life in patients using real-world data and to provide evidence for optimizing postoperative rehabilitation strategies.

Study design

This real-world study enrolled eligible patients(Fig. 1) into a research cohort. Upon admission, generally 3 to 7 days before surgery, nursing staff provided standardized guidance and training, distributing instructional manuals and exercise cards. The specific training included teaching patients how to perform pursed-lip diaphragmatic breathing exercises, respiratory exercise routines, and training with a respiratory trainer (each for 20 min). Patients were instructed to complete the three aforementioned exercises on three self-selected days per week after discharge, and the attending physician reiterated the importance of home-based training before discharge. Patients and their families were informed to return for follow-up visits at the end of the 1st month (T1), 3rd month (T2), and 6th month (T3) post-surgery. Nursing staff followed up with patients weekly via phone calls and social media to remind and encourage them to complete their breathing exercises.

Through the online medical system and questionnaires completed by patients, we collected detailed information, including pulmonary function test results, quality of life assessments, and adherence to breathing exercises. During each follow-up, patients underwent pulmonary function testing to measure FEV1, FVC, DLCO, and arterial oxygen saturation (SPO2). We used the Functional Assessment of Cancer Therapy-Lung instead of the more well-known SF-36 in order to more accurately assess the quality of life in patients with lung cancer.Additionally, patients completed standardized questionnaires to assess quality of life, anxiety, depression, pain, and appetite, allowing us to evaluate the impact of breathing exercises on their postoperative quality of life.

To ensure the scientific rigor and accuracy of the study results, we paid special attention to controlling confounding factors. Through the online medical system, we collected and included in the statistical analysis a range of confounding factors related to the patients' recovery, such as:

1. **Basic Patient Information**: Age, BMI, smoking history.

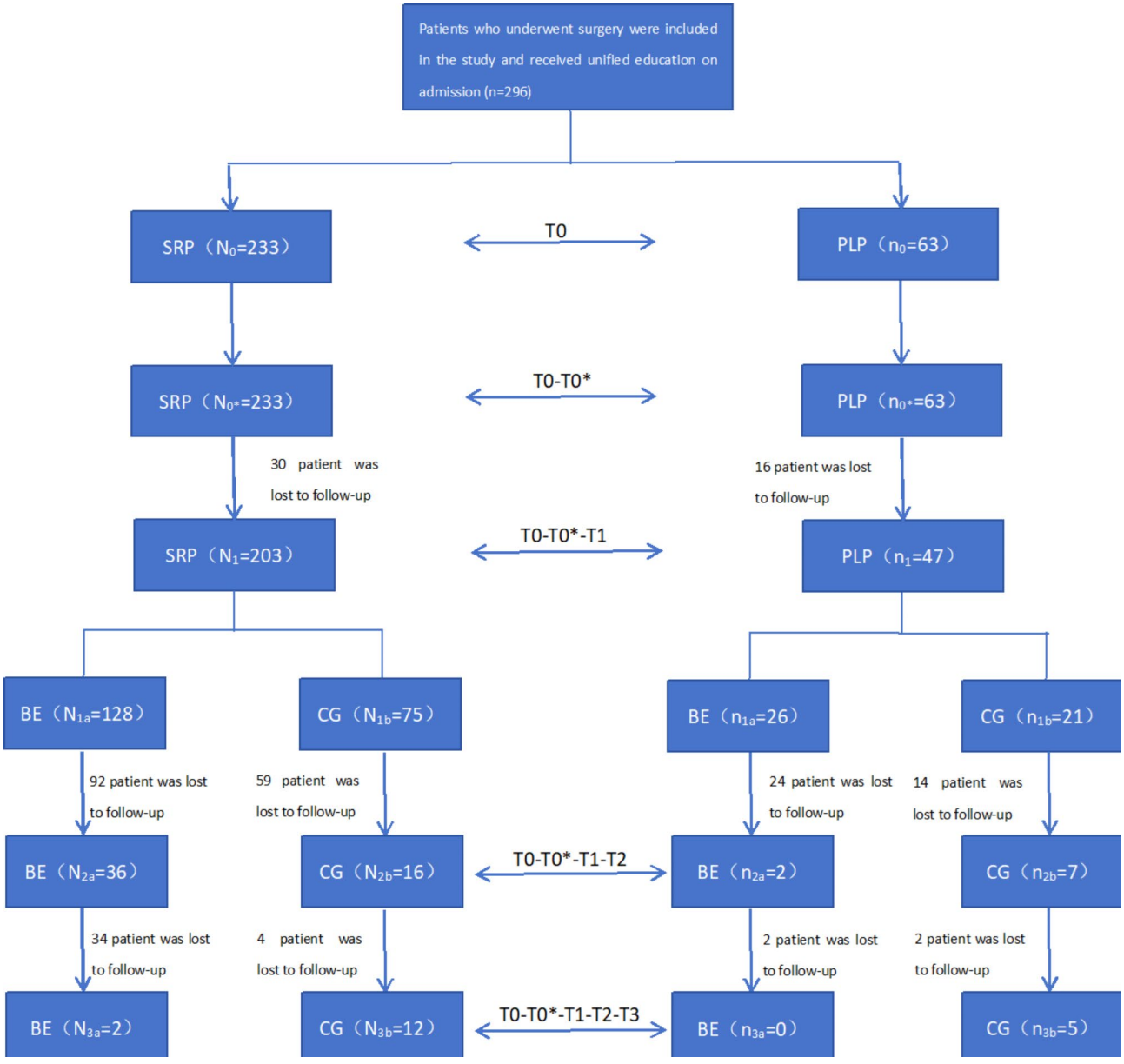

Fig. 1 Patients included in the study and follow-up information

2. **Underlying Diseases**: Including hypertension and coronary heart disease.
3. **Preoperative Treatment**: Whether the patient received nebulized inhalation therapy with a mixture of budesonide and ipratropium bromide suspension prior to surgery, and the duration of such treatment.
4. **Surgical Treatment Method**: Whether the patient underwent lobectomy or sublobar resection.
5. **Medications at Discharge**: Whether the patient was prescribed inhaled medications such as budesonide-formoterol inhalation powder upon discharge.
6. **Living Conditions**: Information on the patient's household economic status and educational level (high school or below, associate degree or above), collected through a questionnaire survey.

These factors were systematically included in the statistical analysis to control for confounding variables and ensure the accuracy and reliability of the study's findings.

By collecting this information, the research team was able to better identify and control potential confounding factors that could influence patients' postoperative recovery, thereby improving the accuracy of the study and the reliability of its results. Patients who adhered to the postoperative breathing exercise plan, completed the relevant questionnaires, and maintained training records during follow-up were classified as the BE group. In contrast,

patients who failed to complete the breathing exercises as required or did not submit their questionnaires on time were classified as the control group.

Assessments were conducted at the following five time points:

1. **At Admission (T0)**: Patients underwent pulmonary function testing, arterial blood gas analysis for oxygen partial pressure measurement, and were encouraged to complete the online questionnaire.
2. ***Before Discharge (T0)***:* Typically 3–4 days post-surgery, arterial blood was drawn for oxygen partial pressure measurement, and patients were reminded to complete the online questionnaire.
3. **At the End of the 1st Postoperative Month (T1)**: Patients underwent pulmonary function testing, arterial blood gas analysis for oxygen partial pressure measurement, and were encouraged to complete the online questionnaire.
4. **At the End of the 3rd Postoperative Month (T2)**: Similar to the procedures conducted at T1.
5. **At the End of the 6th Postoperative Month (T3)**: Similar to the procedures conducted at T1.

Analysis

All analyses were performed using SPSS version 27. The ratios of FEV1, FVC, DLCO, and SPO2 at T1, T2, and T3 relative to T0 were included in the dataset as the data to be analyzed. For questionnaire-related outcomes, the ratios of T1, T2, and T3 relative to T0* were included in the dataset as raw data.

1. Propensity score matching (PSM) was conducted on the raw data to evaluate the differences between the groups.
2. Patients were divided into two subgroups based on the type of surgery: sublobar resection (SRP) and lobectomy (PLP). Subgroup analyses were performed for each, and propensity score matching was conducted for both subgroups to assess intergroup differences.

Differences in outcomes were assessed using the T-test and the Mann-Whitney U test (for non-normally distributed data). All tests were two-sided, and a P-value of < 0.05 was considered statistically significant. The caliper value for propensity score matching was set at 0.02 [10].

Results

A total of 296 patients who underwent surgery for pulmonary nodules at our hospital between March 2023 and November 2023 were included in the cohort, with 233 patients in the SRP group and 63 in the LBP group. However, a certain degree of follow-up loss occurred during the study, resulting in some patients being unable to complete all follow-up evaluations. The detailed follow-up results are as follows:

T1

- **SRP group**: 203 patients completed the follow-up, with 128 in the BE group (63.1%) and 75 in the control group (36.9%).
- **LBP group**: 47 patients completed the follow-up, with 26 in the BE group (55.3%) and 21 in the control group (44.7%).

At this stage, some patients were unable to return for follow-up due to various reasons, such as long distances from the hospital, inconvenient transportation, or postoperative discomfort. The follow-up loss rate was approximately 12.9% in the SRP group (from 233 to 203 patients) and 25.4% in the LBP group (from 63 to 47 patients), which was relatively high.

T2

- **SRP group**: The number of patients completing follow-up decreased to 52, with 36 in the BE group (69.2%) and 16 in the control group (30.8%).
- **LBP group**: Only 9 patients completed the follow-up, with 2 in the BE group (22.2%) and 7 in the control group (77.8%).

At this stage, there was a significant increase in patient loss, with the SRP group's loss rate reaching 77.7%, and the LBP group's loss rate reaching 85.7%. Reasons for patient loss at this stage included the long postoperative recovery period, as some patients had returned to work or their usual living environments, making it difficult to return to the hospital for follow-up. Additionally, some patients may have lost motivation or interest in rehabilitation training, leading to decreased adherence.

T3

- **SRP group**: Only 14 patients completed follow-up, with 2 in the BE group (14.3%) and 12 in the control group (85.7%).
- **LBP group**: 5 patients completed follow-up, all from the control group; no patients from the BE group completed follow-up.

At this stage, patient attrition became more pronounced. The main reasons for loss to follow-up included a gradual decline in patients' interest in the study, further reductions in adherence to rehabilitation training, and the compounded effects of life and work pressures.

Due to the insufficient number of patients who completed the T3 follow-up, the data could not represent the overall recovery status of the cohort. As a result, T3 data were excluded from the overall analysis to avoid statistical bias due to inadequate sample size. Similarly, T3 data were not included in the subgroup analysis for the SRP group. For the LBP group, both T2 and T3 stages were excluded from the analysis due to a critically low sample size. This approach ensured the accuracy of the data analysis and reduced the impact of small sample bias on the study's conclusions. Additionally, some patients refused arterial oxygen saturation measurements during follow-up, leading to incomplete SPO2 data. To ensure data completeness and the credibility of the results, SPO2 was not included in the final analysis.(Table 1).

Table 1 Overall analysis

character	T0-T1($n=250$)	T0-T1-T2($n=45$)
FEV1		
BE group	0.82 ± 0.10	0.87 ± 0.06
control group	0.83 ± 0.11	0.90 ± 0.06
p value	0.343	0.111
FVC		
BE group	0.81 ± 0.13	0.84(0.83–0.88)
control group	0.82 ± 0.13	0.87(0.81–0.90)
p value	0.472	0.458
DLCO		
BE group	1.00(0.88–1.09)	1.06 ± 0.07
control group	0.97(0.85–1.06)	1.07 ± 0.10
p value	0.307	0.871
Appetite		
BE group	1.00(0.57–1.00)	1.29(1.22–1.58)
control group	1.00(0.63–1.00)	1.22(1.00–2.75)
p value	0.609	0.880
Pain		
BE group	0.75(0.50–0.83)	0.21(0.14–0.41)
control group	0.67(0.50–1.00)	0.18(0.11–2.00)
p value	0.674	0.667
LCQ		
BE group	1.02(0.92–1.14)	1.03(0.86–1.15)
control group	1.06(0.91–1.21)	1.05(1.00–1.15)
p value	0.308	0.532
FACT-L		
BE group	0.92(0.70–1.20)	0.84 ± 0.26
control group	0.93(0.69–1.13)	0.85 ± 0.34
p value	0.763	0.938
Anxiety		
BE group	0.76(0.62–0.84)	1.04 ± 0.24
control group	0.80(0.67–0.85)	0.97 ± 0.22
p value	0.539	0.975
Depression		
BE group	0.97(0.84–1.06)	1.00(0.90–1.08)
control group	0.97(0.84–1.06)	0.93(0.86–1.02)
p value	0.397	0.160
Sleep		
BE group	1.00(0.88–1.14)	0.93(0.71–1.08)
control group	1.00(0.89–1.17)	1.00(0.86–1.25)
p value	0.130	0.171
Breathing		
BE group	1.00(0.67–1.00)	0.84(0.50–1.00)
control group	1.00(0.73–1.00)	0.80(0.50–1.00)
p value	0.612	0.650

FEV1, FVC, and DLCO

In the overall analysis, no significant differences were observed across the three outcomes. In the subgroup analysis (Tables 2, 3), all differences were not significant. At T1, the training group had a better trend than the control group in FEV1 (0.83 ± 0.10 vs. 0.80 ± 0.09, $P=0.081$) and FVC (0.82 ± 0.12 vs. 0.79 ± 0.12, $P=0.085$).

Pain and appetite

No significant differences were found in any of the outcomes.

LCQ and FACT-L assessments

No significant differences were observed in any of the outcomes.

Anxiety and depression

In the overall analysis, there were no significant differences in the outcomes. In the subgroup analysis (Tables 2, 3), the LBP training group demonstrated a greater reduction in postoperative anxiety at T1 compared to the control group(0.71 ± 0.09 vs. 0.89 ± 0.17 $P=0.010$). No other significant differences were noted.

Breathing and sleep

No significant differences were found in the overall analysis. In the subgroup analysis, the SRP training group showed better recovery in sleep quality at T2 compared to the control group (0.97 (0.71–1.2) vs. 1.17 (1.03–1.31) $P=0.027$). No other significant differences were observed.

Discussion

Postoperative lung resection significantly impacts patients' lung function and quality of life. A study by Luciana Nunes Titton Lima et al. [11] found that patients' quality of life within the first six months after surgery was generally lower than that of the general population, as assessed by QOL questionnaires, reflecting the negative impact of surgery on patients' daily subjective experiences. Research suggests that systematic pulmonary rehabilitation plays a positive role in postoperative recovery. For example, a study by Soo Koun Kim et al. [12] found that more than three months of systematic pulmonary rehabilitation (including respiratory muscle and skeletal muscle training) improved patients' quality of life more effectively than home-based exercise, and

Table 2 Subgroup analysis of SRP

SRP		
Character	T0-T1($n=144$)	T0-T1-T2($n=16$)
FEV1		
BE group	0.83 ± 0.10	0.87 ± 0.09
control group	0.80 ± 0.09	0.88 ± 0.07
p value	0.081	0.647
FVC		
BE group	0.82 ± 0.12	0.84 ± 0.11
control group	0.79 ± 0.12	0.87 ± 0.07
p value	0.085	0.494
DLCO		
BE group	0.95 ± 0.16	1.06 ± 0.09
control group	0.93 ± 0.18	1.04 ± 0.10
p value	0.535	0.695
Appetite		
BE group	1.00(0.33-1.00)	0.50(0.15-1.00)
control group	1.00(0.17-1.00)	1.00(0.84–1.14)
p value	0.447	0.833
Pain		
BE group	0.75(0.50–0.89)	0.67(0.37–0.84)
control group	0.67(0.50–0.83)	0.71(0.54–0.94)
p value	0.269	0.635
LCQ		
BE group	1.01(0.93–1.14)	1.08 ± 0.13
control group	1.10(0.91–1.22)	1.07 ± 0.30
p value	0.245	0.958
FACT-L		
BE group	0.95(0.74–1.21)	0.75 ± 0.23
control group	0.85(0.67–1.02)	0.77 ± 0.25
p value	0.061	0.893
Anxiety		
BE group	0.76(0.62–0.86)	1.07 ± 0.31
control group	0.75(0.64–0.83)	0.96 ± 0.24
p value	0.715	0.451
Depression		
BE group	0.97(0.82–1.04)	0.93(0.75–1.16)
control group	0.97(0.84–1.05)	0.88(0.83–1.12)
p value	0.683	0.674
Sleep		
BE group	1.00(0.88–1.10)	0.97(0.71–1.20)
control group	1.00(0.86–1.15)	1.17(1.03–1.31)
p value	0.323	0.027
breathing		
BE group	1.00(0.67-1.00)	1.00(0.67-1.00)
control group	1.00(1.00–1.00)	1.00(1.00-1.88)
p value	0.857	0.782

Table 3 Subgroup analysis of LBP

LBP	
Character	T0-T1($n=20$)
FEV1	
BE group	0.74 ± 0.07
control group	0.73 ± 0.08
p value	0.735
FVC	
BE group	0.73 ± 0.10
control group	0.71 ± 0.11
p value	0.560
DLCO	
BE group	1.07 ± 0.07
control group	1.07 ± 0.10
p value	0.945
Appetite	
BE group	1.00(0.50–9.00)
control group	1.00(1.00–2.46)
p value	0.905
Pain	
BE group	0.69 ± 0.18
control group	0.75 ± 0.33
p value	0.606
LCQ	
BE group	1.02(0.77–1.08)
control group	1.01(0.77–1.60)
p value	0.734
FACT-L	
BE group	0.82 ± 0.39
control group	0.94 ± 0.16
p value	0.385
Anxiety	
BE group	0.71 ± 0.09
control group	0.89 ± 0.17
p value	0.010
Depression	
BE group	0.90 ± 0.18
control group	0.94 ± 0.18
p value	0.586
Sleep	
BE group	1.04 ± 0.26
control group	1.10 ± 0.23
p value	0.597
Breathing	
BE group	1.00(0.67–1.00)
control group	1.00(0.94–1.13)
p value	0.145

six months of rehabilitation significantly promoted the recovery of vital capacity (FVC). Additionally, Maja S. Sommer et al. [13] highlighted that rehabilitation programs including health education and psychological counseling benefited the quality of life and mental health of stage IIIa lung cancer patients post-surgery.While systematic rehabilitation is beneficial for postoperative recovery, its availability in hospitals or rehabilitation centers is limited. Therefore, it is necessary to evaluate the recovery effect of home-based rehabilitation training on patients. In the present study, no significant difference in PFT was observed between the training groups of SRP and PLP at 1 month after surgery, and the case-control study by Soo Koun Kim et al. showed similar

experimental results at 1 month after surgery; however, they observed significant differences at 6 months after surgery. As Win et al. [12]. pointed out that pneumonectomy caused a sudden drop in FEV1 and FVC within the first month after surgery, which did not slowly recover until three months after surgery, 49 we believe that pain may be one of the reasons for the nonsignificant difference in PFT in the short term after surgery.At one month post-surgery, the LBP training group experienced significantly reduced anxiety compared to the control group, while no significant difference was observed in the SRP group. Analysis of the collected questionnaires suggests that this difference may be due to higher baseline anxiety levels in the LBP group prior to surgery.Interestingly, Fengju Wang et al. [14] pointed out that cognitive-behavioral stress management (CBSM) was beneficial in alleviating anxiety and depression in NSCLC patients at three and six months post-surgery, incorporating deep breathing exercises and psychological interventions. Although the CBSM group showed better recovery at one month compared to the control group, the difference was not statistically significant. This suggests that postoperative anxiety relief may rely more on repeated deep breathing exercises.Although the SRP training group showed better sleep quality at three months post-surgery compared to the control group, we remain cautious about this result. Upon reviewing the study process, we identified two potential causes: (1) small sample bias due to the limited sample size after propensity score matching (PSM), and (2) some patients in the SRP group included in the analysis had undergone subsequent treatment. According to a study by Mei-Ling Chen et al. [15], patients undergoing chemotherapy experienced poorer sleep quality during the fourth cycle, which could be a key factor contributing to bias in our results.One of the major challenges in postoperative recovery is improving patient adherence. In the early stages of the study, relying solely on nursing staff for health education was insufficient, with a follow-up loss rate as high as 70% at one month post-surgery. However, as the follow-up supervision process improved—including standardized training for health educators, involvement of attending physicians, and weekly reminders via social media and phone calls by study coordinators—Although the return visit rate and training participation rate of patients have been improved, the loss to follow-up rate is still close to half. Compared with training in rehabilitation centers, patients receiving home training mode need more supervision to achieve better results. This study has certain limitations. (1) Because the subjects were mainly from the same medical institution, the sample may be limited in terms of region and population representativeness, and the results lack general applicability. (2) The high rate of loss to follow-up in this study caused a certain selection bias and also led to incomplete follow-up results. If the problem of poor compliance of patients can be solved in the future, a more comprehensive understanding of home-based rehabilitation can be obtained. Therefore, hospital guidance combined with remote supervision by telephone and social software can promote patients to exercise at home and improve the quality of life of patients to a certain extent. This provides a new perspective for postoperative rehabilitation, that is, the digital rehabilitation platform combining the Internet and medical institutions is expected to become the "family rehabilitation therapist" for lung cancer patients.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13019-025-03343-8.

Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Supplementary Material 4

Acknowledgements
Not applicable.

Author contributions
X.Z analyzed the data and wrote the main body of the manuscript, while C.Y, Z.Z, and Q.D participated in data collection, and D.M was involved in the experimental design and guidance.

Funding
1: Beijing science and technology innovation medical development foundation,, KC2023-JX-0288-PQ87 to Ming Dong.
2: Tianjin key Medical Discipling(Specialty) Construction Project: TJYXZDXK-061B to Ming Dong.
3: Diversified Input Project of Tianjin Natural Science Foundation, 21JCYBJC01310 to Xin Wang.
4: Tianjin Advanced Medical Professionals Training Program: TJSQNYXXR-D2-069 to Xin Wang.
5: China Health promotion foundation, Clinical research on IruaK combined with local treatment for stage IIIB-IV ALK-positive non-small cell lung cancer (NSCLC) patients to Ming Dong.

Data availability
Data is supplementary information files.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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Received: 16 October 2024 / Accepted: 19 January 2025
Published online: 04 April 2025

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