Heart Surgery Forum 2024; 27(10): E1228–E1236
doi: 10.59958/hsf.7485
https://journal.hsforum.com/

Systematic Review

Effects of Cardiac Rehabilitation on Patients Undergoing Heart Valve Surgery: A Systematic Review and Meta-Analysis

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Submitted: 24 March 2024 Revised: 9 May 2024 Accepted: 17 May 2024 Published: 23 October 2024

Abstract

Objective: This study assessed the effects of cardiac rehabilitation (CR) on patients undergoing heart valve surgery by collecting literature for meta-analysis. **Methods**: PubMed, ScienceDirect, Embase, Cochrane Library, CNKI, and Web of Science databases were systematically searched from the time of construction to December 2023. Primary outcomes were improvements in the 6 min walking distance (6-MWD) and Barthel index (BI) after CR. Secondary outcomes included short form (SF)-12/36 scale, depression, anxiety, and Morse Fall Scale (MFS) scores. All statistical analyses were performed by using standard statistical procedures provided in Review Manager 5.2 (The Nordic Cochrane Centre, Copenhagen, Denmark). **Results**: A total of 14 studies involving 1687 subjects were included. Pooled data showed that CR care significantly improved 6-MWD (mean difference (MD) = 47.60, 95% confidence interval (CI): [33.70, 61.50], $p < 0.00001$) and BI (MD = 10.88, 95% CI: [7.72, 14.05], $p < 0.00001$). In addition, patients showed no difference in mental component scores (MD = 1.27, 95% CI: [–0.10, 2.64], $p = 0.07$) and significant difference in physical component scores (MD = 1.65, 95% CI: [0.24, 3.06], $p = 0.02$) at CR discharge compared with those at admission. Similar results were observed for depression (MD = –0.13, 95% CI: [–0.60, 0.34], $p = 0.59$) and anxiety scores (MD = –0.44, 95% CI: [–0.88, –0.01], $p = 0.04$). Results also showed that CR significantly improved the MFS score of patients (MD = –5.82, 95% CI: [–9.38, –2.27], $p = 0.001$). **Conclusion**: Our analysis suggested that CR contributes to enhancing exercise tolerance and self-care and improving psychological status in patients undergoing heart valve surgery.

Keywords

cardiac rehabilitation; heart valve surgery; transcatheter aortic valve implantation; valvular heart disease

Introduction

Valvular heart disease (VHD) is a condition wherein the structures and functions of the mitral, aortic, tricuspid, and pulmonary valves are impaired due to rheumatic fever, degenerative changes, and ischemic necrosis [1]. The prolonged overloading of valvular tissues can result in massive damage to cardiomyocytes along with varying degrees of irreversible symptoms, leading to advanced VHD (AVHD). The incidence of heart valve disease increases with age and accounts for one-third of all heart diseases [2]. In China, VHD types exhibit the following incidence rates: 33.6% for combined valve disease, 26.9% for simple mitral regurgitation, 10.6% for simple aortic regurgitation, 5.1% for simple aortic stenosis, 3.1% for simple mitral stenosis, 2.3% for mixed simple aortic valvulopathy, and 1.3% for mixed simple mitral valvulopathy. In the United States, 146,304 patients died of aortic valve disease in the decade of 1999–2019; of these patients, 82.7% died of aortic stenosis [3]. Therefore, the treatment of aortic valve stenosis is crucial.

Transcatheter aortic valve implantation (TAVI) and surgical aortic valve replacement, as important means of treatment for heart valve disease, have a good effect on the condition of low–intermediate- and high-risk patients. Previous reports [4] have shown that patients with AVHD have a high mortality rate and poor long-term outcomes due to poor cardiopulmonary reserves. The mortality rate of patients with AVHD 30 days after heart valve replacement is 5%–10% [4]. Relevant studies have shown that poor cardiopulmonary function in patients with AVHD can lead to a remarkable reduction in the quality of prognostic recovery and considerable increase in the postoperative mortality of patients [5,6]. A meta-analysis demonstrated that in patients with aortic stenosis, transcatheter aortic valve replacement (TAVR) improved functional measures, such as 6 min walking distance (6-MWD), Duke Activity Status Index, and life expectancy [7]. However, approximately one-third of patients post-TAVR lacked substantial improvement in exercise capacity, and a very small number may even exhibit a reduction in exercise capacity [8]. Meanwhile, the incidence of adverse events, such as all-cause and

cardiac mortality, was also higher in this group of patients than in other groups [9]. Therefore, the level of exercise and daily living of patients after heart valve surgery need improvement. Giving patients with AVHD effective clinical nursing interventions during surgical treatment is essential.

Cardiac rehabilitation (CR) is a series of interventions, such as exercise rehabilitation, nutritional support, risk factor interventions, behavioral interventions, psychological guidance, smoking cessation, lipid management, and glucose control, based on five core prescriptions: exercise, psychological, smoking cessation, medication, and nutritional [10]. It provides good preventive and curative interventions for the acute, maintenance, and recovery phases of coronary artery disease, heart valve disease, heart failure, hypertension, and other cardiovascular system diseases, as well as for the entire life course of patients [11]. CR, as the secondary treatment for the prevention of coronary heart disease, can effectively improve cardiopulmonary and vascular endothelial functions and reduce the incidence of cardiac death in patients with coronary heart disease. At the same time, in patients with coronary heart disease, it reduces the occurrence of fatal events, improves prognosis, and enhances and improves the quality of life. In addition, numerous studies have similarly demonstrated that in patients undergoing heart valve surgery, CR can considerably improve and enhance functional and quality of life indicators after heart valve surgery [12,13]. Therefore, in this study, we retrieved and collected studies on CR in patients undergoing heart valve surgery to evaluate the effect of CR.

Method

We followed the PRISMA statement and used the PRISMA checklist (**Supplementary material 1**) to ensure methodological quality.

Literature Search

PubMed, ScienceDirect, Embase, Cochrane Library, CNKI, and Web of Science databases were systematically searched from the time of construction to December 2023. The search strategy was developed by experts, and the search terms and keywords included "heart valve surgery", "transcatheter aortic valve implantation", "TAVI", "cardiac rehabilitation", and "CR". All the retrieved documents were imported into Endnote software to remove duplicates. Moreover, the references in the included literature were manually screened to conduct a comprehensive search. Two professionals independently screened the title and abstract of each study. When an article met the criteria, its full text was obtained for further evaluation.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Study type: clinical studies, including randomized controlled studies (RCTs) and nonrandomized controlled studies. (2) Subjects: patients undergoing heart valve surgery. (3) Intervention: implementation of CR interventions. (4) Outcomes: primary and/or secondary outcomes included in the studies.

Exclusion criteria: (1) Animal experiments or nonhuman studies, noncohort studies, or RCTs. (2) Subjects had other medical conditions that could have affected the results. (3) Studies reported in the form of editorials, abstracts, reviews, letters, expert opinions, or case reports. (4) Data were inadequate or ineligible for inclusion.

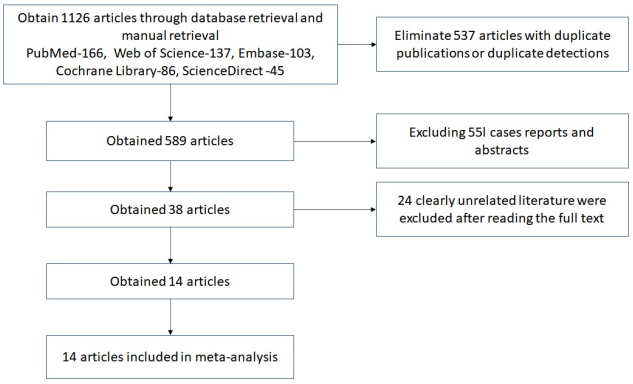

Fig. 1. Literature retrieval.

Data Extraction and Bias Assessment

Two researchers trained in evidence-based methodology independently screened literature, extracted data, and cross-checked information. Disagreements were discussed jointly or referred to a third researcher for arbitration. Data extraction included authors, year, country, sample size, age, sex, intervention frequency and periodicity, and outcome indicators. In addition, two researchers independently assessed the methodological quality of the included literature in accordance with the Cochrane Handbook of Systematic Evaluation. Included studies that met all evaluation criteria were graded A (low risk of bias); those that partially met the evaluation criteria were graded B (moderate risk of bias); and those that met none of the evaluation criteria were graded C (high risk of bias).

Statistical Methods

Outcome indicators were synthesized and statistically analyzed by using Review Manager 5.2 software (The Nordic Cochrane Centre, Copenhagen, Denmark). Continuous data were expressed as mean difference (MD) and 95% confidence interval (CI). Heterogeneity between studies was determined by using the chi-square test and I^2 statis-

Table 1. Basic characteristics of the included studies.

Author	Year	Country	n	Age	Male	Duration of CR	Frequency	Indicators
Eichler *et al.* [15]	2017	Germany	136	80.6 ± 5.0	65	3 weeks	5/week	(1)(3)(4)
Fauchère *et al.* [16]	2014	Switzerland	112	79 ± 6	45	30 days	6/week	(1)(4)
Pressler *et al.* [17]	2016	Germany	30	81 ± 6	18	2 weeks	2/week	(1)(3)
Rogers *et al.* [18]	2018	UK	27	82.04 ± 4.80	12	3 months	-	(1)
Russo *et al.* [19]	2014	Italy	138	83.7 ± 3.6	53	3 weeks	6/week	(2)
Su *et al.* [20]	2019	China	108	55.6 ± 11.8	76	1 week	7/week	(1)(2)(3)
Sun and Su [21]	2021	China	200	69.1 ± 2.7	110	1 week	7/week	(1)(2)(3)
Tarro-Genta *et al.* [22]	2017	Italy	135	82 ± 6	50	3 weeks	6/week	(1)(2)(5)
Tarro-Genta *et al.* [23]	2019	Italy	90	82.7 ± 4.9	33	3 weeks	6/week	(2)(5)
Völler *et al.* [24]	2015	Germany	442	69.94 ± 11.08	271	3 weeks	4–5/week	(1)
Xue *et al.* [25]	2022	China	87	58.20 ± 5.27	56	1 week	-	(1)(4)
Yu *et al.* [26]	2021	China	69	74.7 ± 8.1	54	1 month	-	(1)(2)(4)
Zanettini *et al.* [14]	2014	Italy	59	83.5 ± 5.0	27	3 weeks	6/week	(1)(2)
Zheng [27]	2020	China	54	49.3 ± 5.2	15	1 weeks	7/week	(1)(2)(3)

Note: (1) 6-MWT; (2) Barthel index; (3) SF-12/36; (4) HADS; (5) Morse Fall Scale. CR, Cardiac Rehabilitation; 6-MWT, 6-Minute Walk Test; SF-12/36, Short Form 12/36 Health Survey; HADS, Hospital Anxiety and Depression Scale.

tic. When $p > 0.10$ and $I^2 < 50\%$, studies were homogeneous, and statistics were combined by using the fixed-effects model. When $p \leq 0.10$ and $I^2 > 50\%$, studies were heterogeneous, and statistics were combined by using the random-effects model. Sources of heterogeneity were identified through sensitivity or subgroup analyses to determine whether the final data results were robust. In this study, funnel plots and Egger's test were used to assess whether publication bias existed.

Results

Results of the Literature Search

The initial search yielded 1126 articles (Fig. 1). A total of 537 articles remained after duplicates were removed. A total of 38 articles remained after titles and abstracts were read. A total of 14 articles were finally included after full texts were read.

Evaluation of Literature Bias Quality

Zanettini's study [14] had a quality grade of A. The rest of the studies did not meet at least one of the evaluation criteria, and all had a quality grade of B (Fig. 2).

Basic Characteristics

A total of 1687 patients with VHD were included, and the intervention period was 1–12 weeks. The basic characteristics of the included literature are presented in Table 1 (Ref. [14–27]).

Meta-Analysis of 6-MWD

Twelve studies compared the effect of CR on 6-MWD in patients undergoing heart valve surgery with $I^2 = 75\%$ and high heterogeneity (Fig. 3). The combined results showed that CR significantly improved 6-MWD in patients (MD = 47.60, 95% CI: [33.70, 61.50], $p < 0.00001$). Sensitivity analysis revealed that heterogeneity reduced after the removal of Rogers' study ($p = 0.18$, $I^2 = 28\%$) (**Supplementary material 2**). This result suggested that Rogers' study [18] may be a main source of the high heterogeneity in 6-MWD. Fig. 4 illustrates that subgroup analysis based on CR duration revealed similar results among patients who received CR for less than 1 month (MD = 46.67, 95% CI: [40.10, 53.25], $p < 0.00001$) versus more than 1 month (MD = 76.28, 95% CI: [46.18, 106.39], $p < 0.00001$).

Meta-Analysis of Barthel Index (BI) Scores

Eight studies compared the effect of CR on the BI scores of patients undergoing heart valve surgery with $I^2 = 83\%$ and high heterogeneity (Fig. 5). The combined results showed that CR significantly improved patients' BI scores (MD = 10.88, 95% CI: [7.72, 14.05], $p < 0.00001$). Subgroup analysis by region demonstrated a slight reduction in heterogeneity (Europe: $I^2 = 63\%$, Asian: $I^2 = 81\%$) (Fig. 6). However, sensitivity analysis revealed reduced heterogeneity after the studies of Sun and Tarro-Genta were removed ($p = 0.37$, $I^2 = 6\%$) (**Supplementary material 2**). This result suggested that these studies may a main source of high heterogeneity in BI scores.

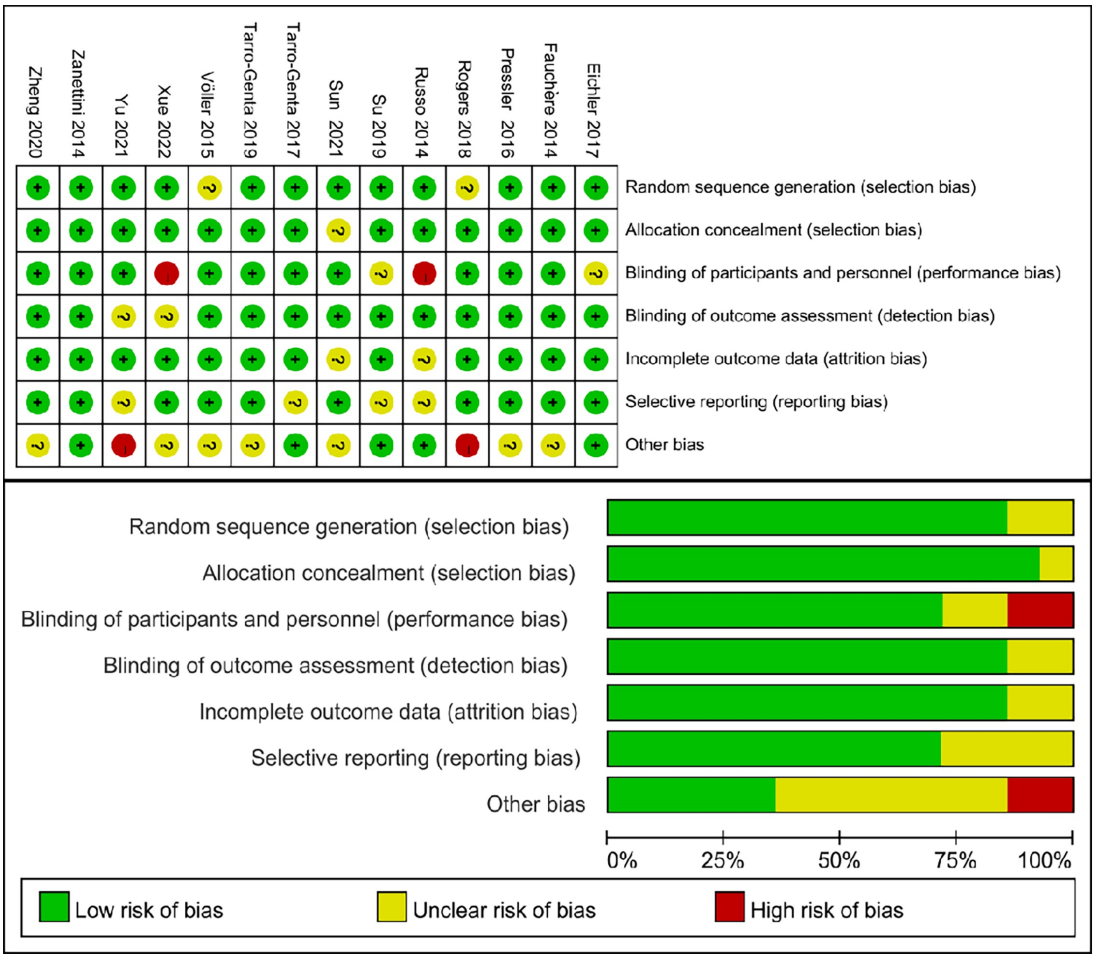

Fig. 2. Results of the risk of bias evaluation.

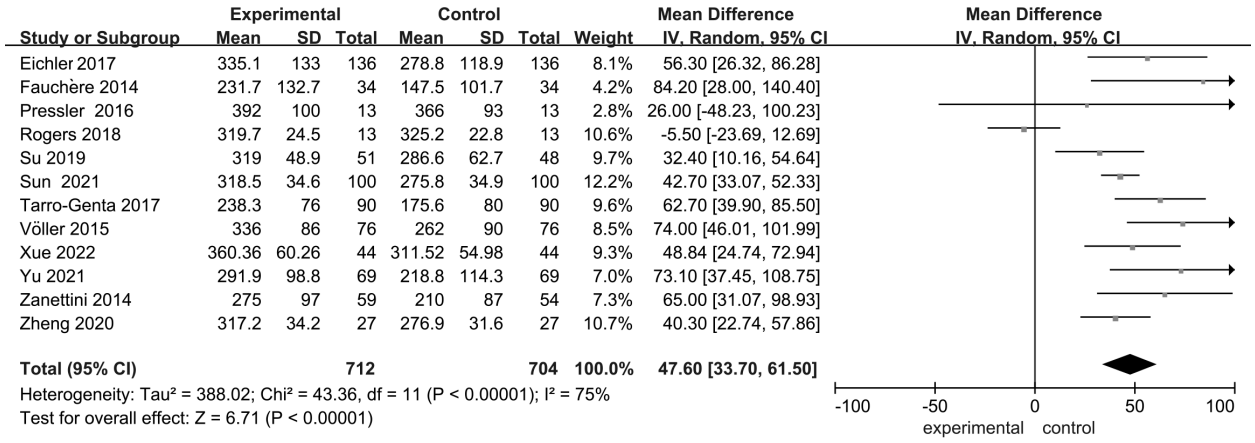

Fig. 3. Forest plot of the effects of cardiac rehabilitation (CR) on 6 min walking distance (6-MWD). SD, Standard Deviation; IV, Independent Variable; CI, Confidence Interval.

Meta-Analysis of Short Form (SF)-12/36

Four studies compared the effect of CR on the SF-12/36 scores of patients undergoing heart valve surgery with low heterogeneity (I^2 = 9 %, Fig. 7). Combined results showed that CR significantly improved the SF scores of patients (MD = 1.45, 95% CI: [0.47, 2.44], p = 0.004). The combined results for PCS and MCS were MD = 1.65, 95% CI: [0.24, 3.06] and MD = 1.27, 95% CI: [–0.10, 2.64], respectively. However, the effect of CR on MCS in patients undergoing heart valve surgery was not significant (p = 0.07).

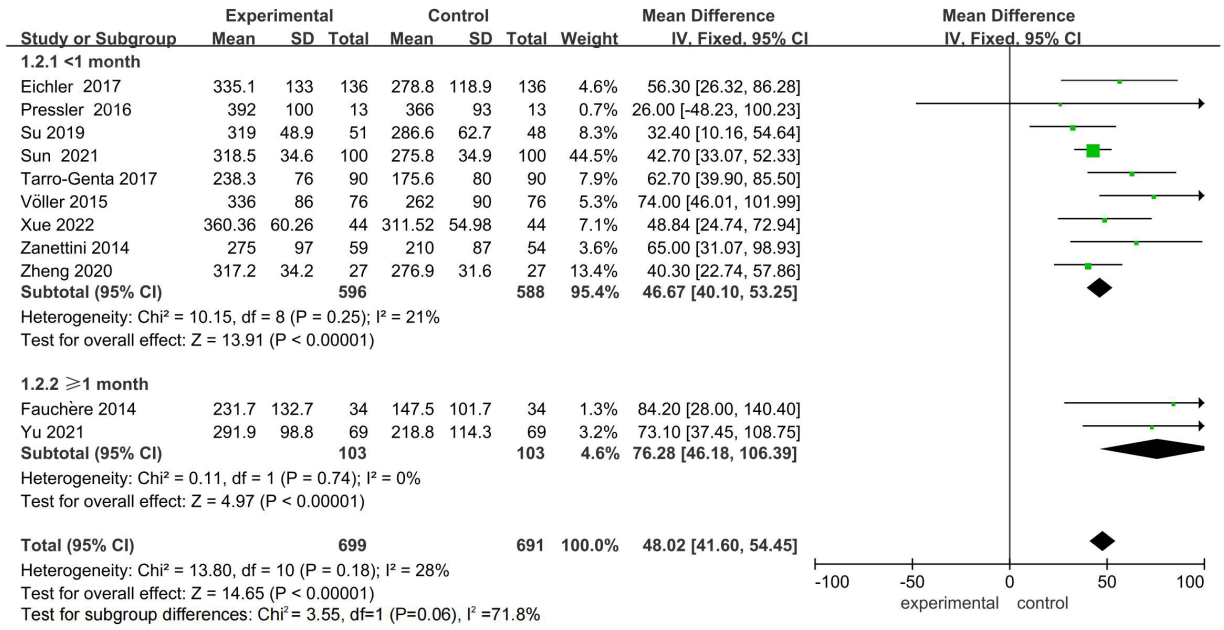

Fig. 4. Subgroup analysis of the effects of CR on 6-MWD.

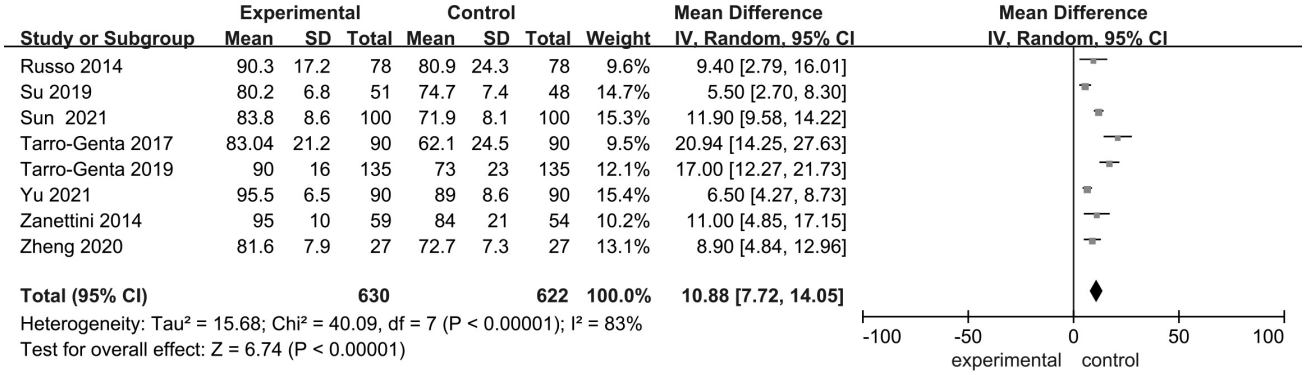

Fig. 5. Forest plot of the effects of CR on Barthel index (BI) scores.

Meta-Analysis of Depression and Anxiety

The effect of CR on anxiety and depression in patients undergoing heart valve surgery was evaluated (Fig. 8). Three studies compared the effect of CR on anxiety and depression in patients undergoing heart valve surgery with $I^2 < 50\%$ and low heterogeneity. The combined results revealed that CR significantly improved patients' anxiety scores (MD = –0.44, 95% CI: [–0.88, –0.01], $p = 0.04$). However, the effect of CR on depression in patients undergoing heart valve surgery was not significant (MD = –0.13, 95% CI: [–0.60, 0.34], $p = 0.59$).

Meta-Analysis of Morse Fall Scale (MFS)

Two studies compared the effect of CR on MFS in patients undergoing heart valve surgery with $I^2 = 0\%$ and low heterogeneity (Fig. 9). The combined results showed that CR significantly improved the MFS scores of patients (MD = –5.82, 95% CI: [–9.38, –2.27], $p = 0.001$).

Publication Bias

In this study, 6-MWD was used as the outcome index for publication bias analysis, and the results showed that the included studies were evenly distributed and only a small number of studies were scattered. This result may be related to the heterogeneity among studies, suggesting that the included studies may have mild publication bias (Fig. 10). After trim-and-fill analysis, Egger's test results revealed that t = 1.70, $p = 0.118$, suggesting that the possibility of publication bias is small.

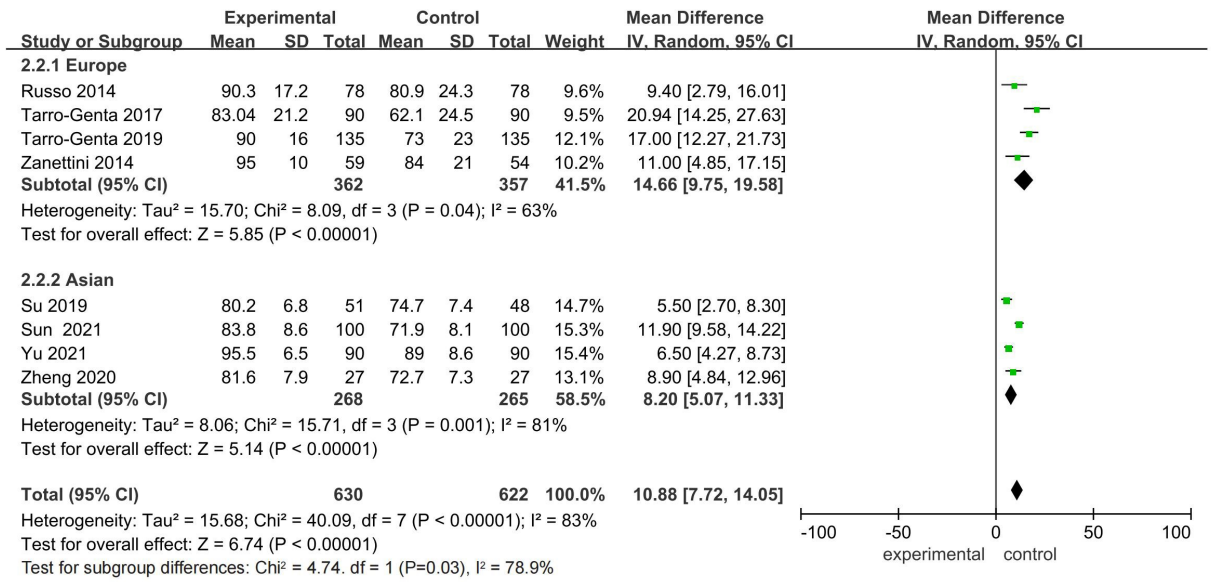

Fig. 6. Subgroup analysis by region.

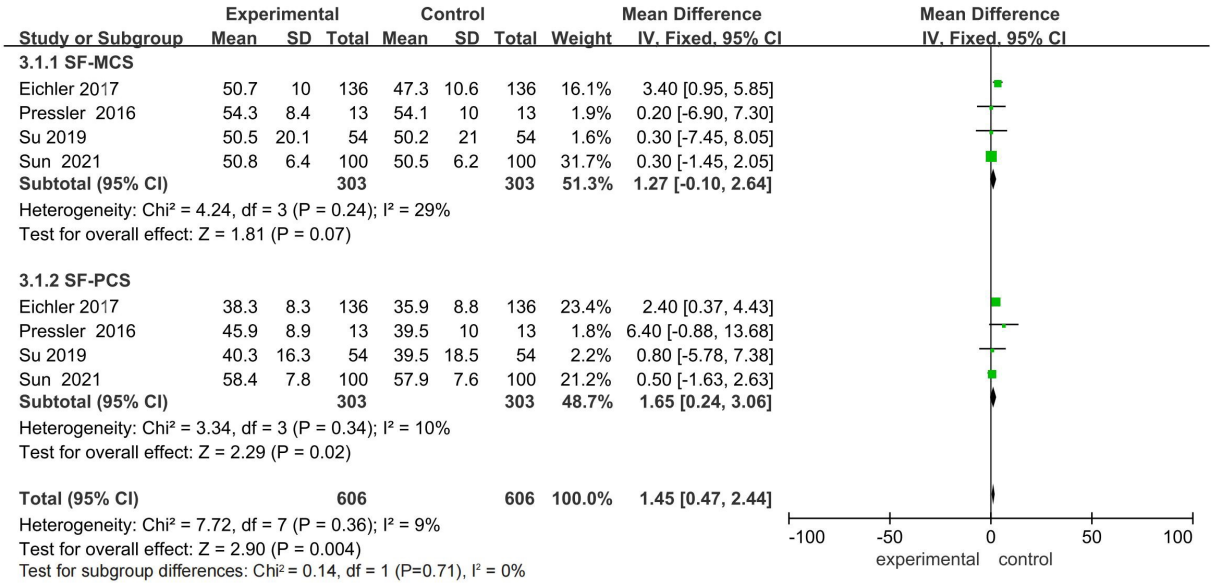

Fig. 7. Forest plot of SF-12/36. SF-MCS, Short-Form Mental Component Summary; SF-PCS, Short-Form Physical Component Summary.

Discussion

We included 14 studies [14–27] involving 1687 subjects in this study. Pooled data showed that CR care significantly improved 6-MWD and BI scores. In addition, the physical component score of patients at CR discharge had significantly improved relative to those at admission. Similar results were observed for depression and anxiety scores. We also found that that CR significantly improved the MFS score of patients. CR nursing provides targeted interventions to patients such that their cardiac function and physical status can be substantially improved and their recovery effect can be remarkably enhanced [28,29].

Prior to this study, three meta-analyses evaluated the effects of CR on patients undergoing heart valve surgery, mainly TAVI, and focused on 6-WMD and BI scores [30–32]. These previous analyses did not comprehensively assess the effect of CR and failed to include patients undergoing other heart valve surgeries and quality of life, de-

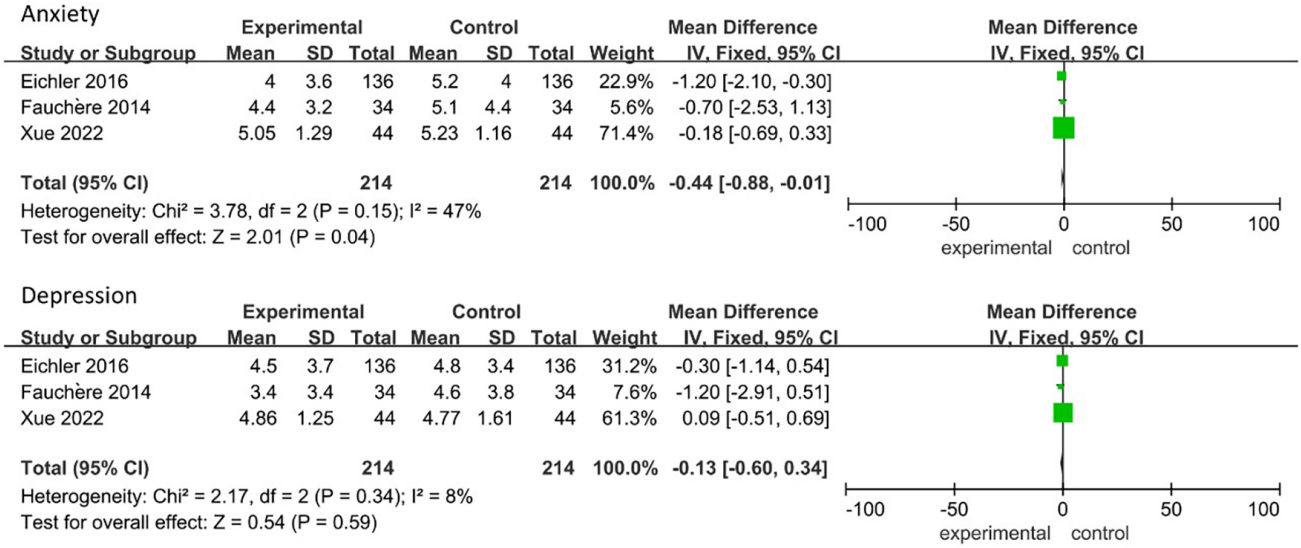

Fig. 8. Forest plot of depression and anxiety.

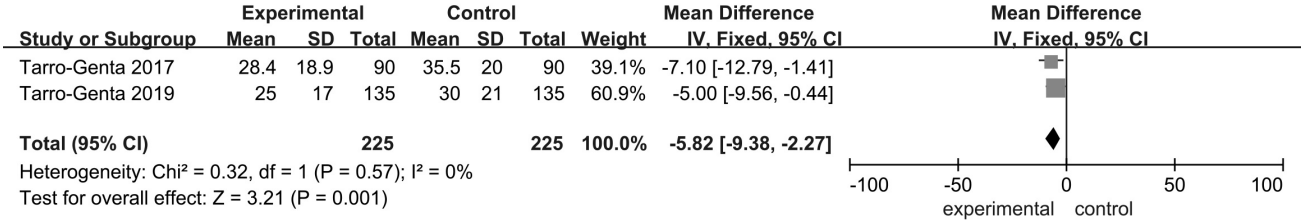

Fig. 9. Forest plot of Morse Fall Scale (MFS).

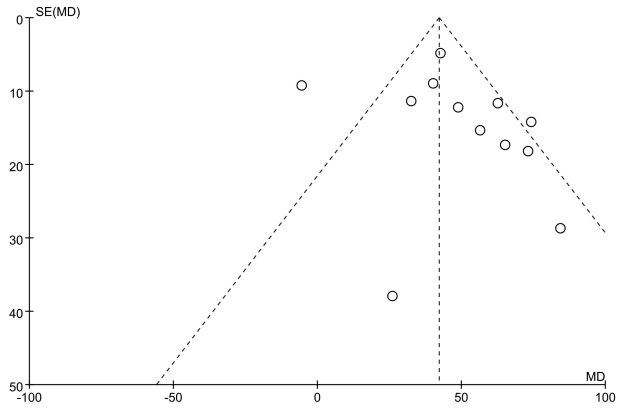

Fig. 10. Funnel plot results. SE, Standard Error; MD, Mean Difference.

pression, anxiety, and MFS outcome metrics. Therefore, we comprehensively assessed the effect of CR on patients undergoing heart valve surgery on the basis of 14 studies involving 1687 patients. Our results showed that CR care significantly improved patients' exercise tolerance (MD = 47.60, 95% CI: [33.70, 61.50], $p < 0.00001$) and activities of daily living (MD = 10.88, 95% CI: [7.72, 14.05], $p < 0.00001$) likely because it increased myocardial blood flow by improving endothelial function and myocardial blood flow reserve, as well as elevated myocardial oxygenation by increasing the utilization of oxygen by active muscles, thus improving exercise endurance [33]. In this study, we performed subgroup analyses on the basis of the period of CR intervention and explored the effects of various differences, revealing that CR interventions of less than 1 month (MD = 46.67, 95% CI: [40.10, 53.25], $p < 0.00001$) or more than 1 month (MD = 76.28, 95% CI: [46.18, 106.39], $p < 0.00001$) demonstrated similar effects on patients' exercise endurance. This finding provides an evidence-based foundation for future clinical interventions. In patients undergoing heart valve surgery, autonomy and mobility, as measured by BI, improved similar to exercise tolerance. Similarly, Penati *et al.* [34] demonstrated this result in hospitalized patients with CR .

CR care had varying degrees of effects on quality of life, psychological status, and MFS in patients undergoing heart valve surgery in addition to their primary metrics. Patients who implemented CR exhibited a significant improvement in their SF-12/36 scale score at discharge (MD = 1.45, 95% CI: [0.47, 2.44], $p = 0.004$) relative to that at admission. Notably, CR care significantly improved patients' PCS scores (MD = 1.65, 95% CI: [0.24, 3.06], $p = 0.02$). However, inconsistent with Eichler *et al.* [15],

we found that the effect on MCS (MD = 1.27, 95% CI: [–0.10, 2.64], p = 0.07) was not significant. This finding needs to be confirmed by additional future studies. Our results demonstrated that CR care was effective in improving patients' anxiety scores (MD = –0.44, 95% CI: [–0.88, –0.01], p = 0.04). However, the effect of CR on patients' depression scores was not significant (MD = –0.13, 95% CI: [–0.60, 0.34], p = 0.59) likely due to inconsistent results from different studies. The results of Xue's study [25] are consistent with the findings of our work. Nevertheless, Fauchère *et al*. [16] indicated that CR did not have a significant effect on the depression and anxiety scores of patients likely due to the absence of psychological intervention in CR. Psychological interventions, such as education, discussion, and emotional support, appear to be effective in treating psychological symptoms in patients undergoing heart valve surgery, resulting in mild and moderate improvements in depression and anxiety. Future studies should consider combining early CR with psychological interventions to promote psychological recovery in patients. In addition, the results of our study showed that heart valve surgery patients who received CR care had a lower risk of falls at discharge (MD = –5.82, 95% CI: [–9.38, –2.27], p = 0.001) than those who did not. These results suggest that CR care has the potential to accelerate recovery in patients undergoing heart valve surgery. However, the effects on some of the recovery indicators found in our study are not completely consistent and still need confirmation by numerous studies.

Our analysis has some limitations: (1) Given the shortage of patient data, we were unable to perform additional subgroup analyses based on other baseline information. (2) Most of the included studies were retrospective and may have been influenced by many factors that affected the accuracy of the combined results. (3) Although we confirmed the beneficial effects of CR care in patients undergoing heart valve surgery, our results were inconsistent with those of some studies. (4) The included studies may have mild publication bias. Therefore, we suggest that future studies expand the sample size to evaluate patients in multiple ways to confirm the benefits of CR.

Conclusion

CR improved exercise tolerance, functional independence, PCS, anxiety, and MFS in patients with VHD undergoing heart valve surgery.

Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available in the Manuscript.

Author Contributions

XK designed the study; all authors conducted the study; JZ collected and analyzed the data; JC and XM participated in drafting the manuscript, and all authors contributed to critical revision of the manuscript for important intellectual content. All authors gave final approval of the version to be published. All authors participated fully in the work, take public responsibility for appropriate portions of the content, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or completeness of any part of the work are appropriately investigated and resolved.

Ethics Approval and Consent to Participate

Not applicable.

Acknowledgment

Not applicable.

Funding

This research received no external funding.

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.59958/hsf.7485.

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