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Original Article

Comparison of Effects of Liuzijue Exercise and Conventional Respiratory Training on Patients after Cardiac Surgery: A Randomized Controlled Trial*

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ABSTRACT **Objective**: To evaluate the feasibility and safety of Liuzijue exercise (LE) for the clinical effect in patients after cardiac surgery. **Methods**: Totally 120 patients who underwent cardiac surgery and were admitted to the Cardiothoracic Intensive Care Unit of Nanjing Drum Tower Hospital between July and Oclober, 2022 were allocated to the LE group, the conventional respiratory training (CRT) group, and the control group by a random number table at a ratio of 1:1:1; 40 patients in each group. All patients received routine treatment and cardiac rehabilitation. LE group and CRT group respectively performed LE and CRT once a day for 30 min for 7 days. Control group did not receive specialized respiratory training. The forced vital capacity, forced expiratory volume in 1 s, peak inspiratory flow rate, peak expiratory flow rate, maximum inspiratory pressure, maximum expiratory pressure, modified Barthel index (MBI), and Hamilton Rating Scale for Anxiety (HAM-A) were evaluated before, after 3 and 7 days of intervention. In addition, the postoperative length of hospital stay (LOS) and the adverse events that occurred during the intervention period were compared. **Results**: A total of 107 patients completed the study, 120 patients were included in the analysis. After 3 days of intervention, the pulmonary function, respiratory muscle strength, MBI and HAM-A of all 3 groups improved compared with that before the intervention (P<0.05 or P<0.01). Compared with the control group, pulmonary function and respiratory muscle strength were significantly improved in the CRT and LE groups (P<0.05 or P<0.01). MBI and HAM-A were significantly improved in the LE group compared with the control and CRT groups (P<0.05 or P<0.01). On the 7th day after intervention, the difference was still statistically significant (P<0.01), and was significantly different from that on the 3rd day (P<0.05 or P<0.01). In addition, on the 7th day of intervention, the pulmonary function and respiratory muscle strength in the LE group were significantly improved compared with those in the CRT group (P<0.01). MBI and HAM-A were significantly improved in the CRT group compared with the control group (P<0.01). There were no significant differences in postoperative LOS among the 3 groups (P>0.05). No training-related adverse events occurred during the intervention period. **Conclusions**: LE is safe and feasible for improving pulmonary function, respiratory muscle strength, the ability to complete activities of daily living and for relieving anxiety of patients after cardiac surgery (Registration No. ChiCTR2200062964).

KEYWORDS Liuzijue exercise, pulmonary function, respiratory muscle strength, activities of daily living, anxiety, cardiac surgery

According to statistics, the total number of cardiovascular surgeries in China in 2021 was 278,056, and cardiopulmonary bypass (CPB) accounted for 63.5% of all cardiovascular surgeries in China.(1) Despite the continuous improvement in cardiac surgery technology and the reduction in perioperative risk,(2) there is still a significant decline in pulmonary function immediately after surgery. This decline in pulmonary function leads to postoperative pulmonary complications (PPCs) and failure of the lung function to return to preoperative levels 1 year postoperarively.(3)

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PPCs include pleural effusion, atelectasis, phrenic nerve paralysis, diaphragmatic dysfunction, pneumonia, pulmonary embolism, and acute respiratory distress syndrome. PPCs increased the mortality of patients who had cardiovascular surgeries by 4 times and extended hospital stays.(4-6) Postoperative lung function is influenced by many factors. Median sternotomies lead to mechanical changes of the chest wall, which reduce lung function.(7) Anesthetic drugs can easily lead to PPCs through immune disorders, resulting in lung injury.(8) CPB caused blood to be exposed to artificial materials, body temperature changes, organ ischemia-reperfusions, surgical trauma and endotoxin release. The exposure of blood to these factors leads to acute inflammatory reactions and then PPCs.(9,10) Postoperative pain, physical injury and limited movement during the postoperative period may further aggravate lung injury.(11) Another potential variable factor leading to PPCs is respiratory muscle dysfunction, which includes changes in respiratory muscle strength and function caused by surgery and respiratory muscle weakness in some patients prior to surgery.(12) The respiratory muscles affected by the surgeries include muscles of the airway, abdominal muscles and the diaphragmatic, and their everyday functions are also limited postoperatively.(13) Additionally, patients after cardiac surgery generally show a decrease in their ability to perform activities of daily living (ADL) and experience negative emotions, such as anxiety.(14-16) Therefore, formulating effective countermeasures is essential to improve patients' overall physical function.

Respiratory training, a widely accepted intervention, was introduced as a treatment option for cardiac surgery patients. The purpose of these exercises in the early postoperative period is to reduce the risk of PPCs, dysfunction, and hospital stay due to changes in lung function.(17) Currently, the respiratory training commonly used for patients undergoing cardiac surgery primarily focuses on training the muscles of respiration. Training muscles of respiration alone may be insufficient to maintain a stable vital capacity and expiratory and inspiratory pressure. The reduction in these lung functions makes it difficult for the patients to maintain adequate airflow and makes them tired.(18)

The Liuzijue exercise (LE), compiled by China Qigong Management Center, is mild and safe and emphasizes meditation and physical activities.(19) It manages exhalation by incorporating 6 different mouth shapes of "Xu, He, Hu, Si, Chui, and Xi." LE, therefore, regulates and controls the respiratory rate in patients and the activities of muscles of respiration; this method also benefits the patients' mental health.(20,21) LE is a suitable form of physical and mental exercise therapy for all ages. LE is based on the holistic concept of Chinese medicine and the theory of physical and mental co-cultivation. This theory is helpful to improve the flow in different organs and meridians, and improve respiratory function and tissue functions.(22) In recent years, LE has been gradually been applied in the treatment of clinical diseases. The use of LE in clinical settings has been found to improve patients' lung function, respiratory muscle strength, exercise ability, health status, mental state, and quality of life.(23-25) However, the clinical effect of LE on patients after cardiac surgery is still unknown.

Therefore, the purpose of this study is to evaluate the feasibility of LE in improving lung function, respiratory muscle strength, ADL and anxiety of patients after cardiac surgery, and to explore its safety and its influence on postoperative length of hospital stay (LOS).

METHODS

Ethical Approval and Registration

This study was approved by the Ethics Committee of Nanjing Drum Tower Hospital (No. 2022-180-02). The study was performed according to the Declaration of Helsinki.

Participants

A total of 134 postoperative patients were enrolled in the study. All patients had undergone cardiovascular surgery in the Cardiothoracic Intensive Care Unit (ICU) of Nanjing Drum Tower Hospital between July and October, 2022.

All patients met the following inclusion criteria: (1) postoperative admission to ICU, including valve repair, valve replacement, aortic replacement, coronary artery bypass graft (CABG), atrioventricular septal defect (AVSD), and radiofrequency ablation (RFA); (2) pull-out tracheal intubation; (3) age ⩾18 years, healthy limbs; (4) New York Heart Association (NYHA) grade of cardiac function was Ⅰ–Ⅲ; (5) circulatory system exhibited hemodynamic stability, no myocardial ischemia within 24 h, no change in vasoactive drug score within 2 h and less than 15 points, the heart rate was 50–120 beats/min, the systolic blood pressure was higher than 90 mm Hg and less than 200 mm Hg, and the average blood pressure was higher than 55 mm Hg and lower than 120 mm Hg; (6) respiratory system presented oxygen saturation was ⩾92%, and inspiratory oxygen concentrations was ⩽60%, respiratory frequency was more than 10 breaths/min and less than 35 breaths/min; (7) active cooperators; and (8) willing to be randomized and sign a written informed consent form.

Patients were excluded according to the following criteria: (1) age <18 years; (2) the use of an intra-aortic balloon, extracorporeal membrane oxygenation, surgical reintervention, and death; (3) hemodynamic instability; (4) severe heart failure, and frequent postoperative arrhythmia; (5) complications of severe cardiovascular and cerebrovascular diseases, respiratory diseases, and liver and kidney failure; (6) severe coagulation dysfunction; (7) myasthenia gravis; (8) lack of subjective initiative; (9) pregnant women and parturients; (10) previous participation in rehabilitation programs; and (11) consciousness, cognition, mental dysfunction, vision or hearing impairment, and low degree of cooperation.

Randomization and Blinding

Using a computer-generated randomization table, an investigator put consecutive numbers in a sealed envelope and randomly divided them into 3 groups at a ratio of 1:1:1. In this scheme, due to the difficultly of achieving double-blinding, the research method and treatment allocation were blinded to outcome evaluators and statistical analysts.

Intervention

A total of 120 patients were randomly assigned to the LE, conventional respiratory training (CRT), and control groups; 40 patients were included in each group. All subjects continued to receive routine postoperative treatment and cardiac rehabilitation (CR). The patients in the LE group chose LE. Patients in the CRT group received CRT. Patients in the control group did not have specified respiratory training. Conventional CR includes joint mobility training, muscle strength training, sitting balance training, sitting transfer training, walking ability training, and ADL training. The intensity of CR was classified according to the Borg score[26] of 11–13, 30 min of training once a day, 5 days a week, until discharge from the hospital. The implementation of the intervention programs was accomplished through a multidisciplinary approach. Patients were trained by experienced therapists, who ensured that the training process conformed to the predetermined protocol.

Participants in the LE group received 7 days of the LE[26] by experienced LE therapists. The therapists informed the patients to keep calm and adjust their breathing through abdominal breathing. The patients gently stretched their limbs to warm up and carried out LE. The therapists guided the patients to perform 6 different exhalation tones ("Xu," "He," "Hu," "Si," "Chui," and "Xi"), exhale first through the mouth and then inhale through the nose, correct the mouth shape, and adjust the position of the lips and tongue if necessary. The patients cooperated with the related physical activities during breathing. Finally, the patients adjusted breathing and relaxed bodies. The training intensity was 11–13 points of Borg score. Each participant was trained once a day for 30 min.

The patients in the CRT group received conventional respiratory training. Patients were instructed to relax bodies and use abdominal muscles for breathing. The therapists placed pillows on both sides of the patients' popliteal fossa to relax abdominal muscles. Patients were guided to perform deep breathing exercises, in which they placed their dominant hand on their abdomen to feel whether the abdomen expanded during inhalation and flattened during exhalation. Patients were instructed on how to establish correct abdominal breathing. Patients were instructed to breathe with their lips contracted, inhale gently through mouths, and exhale slowly through nostrils. The ratio of inhalation to exhalation was 1: 2–4, and the residual volume was eliminated. The therapists guided patients during cough training. In cough training, they instructed the patients to put one hand on the lower chest gently, lean forward slightly, take a deep breath, and cough as much as possible. Patients were instructed to feel the movement and pressure of their diaphragm to control the expiratory airflow better. Training intensity was maintained at a Borg score of 11–13 points. Patients trained 30 min a day for 7 days.

The patients in the control group were not assigned any specific respiratory training and were required to perform general physical activities and maintain their original lifestyle during the 7-day intervention period.

Outcome Assessment

The primary outcomes were improvements in pulmonary function and respiratory muscle strength. The secondary outcomes involved evaluations of abilities in performing ADL and their anxiety levels.[27] All outcomes were assessed by experienced therapists at the Cardiothoracic Surgery Department of Nanjing Drum Tower Hospital before intervention, after 3 and 7 days of intervention. The LOS and adverse events were also recorded as secondary results of this study.

Evaluation of Pulmonary Function and Respiratory Muscle Strength

The forced vital capacity (FVC), the forced expiratory volume in 1 s (FEV1), the peak inspiratory flow rate (PIF), and the peak expiratory flow rate (PEF), as well as the respiratory muscle strength indexes of the maximum inspiratory pressure (MIP) and the maximum expiratory pressure (MEP), of the 3 groups were assessed by a portable lung function detector named XEEK-X1 (Saike Medical Equipment Co., Ltd., China). During the evaluation, patients were seated and were instructed to relax bodies, followed by successive inhalations and exhalations (repeated thrice) through mouths. The highest readings were documented.

ADL

The modified Barthel Index (MBI) was used to evaluate the ADL ability,[28] which has a total score of 100: the score ⩽10 points, entirely dependent; 11–30, severely dependent; 31–45, moderately dependent; 46–49, lightly dependent; and ⩾50, completely independent. The higher the total score, the stronger the ADL ability.

Anxiety

Anxiety assessment was determined by Hamilton Rating Scale for Anxiety (HAM-A) using 14 items[29] with a total score of 30 points. Each item was evaluated on a scale of 0–4 points. A total score of ⩽17 was classified as mild anxiety,18–24 was classified as mild-to-moderate anxiety, while a total score of 25–30 was classified as moderate-to-severe anxiety.

Adverse Events

Adverse events related to postoperative intervention refer to severe chest distress, palpitation, shortness of breath, arrhythmia, syncope, coma, and other symptoms. In addition, serious adverse events, such as disability and even death, which occurred during or within 1 h after training, were also considered to be associated with postoperative interventions. Other adverse events were defined as medical events unrelated to this study. During the study, all adverse events were strictly recorded.

Sample Size

This study is an exploratory article. Based on the previous literature on the calculation of the minimum sample size of the pilot trial,[30] an α level of 0.10, 90% powered and 80% upper confidence limit were used, and the minimum sample size of participants was determined to be 106 cases. In this study, 134 patients were included.

Trial Quality Control

In this study, therapists in charge of training were trained in advance to ensure the unity and standardization of training movements. All researchers have received good clinical practice training, and have clinical professional knowledge, qualifications and appropriate research capabilities. Except the evaluators and statistical analysts, the rest of the researchers fully understood the purpose of clinical research, including plans, indicators and case report form (CRF), and obtained a "Handbook for Researchers" as a reference guide.

This study was carried out in strict accordance with the test plan. At baseline, after 3 and 7 days of intervention, all the indicators were evaluated by the researchers in charge, and the data were recorded in CRF, and then uniformly input into excel spreadsheet.

Statistical Analysis

All analyses were intention-to-treat and performed using IBM SPSS version 25.0 (USA). Missing data were interpolated using multiple interpolation procedure in SPSS and predictive mean matching method (n=20 imputations). In multiple interpolation, the prediction factors include FVC, FEV1, PIF, PEF, MIP, MEP, MBI and HAM-A. The distribution of missing values in this study is shown in Figure 1.

Absolute numbers and percentages described

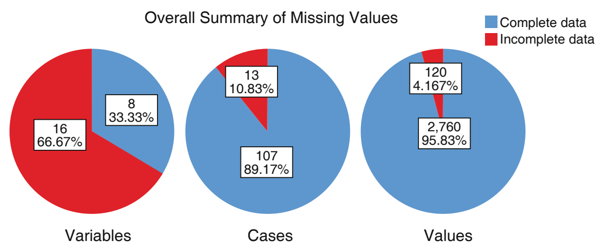

Figure 1. Distribution of Missing Values

categorical variables and grade data. The significance of the difference between categorical variables was analyzed using Chi-square test or Fisher exact probability test and that of the difference in grade data was analyzed using Kruskal-Wallis rank sum test. The Kolmogorov-Smirnov test was used to test the normality of continuous variables, data for which were presented as mean ± standard deviation ($\bar{x} \pm s$) or median (interquartile range) [M (IQR)]. One-way ANOVA or nonparametric Kruskal-Wallis ANOVA test (which does not conform to normal distribution) was used to compare intergroup differences. Paired *t*-test was used to analyze intragroup differences. Two-sided test criteria was used in the present study. Statistical significance was accepted at $P<0.05$. The line chart of the changes of 3 groups of indicators were drawn using GraphPad Prism 9.3.0 (GraphPad Software, USA).

RESULTS

Participants Enrollment, Completion Rate of Intervention

A total of 134 patients were included in the study, and 14 were excluded. Of the 120 patients initially randomized, 13 dropped out of the study, including 3 in the control group (7.5%), 6 in the CRT group (15.0%), and 4 in the LE group (10.0%). There was no significant difference in the dropout rates among the groups ($P>0.05$). A total of 107 participants completed the 7-day plan and were analyzed (Figure 2).

Baseline Characteristics of Patients after Cardiac Surgery

Table 1 shows the baseline characteristics of patients. No significant differences were observed among the 3 groups in age, gender, pulmonary function, respiratory muscle strength, MBI, and HAM-A scores before intervention ($P>0.05$).

Comparison on Pulmonary Function of Patients after Cardiac Surgery

After 3 days of intervention, the pulmonary function of all 3 groups improved compared with that before the intervention ($P<0.05$ or $P<0.01$). Compared with the control group, pulmonary function was significantly improved in CRT and LE groups ($P<0.05$ or $P<0.01$). There was insignificant difference between the CRT and the LE group ($P>0.05$). At day 7 post-intervention, there was a significant difference compared to day 3 ($P<0.05$ or $P<0.01$). In addition, pulmonary function in the LE group was significantly improved after 7 days compared with that in the CRT group ($P<0.01$, Figure 3).

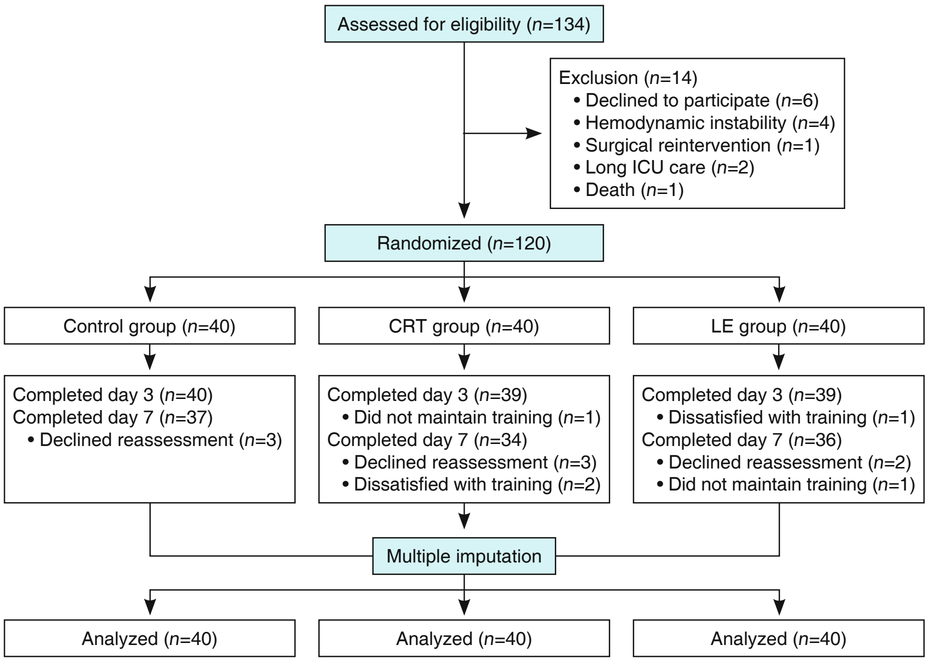

Figure 2. Flow Diagram of Study on Liuzijue Exercise in Patients after Cardiac Surgery

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Table 1. Baseline Characteristics of Participants among Various Groups [Case (%)]

Variable	Control group (40 cases)	CRT group (40 cases)	LE group (40 cases)	*P*
Age (Year, $\bar{x}\pm s$)	56.85±12.56	55.02±14.40	55.09±13.44	0.790
Gender				0.866
Male	26 (65.0)	26 (65.0)	24 (60.0)	
Female	14 (35.0)	14 (35.0)	16 (40.0)	
Body mass index (kg/m^2, $\bar{x}\pm s$)	23.34±3.77	22.57±3.75	23.30±3.49	0.578
History of smoking [Year, M (IQR)]	15.00 (0.00–26.75)	12.00 (0.00–30.00)	11.00 (0.00–26.75)	0.993
Comorbidities				0.991
Pulmonary hypertension	15 (37.5)	12 (30.0)	13 (32.5)	
Hypertension	15 (37.5)	15 (37.5)	14 (35.0)	
Diabetes	8 (20.0)	7 (17.5)	6 (15.0)	
Surgical type				1.000
Valve repair	20 (50.0)	23 (57.5)	20 (50.0)	
Valve replacement	11 (27.5)	15 (37.5)	11 (27.5)	
Aortic replacement	14 (35.0)	14 (35.0)	11 (27.5)	
CABG	12 (30.0)	12 (30.0)	12 (30.0)	
RFA	7 (17.5)	8 (20.0)	8 (20.0)	
AVSD repair	6 (15.0)	8 (20.0)	8 (20.0)	
Operation duration (h, $\bar{x}\pm s$)	4.87±1.39	4.73±1.57	4.67±1.82	0.849
CPB time [min, M (IQR)]	103.0 (66.5–162.8)	124.5 (78.0–155.5)	113.0 (46.0–161.0)	0.910
Aortic cross-clamp time [min, M (IQR)]	70.5 (0.0–99.5)	70.5 (8.5–102.0)	61.0 (28.0–84.8)	0.767
NYHA				0.984
Class Ⅰ	6 (15.0)	6 (15.0)	7 (17.5)	
Class Ⅱ	12 (30.0)	13 (32.5)	11 (27.5)	
Class Ⅲ	22 (55.0)	21 (52.5)	22 (55.0)	
Pleural effusion				0.905
Yes	20 (50.0)	18 (45.0)	19 (47.5)	
No	20 (50.0)	22 (55.0)	21 (52.5)	
Atelectasis				0.258
Yes	8 (20.0)	7 (17.5)	10 (25.0)	
No	32 (80.0)	33 (82.5)	20 (50.0)	
Mechanical ventilation time [h, M (IQR)]	6.31 (4.50–13.25)	6.81 (4.89–13.07)	5.82 (4.18–12.72)	0.513
Start time of postoperative intervention [day, M (IQR)]	2.0 (1.0–3.0)	2.0 (1.0–3.0)	2.0 (1.0–2.7)	0.828

Notes: CABG: coronary artery bypass graft; RFA: radiofrequency ablation; AVSD: atrioventricular septal defect; CPB: cardiopulmonary bypass; NYHA: New York Heart Association; M (IQR): median (interquartile range)

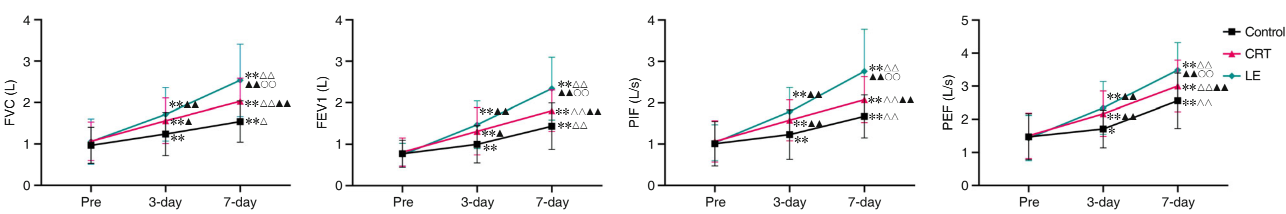

Figure 3. Evaluation of Pulmonary Function in Patients after Cardiac Surgery ($\bar{x}\pm s$, *n*=40)

Notes: $^{*}P$<0.05, $^{**}P$<0.01, compared with pre-intervention in the same group; $^{\triangle}P$<0.05, $^{\triangle\triangle}P$<0.01, compared with 3-day after intervention in the same group; $^{\blacktriangle}P$<0.05, $^{\blacktriangle\blacktriangle}P$<0.01, compared with the control group; $^{\circ}P$<0.05, $^{\circ\circ}P$<0.01, compared with CRT group; the same below; FVC: forced vital capacity; FEV1: forced expiratory volume in 1 s; PIF: peak inspiratory flow rate; PEF: peak expiratory flow rate

Comparison of Respiratory Muscle Strength of Patients after Cardiac Surgery

After 3 days of intervention, the respiratory muscle strength of all 3 groups improved compared with that before the intervention (*P*<0.01). Compared with the control group, respiratory muscle strength was significantly improved in CRT and LE groups (*P*<0.05 or *P*<0.01). There was no significant difference between the CRT group and the LE group (*P*>0.05). At day 7 post-intervention, these significant differences were still significant (*P*<0.01), and a significant difference compared with the 3rd day (*P*<0.01). In addition, respiratory muscle strength in the LE group was significantly improved after 7 days compared with that in the CRT group (*P*<0.01, Figure 4).

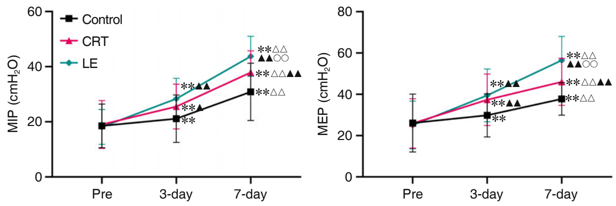

Figure 4. Evaluation of Respiratory Muscle Strength in Patients after Cardiac Surgery ($\bar{x} \pm s$, *n*=40)

Notes: MIP: maximal inspiratory pressure; MEP: maximum expiratory pressure

Comparison of MBI and HAM-A of Patients after Cardiac Surgery

After 3 days of intervention, the MBI of all groups improved compared with that before intervention (*P*<0.01). Compared with the control and the CRT groups, MBI was significantly improved in LE group (*P*<0.01). There was no significant difference between the control and the CRT groups (*P*>0.05). At day 7 post-intervention, these indice were even better compared to day 3 (*P*<0.01). In addition, MBI in the CRT group was significantly improved after 7 days compared with that in the control group (*P*<0.01, Figure 5).

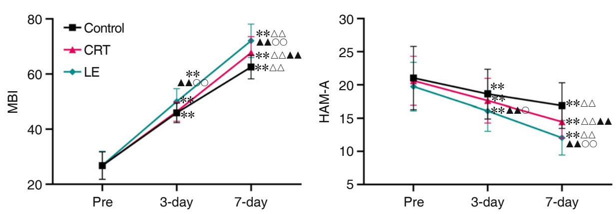

Figure 5. Evaluation of MBI and HAM-A in Patients after Cardiac Surgery ($\bar{x} \pm s$, *n*=40)

Notes: MBI: modified Barthel Index; HAM-A: Hamilton Rating Scale for Anxiety

After 3 days of intervention, the HAM-A of all three groups decreased compared with that before intervention (*P*<0.01). Compared with the control and the CRT groups, HAM-A was significantly decreased in LE group (*P*<0.05 or *P*<0.01). There was no significant difference between the control and the CRT group (*P*>0.05). At day 7 post-intervention, these significant differences were still exist (*P*<0.01) and a significant difference compared to day 3 (*P*<0.01). In addition, HAM-A in the CRT group was significantly decreased after 7 days compared with that in the control group (*P*<0.01, Figure 5).

Comparison of Postoperative LOS

Patients in the control, CRT and LE groups had median postoperative LOS of 9.0 (8.0–13.0) days, 10.0 (8.0–12.0) days, and 9.0 (8.0–12.8) days, respectively. There were no significant differences in postoperative LOS among the 3 groups (*P*=0.438).

Adverse Events

During the study period, there were no adverse events related to the study in all groups.

DISCUSSION

This is a study to examine the feasibility of a 3-arm RCT comparing the effects of LE, CRT, and conventional treatment on the rehabilitation of patients after cardiac surgery. The results revealed that postoperative LE was significantly more effective than CRT in increasing pulmonary function, respiratory muscle strength, and ADL and in alleviating anxiety. However, there was no difference in the postoperative LOS among the 3 groups. In addition, no serious adverse events occurred during this study.

The findings demonstrate that LE can enhance the lung function of patients after cardiac surgery. Decreased lung function is a common symptom in patients after cardiac surgery.[31] It typically manifests as limited lung capacity, impaired ventilation mechanics, decreased lung compliance, and increased respiratory effort.[32] This leads to an increased risk of PPCs. LE, an auxiliary therapy, is a traditional exercise therapy that combines respiratory training with low-intensity aerobic training.[33] The previous systematic review has confirmed that it can improve the pulmonary function of patients.[34] The results of this study are consistent with the previous conclusions.

LE is carried out under the guidance of the holistic view of Chinese medicine. It pays attention to local and systemic adjustment, integrates lip-contraction breathing and abdominal breathing,[35] carries out respiratory training around 6-character pronunciation, assists chest and abdomen respiratory movement, strengthens small airway pressure. In addition, it can prevent premature airway obstruction caused by excessive air flow, prolong exhalation time, and promote the discharge of residual air from the lungs. At the same time, it mobilizes the intercostal muscles, rectus abdominis, pectoralis major, and other respiratory muscles. These muscle groups deepen the depth of breathing, improve lung ventilation, increase the efficiency of lung gas exchange, and improve the abnormal breathing pattern of patients. These improvements are beneficial in improving lung function of patients.(36) In addition, LE can reduce the inflammatory reaction by lowering the levels of interleukin (IL)-4, IL-13, and IL-17 and increasing that of IL-10.(37) As a traditional exercise method to effectively improve lung function in China, the training is necessary to be applied and popularized in patients after cardiac surgery.

This study used MIP and MEP to evaluate respiratory muscle strength effectively.(38) The results showed that the respiratory muscle strength of LE group patients was significantly improved after intervention. Zheng, et al(39) research showed that 3 weeks' LE can improve the mean MIP, and MEP of patients in the early recovery stage of stroke by 31.22% and 45.77% respectively. This study showed that the 3-day training can increase the patients' mean MIP and MEP by 54.99% and 56.90%, and this effect is obvious. The reason may be that as a low-load and slow-speed breathing training, it is more likely to activate the main respiratory muscle group composed of slow-contracting fibers. Therefore, it is less likely to cause fatigue than breathing muscle training alone.(18) Training, through repeated inhalation and exhalation training, makes the diaphragm contract and move downward when inhaling and relax and move upward when exhaling, which increases the range of motion of the diaphragm.(40) In addition, it adopts reverse abdominal breathing and combines the coordinated movement of upper and lower limbs, which further effectively exercises the diaphragm and respiratory muscles.(41) This kind of exercise can improve chest shape—a function of accessory respiratory muscles and fatigue of diaphragm electromyography—and can increase the ratio of type Ⅰ and type Ⅱ fibers in external intercostal muscles.(42,43)

In the current study, the MBI score of patients in the LE group was higher than that in CRT group. This finding is similar to that reported by a previous study by Zhang et al,(44) which revealed that LE could improve the ADL ability of stroke patients. This study provided evidence about the effectiveness of LE on the ADL ability of patients after cardiac surgery. The possible reasons have been analyzed as follows. Thoracotomy in cardiac surgery destroys the integrity of the chest, reduces the degree of postoperative lung expansion, and makes the individual prone to restrictive ventilation disorder, which affects ADL ability. At the same time, postoperative hypermetabolism tends to reduce the muscle strength of patients, which would reduce ADL ability. Studies have shown that even at a low intensity, exercise capacity can be improved by aerobic exercise, including LE.(45) When practicing LE, the upper and lower limbs of patient are coordinated with each other during respiratory training, which not only helps to assist the function of respiratory muscles but also exercises the muscles and joints of the whole body. At the same time, it also enhances the flexibility and the coordination, controls ability of neuromuscular muscles in limbs, and improves the patients' exercise ability, which helps to increase ADL ability.(46) In addition, compared with CRT, LE for soft, even, and slow breathing patterns is more conducive to activating deep core muscles and further improving ADL ability.(47) Moreover, as a self-healing and functional integration aerobic exercise,(48) it can effectively improve VO_2 compared with routine breathing training, owing to which exercise and ADL ability improve.(49)

The results showed that the effect of LE was more significant than that of CRT in alleviating anxiety of patients. Patients admitted to ICU after cardiac surgery are generally exposed to anxiety stressors, such as noise, insomnia, mechanical ventilation, and being bedridden,(50) which makes patients feel nervous and anxious. CRT can adjust breathing rhythm, relax mood, and alleviate anxiety. However, as a traditional health-care exercise in China that can regulate negative emotions. LE emphasizes the importance of calming the mind, regulating breathing, and incorporating gentle physical exercises in the exercise process to reduce panic and anxiety.(51,52) People who insist on training are more likely to stay calm and maintain a positive mood.(52) The effects of LE on relieving anxiety have been discussed in terms of psychosocial, physiological, and neurobiological mechanisms.(53)

The current study results revealed that performing LE for 7 days after cardiac surgery did not reduce the postoperative LOS of patients. These results could be related to factors, such as the large difference in the complexity of conditions of patients, the difference caused by insufficient resources or bed availability, and the short intervention time. The influence of LE on hospitalization time needs to be further explored in future research.

LE is easy to learn, not limited by training venues and training equipment, and has high compliance.[55] Once people learn this skill, they can practice it by themselves. This may be a valuable and cost-effective exercise program. In addition, this exercise involves a slow breathing rate, has no difficulty, and does not involve large amplitude, overloaded trunk and limbs movements. It does not need extra expenses. From the social point of view, considering the rising cost of medical system, it is more attractive to adopt low-cost behavior mode to promote health and prevent diseases. All of which are favorable factors for patients after cardiac surgery. During this research period, there were no adverse events related to the LE occurred, and the patient's adherence rate reached 90%. Therefore, LE may be a promising exercise choice, which can be considered as a safe and effective training method for the rehabilitation of patients after cardiac surgery.

Limitations

Although this randomized controlled trial has been earnestly implemented, the limitations should be considered. In this study, the surgical methods of the patients included in this study are complex, and the results of the study are unknown to the effect of a single surgical method. Secondly, this study did not conduct long-term follow-up to observe the curative effect and dose-effect relationship analysis. In the future research, the scope of the research object would be focused on the influence of LE in the postoperative patients with a certain kind of heart surgery with a long-term follow-up to observe the long-term effect. In addition, in the future, the effects of different LE schemes in patients after cardiac surgery can be compared to explore the best LE program.

Conclusions

The current experimental results of this feasibility show that both LE and CRT increase lung function and respiratory muscle strength, improve the ADL and relieve anxiety in patients after cardiac surgery. It is worth noting that LE showed better effects, especially after 7 days of training. Further research with large sample size is needed to verify the efficacy of this intervention method and clarify its potential mechanism. In addition, the findings of this study did not reveal an improvement in postoperative LOS, and thus, further research is needed in the future.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

Wang L and Zhang N were equally contributed to the conception of the manuscript; Zhang QL and Ge M were contributed to the writing and revision of the manuscript; Zhang QL, Ge M, Chen C, and Fan FD participated in the patients' recruitment and data collection; Jin Y analyzed the data; Ge M and Zhang N were contributed to review and revision of the manuscript. All authors have agreed with the content and approve of the manuscript for submission.

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REFERENCES

1. Chinese Society of Extra-Corporeal Circulation. White book of Chinese cardiovascular surgery and extracorporeal circulation in 2021. Chin J ECC (Chin) 2022;20:196-199.
2. Ramos Dos Santos PM, Aquaroni Ricci N, Aparecida Bordignon Suster É, De Moraes Paisani D, Dias Chiavegato L. Effects of early mobilisation in patients after cardiac surgery: a systematic review. Physiotherapy 2017;103:1-12.
3. Westerdahl E, Jonsson M, Emtner M. Pulmonary function and health-related quality of life 1-year follow up after cardiac surgery. J Cardiothorac Surg 2016;11:99.
4. Mathis MR, Duggal NM, Likosky DS, Haft JW, Douville NJ, Vaughn MT, et al. Intraoperative mechanical ventilation and postoperative pulmonary complications after cardiac surgery. Anesthesiology 2019;131:1046-1062.
5. Tanner TG, Colvin MO. Pulmonary complications of cardiac Surgery. Lung 2020;198:889-896.
6. Zhang MQ, Liao YQ, Yu H, et al. Effect of ventilation strategy during cardiopulmonary bypass on postoperative pulmonary complications after cardiac surgery: a randomized clinical trial. J Cardiothorac Surg 2021;16:319.
7. Dsouza FV, Amaravadi SK, Samuel SR, et al. Effectiveness of inspiratory muscle training on respiratory muscle strength in patients undergoing cardiac surgeries: a systematic review with meta-analysis. Ann Rehabil Med 2021;45:264-273.
8. Mali S, Haghaninejad H. Pulmonary complications

following cardiac surgery. Arch Med Sci Atheroscler Dis 2019;4:e280-e285.

9. Lee MJ, Tannenbaum C, Mao G, et al. Effect of 6% hydroxyethyl starch 130/0.4 on inflammatory response and pulmonary function in patients having cardiac surgery: a randomized clinical trial. Anesth Analg 2021;133:906-914.
10. Shahood H, Pakai A, Rudolf K, et al. The effect of preoperative chest physiotherapy on oxygenation and lung function in cardiac surgery patients: a randomized controlled study. Ann Saudi Med 2022;42:8-16.
11. Lehmkuhl E, Kendel F, Gelbrich G, et al. Gender-specific predictors of early mortality after coronary artery bypass graft surgery. Clin Res Cardiol 2012;101:745-51.
12. Ge X, Wang W, Hou L, et al. Inspiratory muscle training is associated with decreased postoperative pulmonary complications: evidence from randomized trials. J Thorac Cardiovasc Surg 2018;156:1290-1300.e5.
13. Wu MF, Wang TY, Chen DS, et al. The effects of mechanical insufflation-exsufflation on lung function and complications in cardiac surgery patients: a pilot study. J Cardiothorac Surg 2021;16:350.
14. Sato M, Mutai H, Yamamoto S, et al. Decreased activities of daily living at discharge predict mortality and readmission in elderly patients after cardiac and aortic surgery: a retrospective cohort study. Medicine (Baltimore) 2021;100:e26819.
15. Açıkel MET. Evaluation of depression and anxiety in coronary artery bypass surgery patients: a prospective clinical study. Braz J Cardiovasc Surg 2019;34:389-395.
16. Protogerou C, Fleeman N, Dwan K, et al. Moderators of the effect of psychological interventions on depression and anxiety in cardiac surgery patients: a systematic review and meta-analysis. Behav Res Ther 2015;73:151-164.
17. Rodrigues SN, Henriques HR, Henriques MA. Effectiveness of preoperative breathing exercise interventions in patients undergoing cardiac surgery: a systematic review. Rev Port Cardiol 2021;40:229-244.
18. Wang J, Li G, Ding S, et al. Liuzijue qigong versus traditional breathing training for patients with post-stroke dysarthria complicated by abnormal respiratory control: results of a single-center randomized controlled trial. Clin Rehabil 2021;35:999-1010.
19. Gao Y, Yu L, Li X, et al. The effect of different traditional Chinese exercises on blood lipid in middle-aged and elderly individuals: a systematic review and network meta-analysis. Life (Basel) 2021;11:714.
20. Wu W, Liu X, Li P, et al. Effect of Liuzijue exercise combined with elastic band resistance exercise on patients with COPD: a randomized controlled trial. Evid Based Complement Alternat Med 2018;2018:2361962.
21. Li H, Li G, Liu G, et al. Liuzijue Qigong *vs.* traditional breathing training for patients with post-stroke dysarthria complicated with abnormal respiratory control: study protocol of a single center randomized controlled trial. Trials 2018;19:335.
22. Su K, Yuan J, Liu H, et al. The comparative effectiveness of traditional Chinese medicine exercise therapies in elderly people with mild cognitive impairment: a systematic review and network meta-analysis. Front Neurol 2022;13:775190.
23. Xu S, Zhang D, He Q, et al. Efficacy of Liuzijue Qigong in patients with chronic obstructive pulmonary disease: a systematic review and meta-analysis. Complement Ther Med 2022;65:102809.
24. Gao P, Tang F, Liu W, et al. Effect of Liuzijue Qigong on patients with stable chronic obstructive pulmonary disease: a systematic review and meta-analysis. Medicine (Baltimore) 2021;100:e27344.
25. Wu W, Liu X, Liu J, et al. Effectiveness of water-based Liuzijue exercise on respiratory muscle strength and peripheral skeletal muscle function in patients with COPD. Int J Chron Obstruct Pulmon Dis 2018;13:1713-1726.
26. Bok D, Rakovac M, Foster C. An examination and critique of subjective methods to determine exercise intensity: the talk test, feeling scale, and rating of perceived exertion. Sports Med 2022;52:2085-2109.
27. Ma LT. The authentic health Qigong. Beijing: Beijing People's Sports Publishing House 1993:26-68.
28. Shah S, Vanclay F, Cooper B. Improving the sensitivity of the Barthel Index for stroke rehabilitation. J Clin Epidemiol 1989;42:703-709.
29. Al Namat R, Al Namat D, Ciocoiu M, et al. H-FABP levels and psycho-emotional improvement of CABG patients during cardiac rehabilitation. J Cardiovasc Dev Dis 2022;9:242.
30. Whitehead AL, Julious SA, Cooper CL, et al. Estimating the sample size for a pilot randomised trial to minimise the overall trial sample size for the external pilot and main trial for a continuous outcome variable. Stat Methods Med Res 2016;25:1057-1073.
31. Hegazy FA, Mohamed Kamel SM, Abdelhamid AS, et al. Effect of postoperative high load long duration inspiratory muscle training on pulmonary function and functional capacity after mitral valve replacement surgery: a randomized controlled trial with follow-up. PLoS One 2021;16:e0256609.
32. Kendall F, Oliveira J, Peleteiro B, et al. Inspiratory muscle training is effective to reduce postoperative pulmonary complications and length of hospital stay: a systematic review and meta-analysis. Disabil Rehabil 2018;40:864-882.
33. Xiao CM, Zhuang YC. Efficacy of Liuzijue Qigong in individuals with chronic obstructive pulmonary disease in remission. J Am Geriatr Soc 2015;63:1420-1425.
34. Xiao L, Duan H, Li P, et al. A systematic review and meta-analysis of Liuzijue in stable patients with chronic obstructive

pulmonary disease. BMC Complement Med Ther 2020;20:308.
35. Singh D, Agusti A, Anzueto A, Barnes PJ, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive lung disease: the GOLD science committee report 2019. Eur Respir J 2019;53:1900164.
36. Li P, Liu J, Lu Y, et al. Effects of long-term home-based Liuzijue exercise combined with clinical guidance in elderly patients with chronic obstructive pulmonary disease. Clin Interv Aging 2018;13:1391-1399.
37. Chen XB, Li ZJ, Cai Y. Effect of six-word breath exercise on the inflammatory immune factors and pathogen distribution in asthma patients. Chin J Nosocomiol (Chin) 2019;29:2280-2284.
38. Lee K, Cho JE, Hwang DY, et al. Decreased respiratory muscle function is associated with impaired trunk balance among chronic stroke patients: a cross-sectional study. Tohoku J Exp Med 2018;245:79-88.
39. Zheng Y, Zhang Y, Li H, et al. Comparative Effect of Liuzijue Qigong and conventional respiratory training on trunk control ability and respiratory muscle function in patients at an early recovery stage from stroke: a randomized controlled trial. Arch Phys Med Rehabil 2021;102:423-430.
40. Emerich Gordon K, Reed O. The role of the pelvic floor in respiration: a multidisciplinary literature review. J Voice 2020;34:243-249.
41. Yi J, Wang F, Yue R, et al. Effect of sitting and lying Liuzijue for lung rehabilitation in acute exacerbation of chronic obstructive pulmonary disease patients with non-invasive ventilation: study protocol for a randomized controlled trial. Medicine (Baltimore) 2020;99:e22111.
42. Ramirez-Sarmiento A, Orozco-Levi M, Guell R, et al. Inspiratory muscle training in patients with chronic obstructive pulmonary disease: structural adaptation and physiologic outcomes. Am J Respir Crit Care Med 2002;166:1491-1497.
43. Charususin N, Dacha S, Gosselink R, et al. Respiratory muscle function and exercise limitation in patients with chronic obstructive pulmonary disease: a review. Expert Rev Respir Med 2018;12:67-79.
44. Zhang Y, Wang C, Yang J, et al. Comparing the effects of short-term Liuzijue exercise and core stability training on balance function in patients recovering from stroke: a pilot randomized controlled trial. Front Neurol 2022;13:748754.
45. Qingguang Z, Shuaipan Z, Jingxian LI, et al. Effectiveness of Liu-zi-jue exercise on coronavirus disease 2019 in the patients: a randomized controlled trial. J Tradit Chin Med 2022;42:997-10053.
46. Kong L, Ren J, Fang S, et al. Traditional Chinese exercises on pain and disability in middle-aged and elderly patients with neck pain: a systematic review and meta-analysis of randomized controlled trials. Front Aging Neurosci 2022;14:912945.
47. Speyer R, Bogaardt HC, Passos VL, et al. Maximum phonation time: variability and reliability. J Voice 2010;24:281-284.
48. Liu X, Li P, Xiao L, et al. Effects of home-based prescribed pulmonary exercise by patients with chronic obstructive pulmonary disease: study protocol for a randomized controlled trial. Trials 2019;20:41.
49. Turquetto ALR, Dos Santos MR, Agostinho DR, et al. Aerobic exercise and inspiratory muscle training increase functional capacity in patients with univentricular physiology after fontan operation: a randomized controlled trial. Int J Cardiol 2021;330:50-58.
50. Kakar E, Billar RJ, van Rosmalen J, et al, Takkenberg JJM, Jeekel J. Music intervention to relieve anxiety and pain in adults undergoing cardiac surgery: a systematic review and meta-analysis. Open Heart 2021;8:e001474.
51. Guo Y, Xu M, Ji M, et al. Effect of Liuzijue Qigong on patients with chronic obstructive pulmonary disease: protocol for a systematic review and meta-analysis. Medicine (Baltimore) 2018;97:e12659.
52. Tang Y, Jiang J, Shen P, et al. Liuzijue is a promising exercise option for rehabilitating discharged COVID-19 patients. Medicine (Baltimore) 2021;100:e24564.
53. Tang J, Huang W, Chen X, et al. Liuzijue Qigong: a voice training method for unilateral vocal fold paralysis patients. Ann Otol Rhinol Laryngol 2019;128:654-661.
54. Chan SHW, Tsang HWH. The beneficial effects of Qigong on elderly depression. Int Rev Neurobiol 2019;147:155-188.
55. Li C, Zheng D, Luo J. Effects of traditional Chinese exercise on patients with cognitive impairment: a systematic review and bayesian network meta-analysis. Nurs Open 2021;8:2208-2220.

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