Prospective Clinical Research Report

Journal of INTERNATIONAL MEDICAL RESEARCH

Journal of International Medical Research
50(7) 1–13

DOI: 10.1177/03000605211044320
journals.sagepub.com/home/imr
SAGE

Effectiveness of early cardiac rehabilitation in patients with heart valve surgery: a randomized, controlled trial

Wei Xue, Zhang Xinlan and Zheng Xiaoyan

Abstract

Objective: Complications of heart valve surgery lead to physical inactivity and produce harmful effects. This study aimed to investigate the role of a cardiac rehabilitation program and its long-term effect in patients after heart valve surgery.

Methods: We performed a single-blind, randomized, controlled trial. Patients with heart valve surgery were randomly assigned to receive early cardiac rehabilitation (intervention group, 44 patients) or the usual care (control group, 43 patients). The intervention group performed sitting, standing, and walking exercises, followed by endurance training. The control group received usual care and did not engage in any physical activity. Physical function was assessed by the Short Physical Performance Battery (SPPB) and other measurement tools.

Results: The intervention group showed a significant beneficial effect regarding physical capacity as shown by the SPPB and the 6-minute walking test at hospital discharge, and a better long-term effect was achieved at 6 months compared with the control group. An improvement in physical function (e.g., the SPPB) after hospital discharge predicted follow-up mortality (odds ratio = 0.416, 95% confidence interval: 0.218–0.792).

Conclusion: Early cardiac rehabilitation appears to be an effective approach to improve the physical function and survival of patients with heart valve surgery.

Keywords

Coronary artery disease, heart valve surgery, early cardiac rehabilitation, physical function, mental health, short physical performance battery, exercise

Date received: 5 January 2021; accepted: 17 August 2021

Department of Cardiovascular Surgery, The First Affiliated Hospital of Anhui Medical University, Hefei, Anhui, China

Corresponding author:
Zheng Xiaoyan, Department of Cardiovascular Surgery, The First Affiliated Hospital of Anhui Medical University, 120 Wanshui Road, High-tech Zone, Hefei City, Anhui Province, 230000, China.
Email: 3530175086@qq.com

The trial was retrospectively registered in the ISCTRN database (reference number: ISRCTN54158701).

Introduction

Valvular heart disease is a major and growing public health issue accompanied by population aging and a lengthy life expectancy in developing countries. Heart valve surgery is a well-established procedure worldwide with excellent cardiovascular benefits, quality of life, and mortality rates.[1] However, patients who have heart valve surgery often experience complications in the postoperative period because of the complexity of the procedure, including low cardiac output syndrome, postoperative bleeding, infection, and difficulty in glycemic control.[2,3]

Complications in the postoperative period of heart valve treatment increase sedation and bed rest,[4] leading to an extended period of physical inactivity and muscle weakness.[5] The harmful effects of physical inactivity involve reduced muscle protein synthesis, increased proteolysis, and loss of muscle strength and lean mass.[6–8] These issues prevent patients from fully returning to a normal functional ability[8] and increasing the risk of readmission and mortality.[9,10]

The importance of adequate physical activity has been stressed by clinical guidelines.[11] Physical activity and exercise-based cardiac rehabilitation are thought to increase cardiorespiratory fitness and reduce long-term cardiac mortality and short-term hospitalization in patients with coronary heart disease.[12–14] Additionally, physical exercise is associated with reduced respiratory complications, decreased loss of muscle strength, and a decline in hospital readmission rates in patients with coronary heart disease.[15–17] Therefore, exercise-based cardiac rehabilitation is recommended after heart valve surgery to increase physical capacity and improve clinical outcomes.

Maintaining adequate physical activity for patients who have heart valve surgical treatment may be challenging and causes safety issues outside the hospital. Therefore, exercise-based cardiac rehabilitation should be considered in these patients. Recently, early cardiac rehabilitation was applied to patients with cardiac surgery in the in-hospital setting,[18] and it decreased the duration of the hospital stay and medical costs after cardiac surgery.[19,20] However, the role of early cardiac rehabilitation on physical and psychological functions and its long-term effects on patients who have heart valve surgery have not been fully determined.

This study aimed to investigate the role of early cardiac rehabilitation in physical and psychological function and its long-term effects in patients with heart valve surgery. Early cardiac rehabilitation was performed in the hospital setting on the day after the operation.

Methods

Participants

The was a prospective study that was performed in a hospital setting. The sample size was calculated by the difference between two independent means (two groups) using G*Power software (version 3.1.9.7; Heinrich-Heine-University, Düsseldorf, Germany),[21] using the following parameters: alpha $=$ 0.05, power $(1-\beta)=0.80$, and effect size $=0.7$. The sample size was determined to be 37 patients or more in each group. Considering a possible dropout of 10%, the final sample size was determined to be 40 patients or more in each group. Ninety-seven consecutive patients who had heart valve surgery performed were enrolled in the study between January 2018 and December 2019 (Figure 1). The inclusion

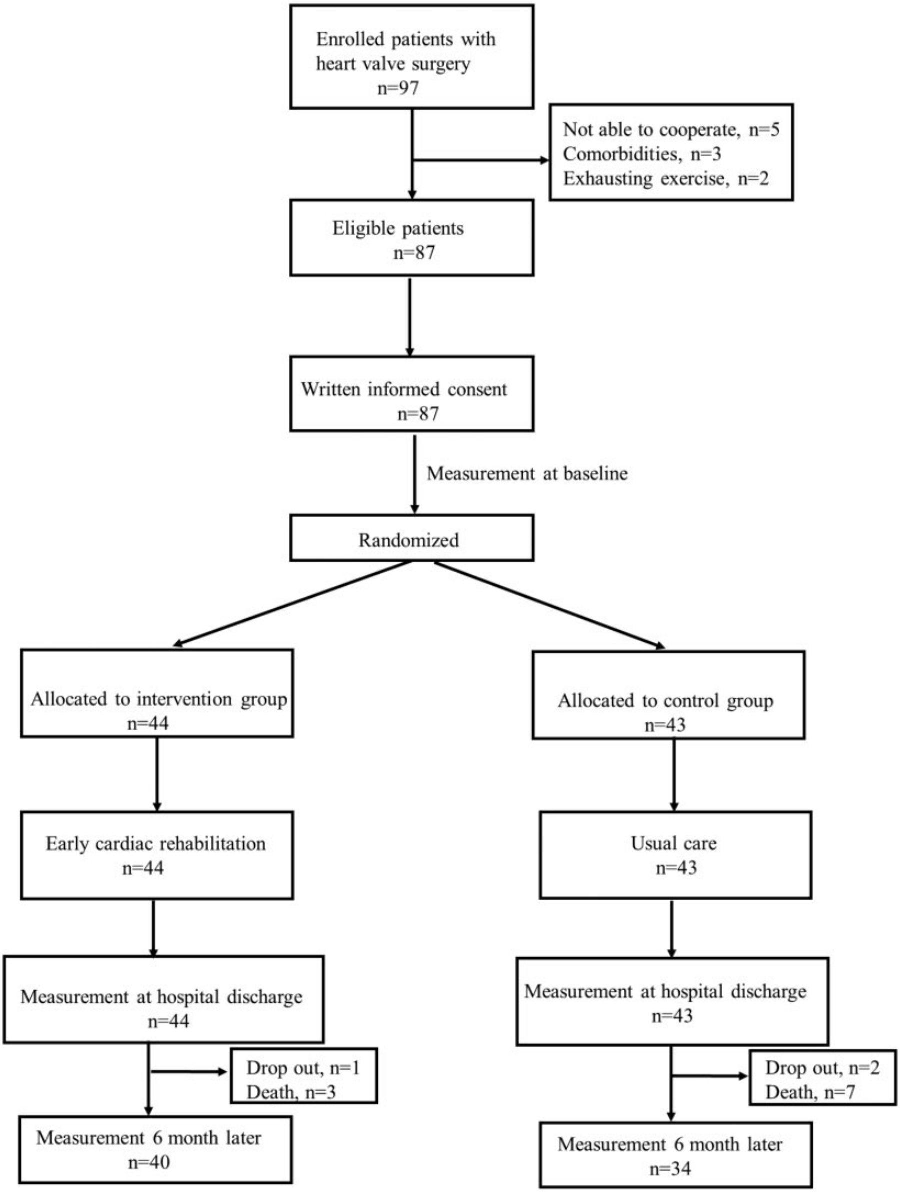

Figure 1. Flowchart showing patient selection for participation in early cardia rehabilitation.

criteria were elective left-sided or right-sided heart valve surgery, including aortic, mitral, tricuspid, and pulmonary valve replacement, >18 years old, and being able to understand and complete measurements and provide informed written consent. One experienced physician performed the assessment for eligibility. The exclusion criteria were ischemic heart disease before surgery, diseases in the musculoskeletal system, comorbidity complicating physical activity, and an expectation to not cooperate in the trial instructions. Patients who had persistent or paroxysmal atrial fibrillation diagnosed by Holter electrocardiography preoperatively were excluded from this study. Patients who underwent an emergency surgical treatment or transcatheter aortic valve implantation were also excluded. The study was approved by the Medical Ethics Committee of Anhui Medical University (Hefei City, China; January 4, 2018; approval number: AHMULS20180465) and complied with the Declaration of Helsinki. The trial was retrospectively registered in the ISCTRN database (ISRCTN54158701, http://www.isrctn.com/).

Randomization

The early cardiac rehabilitation program was conducted in a randomized, controlled trial (RCT), which followed the CONSORT statement (http://www.consort-statement.org/). Patients were grouped by simple random sampling. The randomization program was created using a computer and performed by an investigator who was not involved in the treatment and recruitment of patients. The allocation of patients was screened, and allocations were placed in numbered, sealed, opaque envelopes. On the first day of treatment after surgery, the envelope that was allocated to the patient was unfolded by the physical therapist. Patients were randomly assigned to two groups of those who received cardiac rehabilitation (intervention group) or those who received the usual care (control group). Before surgery (baseline), at hospital discharge, and after 6 months of follow-up, the physical capacity and psychological status were measured. Blinding of the participants and clinicians is usually inconceivable in a rehabilitation trial. Nonetheless, outcome assessment, data management, and statistical analyses were performed with blinding to the allocation groups.

Intervention and controls

Implementation of this study followed the StaRI statement of the Equator Network guideline (https://www.equator-network.org/). The intervention group underwent the cardiac rehabilitation program from the day following surgery in accordance with a clinical guideline for rehabilitation in patients with cardiovascular disease.[22] This rehabilitation exercise program comprised lower and upper extremity exercise in bed, sitting on the edge of the bed, standing at the bedside, and walking around the bed and for 100 m in the ward. The exercise included four sessions lasting for 4 days, three times a day, with approximately 30 minutes each time. After the rehabilitation exercise, patients continued with gait practice for up to 500 m and carried out endurance training by using a stationary bike in the rehabilitation center of the hospital. The training session took place three times a day with approximately 30 minutes each time until they were discharged from the hospital. The intensity of physical activity was limited by clinical conditions and activity tolerance, and monitored and assisted by physical therapists. The control group did not participate in any rehabilitation program and only received routine clinical care during the duration of the hospital stay.[22]

Data collection

The investigators assessed all patients on the day before surgery (baseline assessment), the day of hospital discharge, and 6 months after hospital discharge.

Primary measurement: physical function. The Short Physical Performance Battery (SPPB) was used to evaluate physical function.[23] The SPPB is a useful and well-established tool for assessing the physical ability of elderly people,.[24] The SPPB consists of a timed 4-minute walking test, a five-repetition sit-to-stand test, and a set of standing balance.[23] Each measurement was assigned a score ranging from 0 to 4. The total scores (0–12) were used to obtain an overall measurement of physical function. The SPPB is advantageous and has been widely used in the clinical setting.[25,26]

Secondary measurement: mental health. The mental health of patients was measured with a mental component summary (MCS) from the 12-item Short-Form Health Survey,[27] as recommended by a previous study.[28]

Six-minute walking test and other physical and mental measurements. We performed the 6-minute walking test (6MWT), which involved measurement of the 6-minute walking distance and is a submaximal functional test indicative of performing daily activities.[29] The safety and feasibility of this test have led to its use in cardiovascular rehabilitation.[30] The physical component summary (PCS) from the 12-item Short-Form Health Survey and the Hospital Anxiety and Depression Scale were also included as self-reported measurements.

Outcome measurements: readmission and mortality. After 6 months of hospital discharge, all-cause readmission and mortality as outcome measurements were collected from the clinical records and follow-up investigation by the research team.

Statistical analysis. The intention-to-treat analysis was recommended in the RCT.[31] For outcomes of patients who withdrew from the trial, an intention-to-treat analysis was performed using the last value (e.g., at the time point of hospital discharge) obtained for each of the outcome measures. Finally, normality was examined by the Kolmogorov–Smirnov test. Data are expressed as mean with standard deviation for continuous variables (e.g., SPPB, PCS, MCS, and 6MWT) and as the frequency and percentage for categorical variables (e.g., sex, type of valve, readmission, and mortality). Group comparisons of categorical variables were carried out with the chi-square test. Comparisons of continuous variables between the two groups were performed using the independent sample t-test and repeated analysis of variance. Age, sex, the length of hospital stay, and types of surgery were selected as confounding factors. Differences with a two-sided p value of <0.05 were considered significant. Post-hoc analysis was adjusted by Bonferroni multiple comparison correction. Logistic regression analysis was also performed to assess the predictive effects of the main measurement variables on clinical outcomes (e.g., readmission and mortality). All statistical analyses were performed using IBM SPSS version 21.0 (IBM Corp., Armonk, NY, USA).

Results

Baseline characteristics

After applying the inclusion and exclusion criteria, 87 patients were included in this study and met the sample size requirements. There were 44 patients in the intervention group and 43 in the control group. One patient in the intervention group and two in the control group dropped out after 6 months of follow-up. The patients' characteristics are shown in Table 1. The mean age of the participants in the intervention and control groups was 58.20 ± 5.27 and 57.98 ± 4.18 years, respectively. The majority of the intervention group (65.91%) and the control group (62.79%) were men. All patients had heart valve disease, but primarily had aortic valve stenosis (43%) and mitral valve regurgitation (35%). The percentages of patients in the invention and control groups who completed the trial

Table 1. Demographic and clinical characteristics of the participants.

Characteristics	Invention group (n = 44)	Control group (n = 43)	t (χ^2)	*p*
Sex, male/female	29/15	27/16	0.09	0.761
Age, years	58.20 ± 5.27	57.98 ± 4.18	0.23	0.824
BMI, kg/m^2	23.09 ± 2.23	23.28 ± 2.59	0.363	0.717
Systolic blood pressure, mm Hg	130–170	132–180	0.893	0.422
Diastolic blood pressure, mm Hg	77–100	75–100	1.235	0.121
Total cholesterol, g/L	0.046–0.011	0.047–0.011	0.764	0.413
Symptoms before surgery, n	32	31	0.07	0.948
Type of heart valve, n			0.16	0.992
Aortic valve	30	31		
Mitral valve	8	7		
Other[a]	6	5		
Hypertension	28	27	0.07	0.936
Hypercholesterolemia	19	16	0.32	0.570
Postoperative LVEF, %	51–10	52–11	0.857	0.413

Values are mean ± standard deviation, number, or range.
[a]Other includes concomitant aortic and mitral valve surgery or right-sided valves.
BMI, body mass index; LVEF, left ventricular ejection fraction.

were 90.91% and 79.07%, respectively. The demographic and clinical variables did not differ between the two groups, which suggested no evidence of baseline imbalances.

Effectiveness of early cardiac rehabilitation

Repeated analysis of variance analysis showed that SPPB scores improved over time, and the mean improvement was greater in the intervention group than in the control group (F = 9.55, $p < 0.001$). Moreover, there was a significant main effect of mean SPPB scores between the intervention and control groups (F = 5.40, $p = 0.002$, Table 2). Post-hoc comparison showed that patients in the intervention group showed a significant improvement in physical function (SPPB) at hospital discharge (mean difference = 1.07 ± 1.89, $p = 0.001$, effect size = 0.380) and after 6 months of follow-up (mean difference = 1.16 ± 2.73, $p = 0.023$, effect size = 0.323) compared with those in the control group (Table 2). The Cohen's d of the crude mean difference in physical function (SPPB) between the groups was 0.819 and 0.682 at hospital discharge and after 6 months, respectively. These values were >0.50, which indicated a moderate clinical effect and a long-term effect.

Similarly, physical outcomes, including the PCS score and 6MWT distance, showed a significant improvement in the intervention group at hospital discharge and at 6 months of follow-up compared with those at baseline (Table 2). In addition, the intervention group showed a shorter length of stay in the hospital compared with that in the control group (t = 8.30, $p < 0.001$; Table 3). However, the Hospital Anxiety and Depression Scale and MCS scores were not significantly different between the two groups at different time points (Table 2).

Effect of variables on outcomes

In regression analysis, age, sex, the type of surgery, and physical functional

Table 2. Physical function and mental health measurements between the two groups at three time points.

	Intervention group			Control group			Between-group comparison	
	Baseline (n = 44)	Hospital discharge (n = 44)	After 6 months (n = 40)	Baseline (n = 43)	Hospital discharge (n = 43)	After 6 months (n = 34)	F	*p*
SPPB	8.86 ± 1.52	10.18 ± 1.28	10.11 ± 1.70	8.74 ± 1.83	9.09 ± 1.38	8.95 ± 1.70	5.40	0.002
p	0.684	0.001	0.023	–	–	–		
PCS	40.66 ± 5.64	51.30 ± 8.84	51.16 ± 8.70	40.63 ± 5.32	45.91 ± 7.18	45.56 ± 7.38	5.51	0.002
p	0.417	0.299	0.001	–	–	–		
MCS	46.45 ± 7.04	50.16 ± 6.47	51.75 ± 8.05	47.58 ± 7.16	48.79 ± 7.19	48.14 ± 8.47	1.29	0.283
p	0.329	0.292	0.110	–	–	–		
6MWT (m)	311.52 ± 54.98	360.36 ± 60.26	415.50 ± 65.68	309.58 ± 57.44	316.56 ± 61.14	367.77 ± 54.69	7.10	<0.001
p	0.326	0.000	0.004	–	–	–		
HADS-A	5.23 ± 1.16	5.05 ± 1.29	5.16 ± 1.75	4.91 ± 1.23	5.00 ± 1.16	5.12 ± 1.61	0.59	0.624
p	0.335	0.761	0.512	–	–	–		
HADS-D	4.77 ± 1.61	4.86 ± 1.25	4.70 ± 1.13	4.93 ± 1.55	4.86 ± 1.11	4.60 ± 1.28	0.02	0.996
p	0.827	0.927	0.961	–	–	–		

Values are mean ± standard deviation.

SPPB, Short Physical Performance Battery; PCS, physical component summary; MCS, mental component summary; 6MWT, 6-minute walking test; HADS, Hospital Anxiety and Depression Scale.

Table 3. Clinical outcome measurements in the two groups.

Variables	Intervention group	Control group	t (χ^2)	*p*
Length of hospital stay (days)	6.20 ± 1.07	8.16 ± 1.13	8.30	<0.001
Readmission	5	8	0.90	0.344
Death	3	7	1.91	0.167

Values are mean ± standard deviation or number.

Table 4. Logistic regression analysis for predicting the likelihood of mortality.

							95% CI for OR	
	B	SE	Wald	df	*p*	OR	Lower	Upper
Age	0.058	0.105	0.306	1	0.580	1.060	0.862	1.303
Sex	0.513	0.780	0.433	1	0.511	1.671	0.362	7.714
Type of heart valve	−0.699	0.777	0.809	1	0.368	0.497	0.108	2.280
SPPB	−0.878	0.329	7.126	1	0.008	0.416	0.218	0.792
PCS	−0.023	0.050	0.212	1	0.645	0.977	0.886	1.078
6MWT	−0.002	0.007	0.132	1	0.716	0.998	0.984	1.011

CI, confidence interval; OR, odds ratio; SE, standard error; df, degrees of freedom; SPPB, Short Physical Performance Battery; PCS, physical component summary; 6MWT, 6-minute walking test.

measurements (SPPB, PCS, and 6MWT) after early cardiac rehabilitation were entered into the logistic model, which assessed their effects on readmission and mortality (Table 3).

A logistic model was also used to predict mortality ($\chi^2(6) = 12.62$, $p = 0.049$, Nagelkerke $R^2 = 0.265$). Among the independent variables included in the model, only the SPPB was significant predictor of mortality ($B = 0.878$, $p = 0.008$, OR = 0.416, 95% CI: 0.218–0.792; Table 4), and a higher physical function was associated with a higher survival rate in patients with heart valve surgery.

Discussion

We investigated the effectiveness of early cardiac rehabilitation on patients with heart valve surgery in the hospital setting. We found that early cardiac rehabilitation was effective in significantly increasing physical function in patients and this effect remained in the long-term. Furthermore, improved physical function was associated with a higher survival rate after heart valve surgery. These results suggest that early cardiac rehabilitation is an effective approach for improving clinical outcomes in patients with heart valve surgery.

Patients who have cardiac surgery performed are accompanied by prolonged physical inactivity associated with reduced functional capacity. Physical activity positively affects cardiorespiratory fitness and cardiovascular function.[32] Our study showed that participation in early cardiac rehabilitation improved physical capacity, including daily activity, such as an increased walking distance. This finding is similar to that in previous studies using exercise-based cardiac rehabilitation after hospital discharge.[33,34] These studies reported an improved physical performance after exercise training in patients who had heart valve surgery, regardless of the type of surgery or the preoperative risk. This finding suggests that cardiac rehabilitation is beneficial in patients with heart valve surgery for enhancing functional capacity because increased physical activity and fitness lead to additional improvement in the health status.[35]

There is a temporal relationship between exercise-based cardiac rehabilitation and the long-term physical activity level. Previous studies showed a significant increase in the physical activity level (e.g., walking distance) in patients with heart valve surgery who participated in cardiac rehabilitation compared with non-participants at 3 months to 1 year after rehabilitation.[15,36,37] Consistent with this finding, we observed a long-term effect of early cardiac rehabilitation on physical function at 6 months after hospital discharge. Several studies have shown that patients who have cardiac surgery and receive an exercise training program show significantly greater improvement in self-efficacy than those who have usual care,[38,39] which is sustained after the intervention and hospital discharge. Therefore, a possible reason for this long-term effect is that an improvement in physical function and heart rate recovery may positively affect the self-efficacy of patients. This in turn increases their confidence in physical activity, which may affect long-term functional capacity, such as walking longer distances.

In addition, high rates of hospital readmission and mortality have been reported in patients with valve surgery.[40,41] Physical activity is efficacious in decreasing mortality and readmission rates in patients with coronary heart disease.[15] The association between the physical activity level and survival in patients with heart valve surgery in the long term has been studied. These studies showed significant survival benefits after exercise-based cardiac rehabilitation.[42,43] The present study showed that early cardiac rehabilitation resulted in a long-term effect on survival in patients with heart valve surgery. Additionally, participation in early cardiac rehabilitation was associated with a significant reduction in mortality because early cardiac rehabilitation contributes to a positive recovery of physical function after the surgery and a reduced length of hospital stay. Physical function has a preventive effect on mortality because it positively affects low-density lipoprotein cholesterol levels and blood pressure regulation. Our results are in agreement with those from previous meta-analysis studies.[44–46] These previous studies reported a benefit of cardiac rehabilitation for a reduction in mortality and hospitalization rates. However, physical function did not predict hospital readmission in the present study. The reason for this lack of finding could be because hospital readmission in this study was for single cardiac events or symptoms, which may not be related to physical function. Moreover, heart failure is the reason for many readmissions in patients with heart valve surgery.[41]

It should be noted that in our study, the mental health of patients was not improved by early cardiac rehabilitation. This result is in accordance with that in a previous study[47] because no psychological intervention was performed in patients in the present study. Psychological interventions (e.g., education, discussion, and emotional support) appear to be effective in treating psychological symptoms of coronary heart disease, resulting in small and moderate improvements in depression and anxiety.[48–50] Future research should consider the combination of early cardiac rehabilitation and psychological intervention to promote psychological recovery in patients.

The present study has several limitations. First, we focused on an early cardiac rehabilitation program only in patients undergoing elective heart valve surgery. The effect of early rehabilitation in patients undergoing other cardiac vascular surgeries should also be investigated. Second, physical function measurements included self-reported questionnaires such as the PCS. Although self-reported PCS measurement has shown good reliability and validity in previous studies,[51,52] there is still a likelihood of overestimation for the physical activity level. Third, although we adjusted for confounders, including detailed demographical variables and intraoperative clinical characteristics, we cannot exclude the possibility that early rehabilitation was affected by other factors, such as postoperative complications.

In summary, early cardiac rehabilitation is associated with a marked improvement in physical function in patients with heart valve surgery and may promote long-term survival. Early cardiac rehabilitation in the hospital could be an effective approach to improve the functional capacity and clinical outcomes for surgical patients.

Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author contributions

Zhang Xinlan and Zheng Xiaoyan designed the study and submitted the manuscript. Wei Xue collected and analyzed data. Zhang Xinlan drafted the article. Zheng Xiaoyan and Wei Xue supervised this study. All authors read the final version of the manuscript and approved it for publication.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

ORCID iD

Wei Xue https://orcid.org/0000-0002-6739-8784

References

1. Barreto-Filho JA, Wang Y, Dodson JA, et al. Trends in aortic valve replacement for elderly patients in the United States, 1999-2011. *JAMA* 2013; 310: 2078–2085.
2. Hansen TB, Zwisler AD, Berg SK, et al. Cardiac rehabilitation patients' perspectives on the recovery following heart valve surgery: a narrative analysis. *J Adv Nurs* 2016; 72: 1097–1108.
3. Oterhals K, Fridlund B, Nordrehaug JE, et al. Adapting to living with a mechanical aortic heart valve: a phenomenographic study. *J Adv Nurs* 2013; 69: 2088–2098.
4. Nozawa E, Kobayashi E, Matsumoto ME, et al. Avaliação de fatores que influenciam no desmame de pacientes em ventilação mecânica prolongada após cirurgia cardíaca. *Arq Bras Cardiol* 2003; 80: 301–310.
5. Cordeiro ALL, Borges DL, Peruna MP, et al. Correlation between length of hospital stay and gait speed in patients submitted to cardiac surgery. *International Journal of Cardiovascular Sciences* 2017; 30: 123–127.
6. Ferrando AA, Lane HW, Stuart CA, et al. Prolonged bed rest decreases skeletal muscle and whole body protein synthesis. *Am J Physiol* 1996; 270(4 Pt 1): E627–E633.
7. Truong AD, Fan E, Brower RG, et al. Bench-to-bedside review: Mobilizing patients in the intensive care unit – from pathophysiology to clinical trials. *Critical Care* 2009; 13: 216.
8. Coker RH, Hays NP, Williams RH, et al. Bed rest promotes reductions in walking speed, functional parameters, and aerobic fitness in older, healthy adults. *J Gerontol A Biol Sci Med Sci* 2015; 70: 91–96.
9. Kim S-H, Cha S, Kang S, et al. High prevalence of physical inactivity after heart valve surgery and its association with long-term mortality: A nationwide cohort study. *Eur J Prev Cardiol* 2020: 2047487320903877.
10. Maniar H. Hospital readmissions after cardiac surgery: is it a game worth playing? *J Thorac Cardiovasc Surg*. 2015; 149: 858.

11. Smith SC Jr, Benjamin Emelia J, Bonow Robert O, et al. AHA/ACCF secondary prevention and risk reduction therapy for patients with coronary and other atherosclerotic vascular disease: 2011 update: a guideline from the American Heart Association and American College of Cardiology Foundation. *Circulation* 2011; 124: 2458–2473.
12. Blair SN, Kampert JB, Kohl HW 3rd, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA* 1996; 276: 205–210.
13. Heran BS, Chen JMH, Ebrahim S, et al. Exercise-based cardiac rehabilitation for coronary heart disease. *Cochrane Database Syst Rev* 2011: CD001800.
14. Piepoli MF, Corrà U, Benzer W, et al. Secondary prevention through cardiac rehabilitation: from knowledge to implementation. A position paper from the Cardiac Rehabilitation Section of the European Association of Cardiovascular Prevention and Rehabilitation. *Eur J Cardiovasc Prev Rehabil* 2010; 17: 1–17.
15. Pressler A, Förschner L, Hummel J, et al. Long-term effect of exercise training in patients after transcatheter aortic valve implantation: Follow-up of the SPORT: TAVI randomised pilot study. *Eur J Prev Cardiol* 2018; 25: 794–801.
16. Balady Gary J, Ades Philip A, Bittner Vera A, et al. Referral, enrollment, and delivery of cardiac rehabilitation/secondary prevention programs at clinical centers and beyond. *Circulation* 2011; 124: 2951–2960.
17. Borghi-Silva A, Mendes RG, Costa FdSM, et al. The influences of positive end expiratory pressure (PEEP) associated with physiotherapy intervention in phase I cardiac rehabilitation. *Clinics (Sao Paulo)* 2005; 60: 465–472.
18. da Costa Torres D, dos Santos PMR, Reis HJL, et al. Effectiveness of an early mobilization program on functional capacity after coronary artery bypass surgery: A randomized controlled trial protocol. *SAGE Open Med* 2016; 4: 2050312116682256.
19. Cheng Davy CH, Wall C, Djaiani G, et al. Randomized assessment of resource use in fast-track cardiac surgery 1-year after hospital discharge. *Anesthesiology* 2003; 98: 651–657.
20. Ender J, Borger MA, Scholz M, et al. Cardiac surgery fast-track treatment in a postanesthetic care unit: six-month results of the leipzig fast-track concept. *Anesthesiology* 2008; 109: 61–66.
21. Faul F, Erdfelder E, Lang A-G, et al. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods* 2007; 39: 175–191.
22. JCS Joint Working Group. Guidelines for rehabilitation in patients with cardiovascular disease (JCS 2012). *Circ J* 2014; 78: 2022–2093.
23. Guralnik JM, Simonsick EM, Ferrucci L, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol* 1994; 49: M85–M94.
24. Pavasini R, Guralnik J, Brown JC, et al. Short Physical Performance Battery and all-cause mortality: systematic review and meta-analysis. *BMC Med* 2016; 14: 215.
25. Hanada M, Yamauchi K, Miyazaki S, et al. Short-Physical Performance Battery (SPPB) score is associated with postoperative pulmonary complications in elderly patients undergoing lung resection surgery: a prospective multicenter cohort study. *Chron Respir Dis* 2020; 17: 1479973120961846.
26. Morisawa T, Ueno K, Fukuda Y, et al. Significance of sequential cardiac rehabilitation program through inter-hospital cooperation between acute care and rehabilitation hospitals in elderly patients after cardiac surgery in Japan. *Heart Vessels* 2017; 32: 1220–1226.
27. Ware J Jr, Kosinski M and Keller SD. A 12-item Short-Form health survey: construction of scales and preliminary tests of reliability and validity. *Med Care* 1996; 34: 220–233.
28. Berry C and McMurray J. A Review of quality-of-life evaluations in patients with congestive heart failure. *Pharmacoeconomics* 1999; 16: 247–271.
29. Acquistapace F and Piepoli MF. The walking test: use in clinical practice. *Monaldi Arch Chest Dis* 2009; 72: 3–9.

30. Du H, Newton PJ, Salamonson Y, et al. A Review of the six-minute walk test: its implication as a self-administered assessment tool. *Eur J Cardiovasc Nurs* 2009; 8: 2–8.
31. Smart NA, Waldron M, Ismail H, et al. Validation of a new tool for the assessment of study quality and reporting in exercise training studies: TESTEX. *Int J Evid Based Healthc* 2015; 13: 9–18.
32. Mikkelsen N, Cadarso-Suárez C, Lado-Baleato O, et al. Improvement in $VO_{2\ peak}$ predicts readmissions for cardiovascular disease and mortality in patients undergoing cardiac rehabilitation. *Eur J Prev Cardiol* 2019; 27: 811–819.
33. Pardaens S, Moerman V, Willems A-M, et al. Impact of the preoperative risk and the type of surgery on exercise capacity and training after valvular surgery. *Am J Cardiol* 2014; 113: 1383–1389.
34. Savage PD, Rengo JL, Menzies KE, et al. Cardiac rehabilitation after heart valve surgery: comparison with coronary artery bypass grafting patients. *J Cardiopulm Rehabil Prev* 2015; 35: 231–237.
35. Warburton DER, Nicol CW and Bredin SSD. Health benefits of physical activity: the evidence. *CMAJ* 2006; 174: 801–809.
36. Wolszakiewicz J, Piotrowicz E, Foss-Nieradko B, et al. A novel model of exercise walking training in patients after coronary artery bypass grafting. *Kardiol Pol* 2015; 73: 118–126.
37. Marchionni N, Fattirolli F, Fumagalli S, et al. Improved exercise tolerance and quality of life with cardiac rehabilitation of older patients after myocardial infarction. *Circulation* 2003; 107: 2201–2206.
38. Wang LW, Ou SH, Tsai CS, et al. Multimedia exercise training program improves distance walked, heart rate recovery, and self-efficacy in cardiac surgery patients. *J Cardiovasc Nurs* 2016; 31: 343–349.
39. Carlson JJ, Johnson JA, Franklin BA, et al. Program participation, exercise adherence, cardiovascular outcomes, and program cost of traditional versus modified cardiac rehabilitation. *Am J Cardiol* 2000; 86: 17–23.
40. Sibilitz KL, Berg SK, Thygesen LC, et al. High readmission rate after heart valve surgery: a nationwide cohort study. *Int J Cardiol* 2015; 189: 96–104.
41. Vassileva CM, Ghazanfari N, Spertus J, et al. Heart failure readmission after mitral valve repair and replacement: five-year follow-up in the medicare population. *Ann Thorac Surg* 2014; 98: 1544–1550.
42. Goel K, Pack QR, Lahr B, et al. Cardiac rehabilitation is associated with reduced long-term mortality in patients undergoing combined heart valve and CABG surgery. *Eur J Prev Cardiol* 2015; 22: 159–168.
43. Rimington H, Weinman J and Chambers JB. Predicting outcome after valve replacement. *Heart* 2010; 96: 118–123.
44. Kabboul NN, Tomlinson G, Francis TA, et al. Comparative effectiveness of the core components of cardiac rehabilitation on mortality and morbidity: a systematic review and network meta-analysis. *J Clin Med* 2018; 7: 1–20.
45. Oldridge N. Exercise-based cardiac rehabilitation in patients with coronary heart disease: meta-analysis outcomes revisited. *Future Cardiol* 2012; 8: 729–751.
46. Clark AM, Hartling L, Vandermeer B, et al. Meta-analysis: secondary prevention programs for patients with coronary artery disease. *Ann Intern Med* 2005; 143: 659–672.
47. Sibilitz KL, Berg SK, Rasmussen TB, et al. Cardiac rehabilitation increases physical capacity but not mental health after heart valve surgery: a randomised clinical trial. *Heart* 2016; 102: 1995–2003.
48. Whalley B, Rees K, Davies P, et al. Psychological interventions for coronary heart disease. *Cochrane Database Syst Rev* 2011; (8): CD002902.
49. Whalley B, Thompson DR and Taylor RS. Psychological interventions for coronary heart disease: Cochrane systematic review and meta-analysis. *Int J Behav Med* 2014; 21: 109–121.
50. Richards SH, Anderson L, Jenkinson CE, et al. Psychological interventions for coronary heart disease: cochrane systematic

review and meta-analysis. *Eur J Prev Cardiol*. 2018; 25: 247–259.

51. Iung B, Baron G, Butchart EG, et al. A prospective survey of patients with valvular heart disease in Europe: the Euro Heart Survey on Valvular Heart Disease. *Eur Heart J* 2003; 24: 1231–1243.
52. Cheak-Zamora NC, Wyrwich KW and McBride TD. Reliability and validity of the SF-12v2 in the medical expenditure panel survey. *Qual Life Res* 2009; 18: 727–735.