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Systematic Review

Effects of Exercise-Based Cardiac Rehabilitation on Patients Undergoing Percutaneous Coronary Intervention: A Systematic Review and Meta-Analysis

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Abstract

Objective: This study aims to systematically analyze the impact of exercise-based cardiac rehabilitation on patients undergoing percutaneous coronary intervention (PCI). **Methods**: We searched for original studies on the effect of exercise-based cardiac rehabilitation on patients undergoing PCI published in domestic and foreign databases such as PubMed, Web of Science, Embase, Cochrane Library, China Knowledge Network (CNKI), and VIP until December 2023. Studies retrieved were screened, and meta-analysis was extracted. The quality of the literature was evaluated; meta-analysis was carried out by RevMan5.4 software (Cochrane Collaboration, Oxford, UK). **Results**: A total of 1073 sufferers undergoing PCI were included in 11 literatures. Meta-analysis displayed that cardiogenic mortality [risk ratio (RR) = 0.23, 95% confidence interval (CI) (0.08, 0.64)], coronary restenosis rate [RR = 0.59, 95% CI (0.41, 0.87)], revascularization rate [RR = 0.58, 95% CI (0.43, 0.79)], incidence of recurrent angina pectoris [RR = 0.41, 95% CI (0.27, 0.62)], and late lumen loss [RR = –0.60, 95% CI (–0.98, –0.23)] in the trial group, were lower than those in the control group ($p < 0.05$). No significant difference was found in the recurrence rate of myocardial infarction between the test group and the control group [RR = 0.52, 95% CI (0.22, 1.25)]. **Conclusion**: Exercise-based cardiac rehabilitation therapy can effectively reduce the risk of major adverse cardiocerebrovascular events, such as cardiogenic death and coronary restenosis after PCI; it reduces the late lumen loss of the stent coronary segment and has no obvious effect on the recurrence of myocardial infarction. However, this therapy tends to reduce the recurrence rate of myocardial infarction.

Keywords

exercise; cardiac rehabilitation; percutaneous coronary intervention; coronary heart disease; systematic review; meta-analysis

Introduction

With the change of people's diet and living standards, the incidence of coronary heart disease increases yearly and it has become a common cause of heart disease-related death worldwide [1]. Medical science and technology has experienced great progress, and the remedy of sufferers with coronary heart disease is gradually diversified. Percutaneous coronary intervention (PCI) is one of the main strategies for clinical remedy of patients with coronary heart disease. The method can quickly dredge the stenotic or occlusive coronary artery, improve myocardial perfusion, and save patients' lives. It has been proved that it can obviously improve the prognosis of patients with coronary heart disease and occupies an irreplaceable position in the cardiovascular field [2,3]. However, PCI is not the end point of remedy for sufferers with coronary heart disease, and the cardiovascular risk elements are not relieved after treatment, which does not fundamentally inhibit the occurrence and progression of coronary heart disease. In addition, PCI can lead to endothelial cell damage and even result in thrombosis or restenosis, induce coronary artery embolism, and then lead to myocardial damage or ischemia, which broughts a heavy burden to the family and society [4–6]. Therefore, scholars need to strengthen the recovery of sufferers with coronary heart disease after PCI, prolong survival time, and improve life quality. In recent years, with the rapid development of rehabilitation medicine, exercise-based cardiac rehabilitation therapy has entered the people's field of vision and is gradually applied to the postoperative rehabilitation of patients with PCI. Cardiac recovery therapy is a whole-process and synthesize medical–management method, including exercise, psychological intervention, lifestyle and behavior changes, and other measures; among which, exercise is the best medicine. Lack of exercise plays an important role in the occurrence and progression of cardiovascular diseases. Exercise can enhance the therapy compliance of patients with coronary heart disease, ameliorate bad mood, boost patients' self-efficacy and quality of life, which make a big difference to human health

[7]. After PCI, especially in the recovery stage of operation, exercise can effectively ameliorate the clinical symptoms of patients, and it is usually combined with routine treatment [8]. Exercise has a crucial role in promoting the recovery of patients after PCI and reducing the risk of recurrence; it has become an important part of contemporary coronary heart care. The American Heart Association (AHA) has regarded exercise as the center of exercise-based cardiac rehabilitation therapy. Although many positive suggestions for exercise-based cardiac rehabilitation therapy have been reported, it has not been widely and fully utilized. Few systematic analysis has been conducted on the advantages of cardiac recovery on this population. In this regard, the present study selected published literature on the effects of exercise-based cardiac rehabilitation on PCI patients for systematic analysis to ameliorate the prognosis and quality of life of patients after PCI.

Materials and Methods

This meta-analysis was carried out in accordance with the PRISMA (**Supplementary Material 1**).

Document Retrieval Strategy

Original studies on the effect of exercise-based cardiac recovery on patients undergoing PCI published in domestic and foreign databases such as Pubmed, Web of Science, Embase, Cochrane Library, China knowledge Network (CNKI), and VIP were searched until December 2023. The key words were as follows: coronary heart disease, percutaneous coronary intervention, PCI, exercise, yoga, jogging, tai chi, cardiac rehabilitation. MeSH words were combined combined with entry word to search; with Pubmed as an example: (coronary heart disease) AND (percutaneous coronary intervention OR PCI) AND (exercise or yoga or jogging or Tai Chi) and (cardiac rehabilitation).

Literature Inclusion Criteria

(1) All patients were treated with PCI without limitation of age and sex, and the postoperative follow-up period was more than 3 months; (2) intervention: the experimental group received cardiac rehabilitation exercise therapy, and the control group received routine nursing or drug intervention; (3) randomized controlled trials (RCT) written in English or Chinese literature without any restriction on the use of blind method; (4) outcome indicators: revascularization, recurrence of myocardial infarction, cardiogenic death, angina pectoris, coronary restenosis.

Literature Exclusion Criteria

(1) Patients not treated with PCI; (2) lack of rehabilitation exercise in intervention measures; (3) literature on animal experiments or reviews; (4) literature of repeated publication and poor quality; (5) literature with obvious errors or insufficient accuracy in data; (6) literature of abstracts, case reports and minutes of meetings; (7) literature with unclear intervention measures; and (8) literature with abstracts but not full text.

Literature Screening and Data Extraction

Two researchers were selected to input the results of database search into EndnoteX8 (Clarivate Analytics, Philadelphia, PA, USA) document management software. After the repeated published literature was excluded, the articles were screened according to the research purpose, inclusion criteria, and exclusion criteria. During browsing of the title and abstract of the documents, if it is related to the research content, you can further read the full text. The inclusion of the literature needs to be cross-checked by two researchers. If the two researchers have different opinions on whether the literature should be included in the screening process, then they can discuss and determine whether the literature should be included or not. If there is any dispute about the inclusion of the document, a third researcher can be selected to decide whether to include the document. Data were independently assessed by two researchers according to the standardized data extraction table. The data extracted include first author, country, publication time, sample size, treatment method, outcome index and so on. We cross-check the extracted data to guarantee the preciseness of data extraction.

Document Quality Evaluation

The evaluation criteria are Cochrane manual 5.1.0 bias risk assessment tool (https://training.cochrane.org/handbook), which includes six aspects: the generation of random methods, the concealment of allocation schemes, the use of blind methods, the completeness of outcome reports, selective bias reports, and other sources of bias. Then the included literature is evaluated as “high risk”, “low risk” and “unclear”, and the literature is classified as A, B and C. If the literature meets all the above criteria, it will be classified as grade A, and only part of the criteria will be classified as grade B. It is completely inconsistent with the above criteria as grade C.

Statistical Methods

Meta analysis was carried out by RevMan5.4 software (Cochrane Collaboration, Oxford, UK). The ratio ratio (RR) was selected as the effect index, and the corresponding 95% confidence interval (CI) was computed, which was expressed by forest map. It is clear whether there is heterogeneity among documents. If $p > 0.1$ and $I^2 < 50\%$, it means that the heterogeneity among documents is small, and fixed effect model is opted to analyze. If $p < 0.1$ and

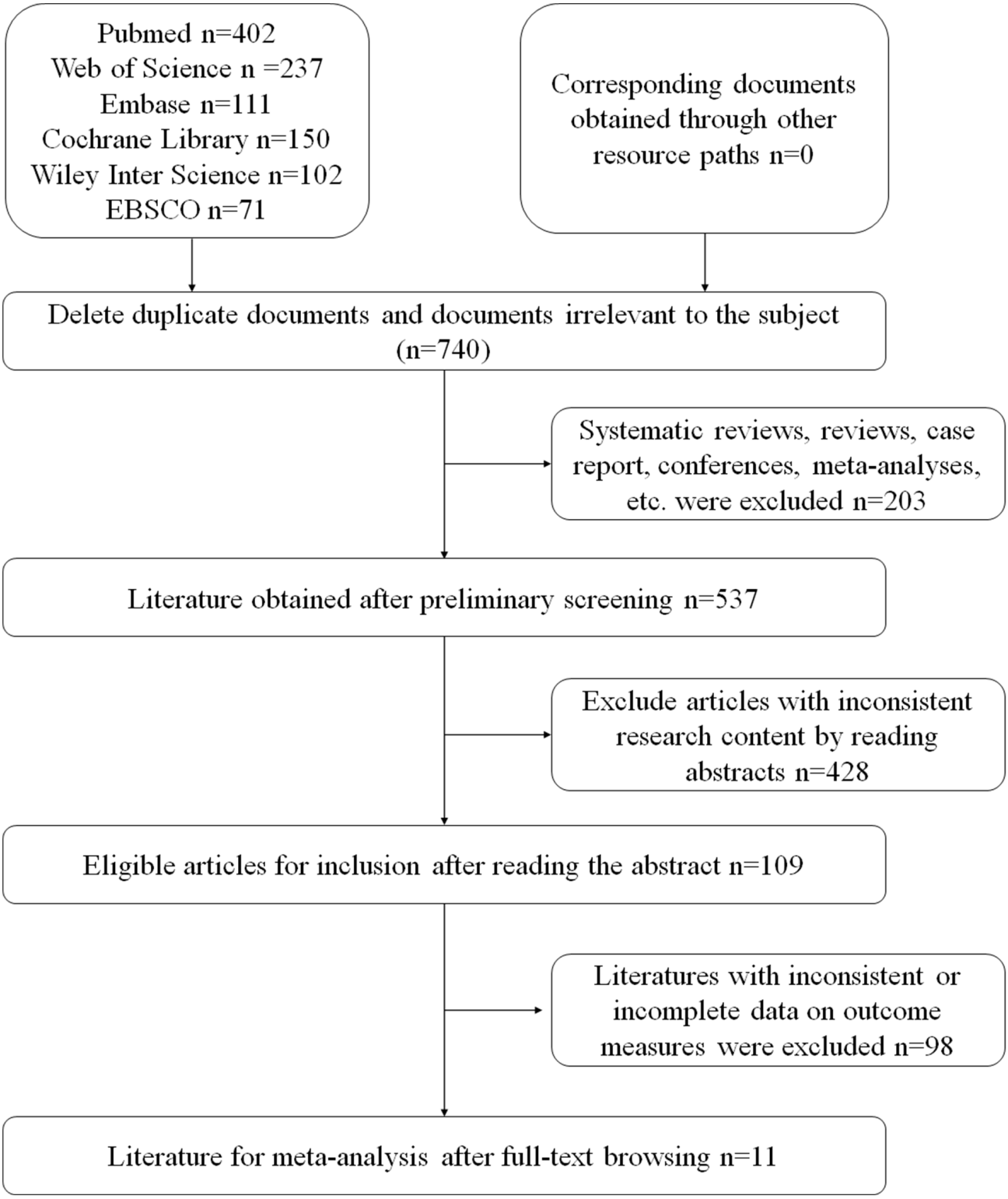

Fig. 1. Flow chart of document retrieval.

Table 1. Basic traits of literature included in the literature.

Literature	Number of cases (experimental group/control group)	Interventions		Follow-up time	Outcome indicators
		Test group	Control group		
Wu *et al*. 2013 [9]	30/30	Walking, jogging, Tai Chi, *etc*.	Routine care combined with drug therapy	6 months	Cardiac death, recurrence of myocardial infarction, coronary restenosis, recurrent angina
Hofman-Bang *et al*. 1999 [10]	45/41	Physical exercise, unknown	Routine care	24 months	Myocardial infarction recurrence, revascularization
Liu *et al*. 2015 [11]	30/30	Down stairs	Routine care combined with drug therapy	3 months	Maximum exercise endurance, total exercise duration
Belardinelli *et al*. 2001 [12]	59/59	Stretching, aerobics, step exercises	Medical treatment	6 months	Cardiac death, recurrence of myocardial infarction, coronary restenosis, repeat revascularization
Cui *et al*. 2006 [13]	26/31	Walking, boating, cycling	Medical treatment	3 months	Maximum exercise endurance, total exercise duration, angina pectoris
Mei *et al*. 2009 [14]	150/150	walk	routine care	6~38 months	Coronary artery restenosis, recurrent angina
Niu *et al*. 2017 [15]	132/124	Calisthenics, fast/slow walking	Medical treatment	12 months	Recurrence of myocardial infarction, recurrent angina, cardiac death
Hansen *et al*. 2009 [16]	194/245	Treadmill, cycling, rocker exercise, *etc*.	Medical treatment	24 months	Cardiac death, repeat revascularization
Dendale *et al*. 2005 [17]	140/83	Treadmill, bicycle, rocker exercise	Medical treatment	3 months	Recurrence of myocardial infarction, recurrent angina, coronary restenosis, cardiac death, repeat revascularization
Lee *et al*. 2013 [18]	37/39	Running, cycling, self-management exercise	Routine care	9 months	Late lumen loss
Munk *et al*. 2009 [19]	74/74	Cycling, running, stretching	Routine nursing allied health education	6 months	Late lumen loss

Table 2. Quality evaluation of included literature.

Included documents	Randomly assigned	Allocation hidden	Blind method	Full data report	Optional results reporting	Other sources of bias	Rating
Wu *et al*. 2013 [9]	low risk	low risk	low risk	low risk	low risk	low risk	Class A
Hofman-Bang *et al*. 1999 [10]	low risk	high risk	high risk	low risk	low risk	low risk	Class B
Liu *et al*. 2015 [11]	low risk	not sure	high risk	low risk	low risk	low risk	Class B
Belardinelli *et al*. 2001 [12]	low risk	not sure	low risk	low risk	low risk	low risk	Class B
Cui *et al*. 2006 [13]	low risk	not sure	high risk	low risk	low risk	low risk	Class B
Mei *et al*. 2009 [14]	low risk	high risk	high risk	low risk	low risk	low risk	Class B
Niu *et al*. 2017 [15]	low risk	not sure	high risk	low risk	low risk	low risk	Class B
Hansen *et al*. 2009 [16]	low risk	not sure	high risk	low risk	low risk	low risk	Class B
Dendale *et al*. 2005 [17]	low risk	not sure	high risk	low risk	low risk	low risk	Class B
Lee *et al*. 2013 [18]	low risk	low risk	high risk	low risk	low risk	low risk	Class B
Munk *et al*. 2009 [19]	low risk	low risk	high risk	low risk	low risk	low risk	Class B

$I^2 > 50\%$, it reveals that there is obvious heterogeneity among the literatures. Random effect model is opted to analyze. Publication bias was evaluated visually using funnel plots and statistically via Egger's regression test.

Results

Document Retrieval Process

1073 articles were obtained by preliminary screening, 740 articles were obtained after excluding repetitive documents and those unrelated to the subject, and 11 articles were finally obtained after reading titles, abstracts and full texts [9–19]. The flow chart of literature retrieval is as follows in Fig. 1.

Basic Traits of Inclusion in the Literature

All the 11 articles are RCT, including 5 English articles and 5 Chinese articles, published from 1999 to 2017. 1823 sufferers undergoing PCI were enrolled in the study, of which 917 patients received exercise-based cardiac rehabilitation therapy combined with drug intervention, and 906 patients received routine nursing and drug intervention with a follow-up time from 3 to 38 months. The basic traits included in the documents are as follows in Table 1 (Ref. [9–19]).

Quality Evaluation of Included Literature

Of the 11 articles, 1 was rated as grade A and 10 as grade B. All the literatures mentioned the generation of random methods, 2 articles related to the use of blind methods, 9 articles mentioned distributive hiding, all literatures had complete data reports and no other sources of bias. The quality evaluation of the included documents is shown in Table 2 (Ref. [9–19]) and Fig. 2.

Publication Bias

Publication bias was assessed visually using funnel plots. The funnel plot for the meta-analysis of exercise-based cardiac rehabilitation on patients undergoing PCI is shown in Fig. 3. The funnel plot displayed an overall even distribution with six literature studies distributed on the right side and four on the left side. The 11 papers (Ref. [9–19]) have good left-right symmetry of funnel plot and therefore may not have publication bias. In addition, publication bias was evaluated statistically through Egger's regression test. The results of Egger's test was $t = -4.31$, $p < 0.001$, which was statistically significant. Consequently, it can be inferred that this meta-analysis is subject to a certain degree of publication bias.

Meta Analysis

Cardiac Death

Five studies investigated the cardiogenic mortality of the two groups of patients, and heterogeneity was not found between the two groups (I^2 0% quotient 0.61). Fixed effect model was selected for analysis. The forest map revealed that the cardiogenic mortality in the test group was sharply lower than that in the control group [RR = 0.23, 95% CI (0.08, 0.64), $p < 0.05$]. Fig. 4 is as follows.

Recurrence of Myocardial Infarction

Five literatures determined the recurrence rate of myocardial infarction in the two groups, and heterogeneity was not found between the two groups (I^2 0.0% quotient 0.85). Fixed effect model was selected for analysis. The forest map exhibited the lack of obvious difference in the recurrence rate of myocardial infarction between the test group and the control group [RR = 0.52, 95% CI (0.22, 1.25), $p > 0.05$]. Fig. 5 is presented below.

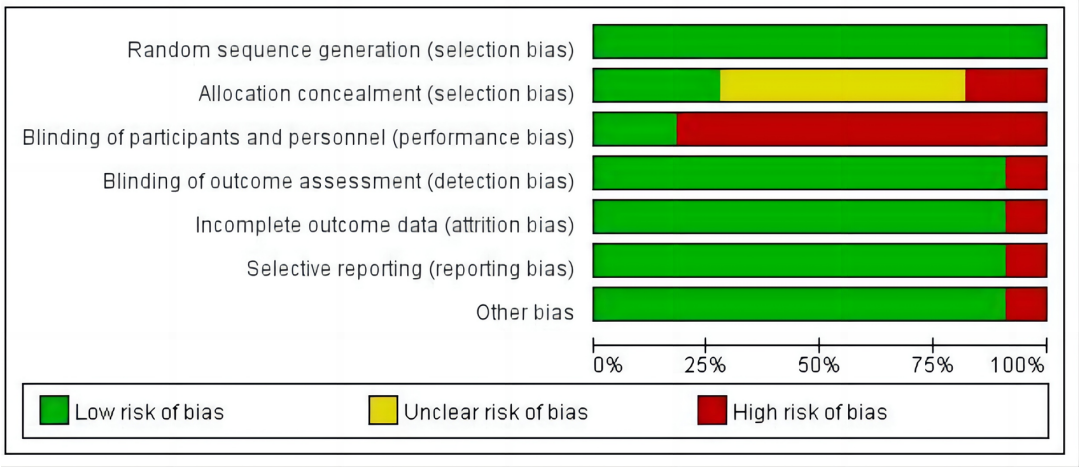

Fig. 2. Quality evaluation of included literature.

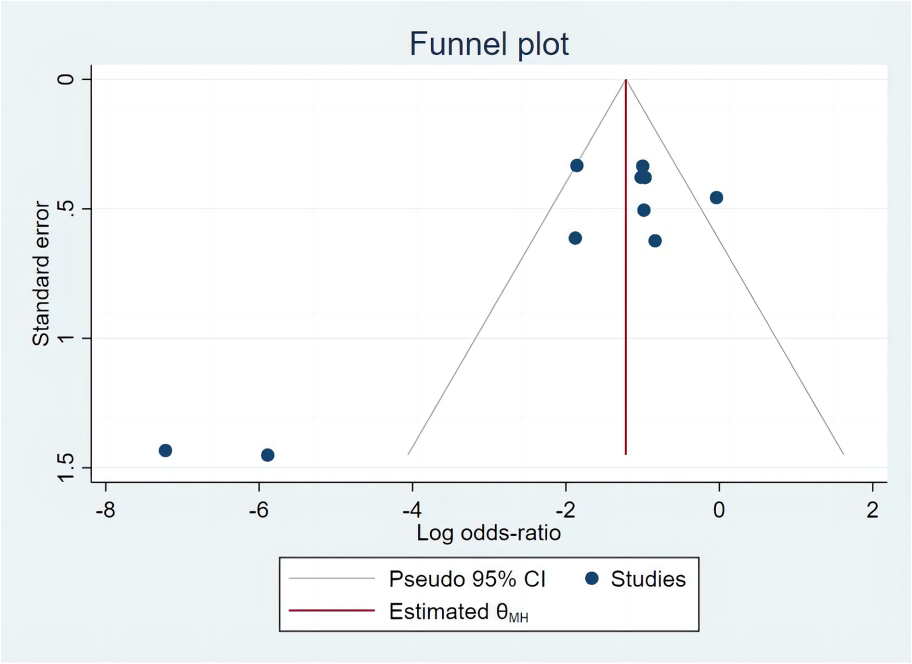

Fig. 3. Funnel plot of the meta-analysis of exercise-based cardiac rehabilitation on patients undergoing percutaneous coronary intervention (PCI). CI, Confidence Interval; MH, Mantel-Haenszel.

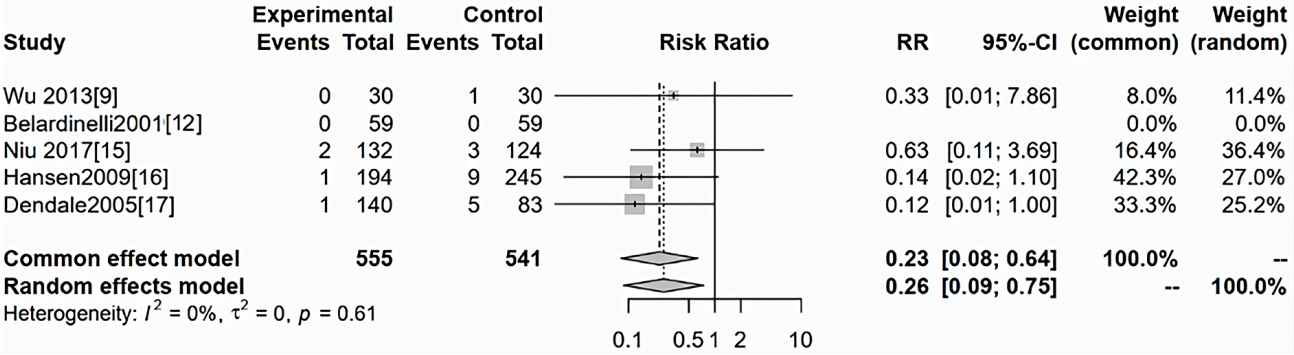

Fig. 4. Forest map of comparison of cardiogenic mortality between two groups of patients. RR, Risk Ratio.

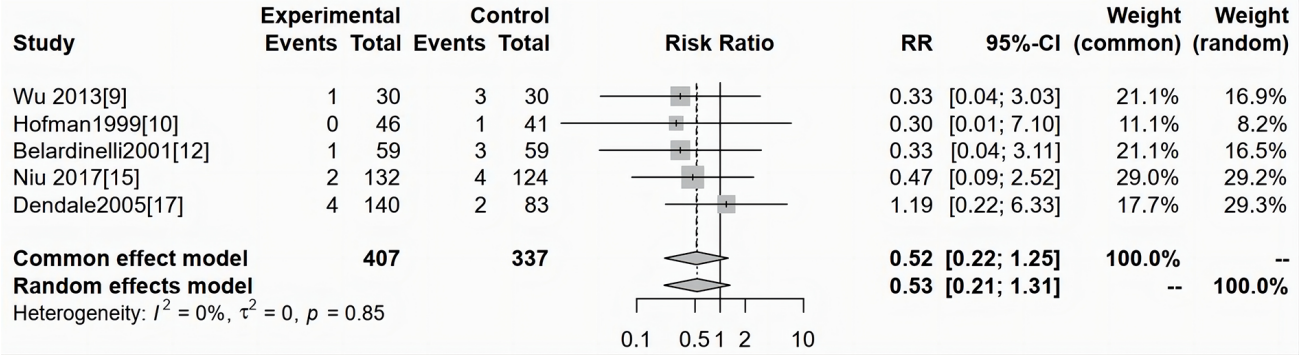

Fig. 5. Forest map of comparison of recurrence rate of myocardial infarction between two groups of patients.

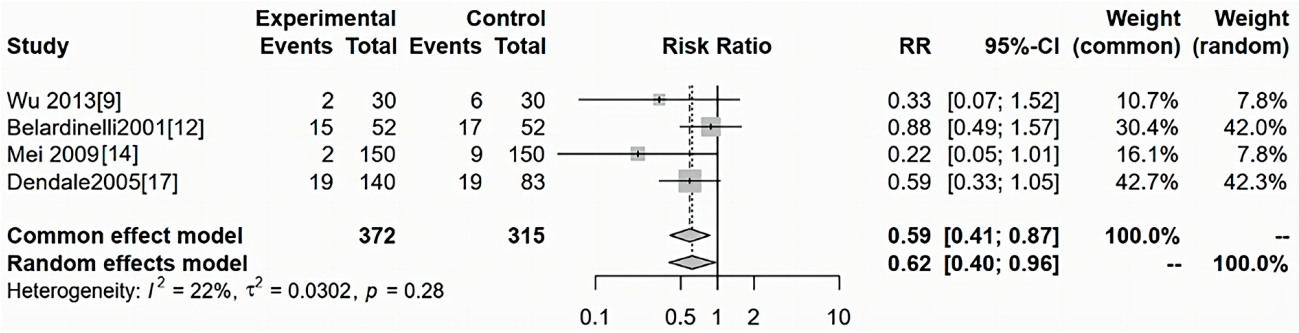

Fig. 6. Forest map of comparison of coronary restenosis rates between two groups of patients.

Coronary Restenosis Rate

Four studies evaluated the recurrence rate of myocardial infarction in the two groups, and heterogeneity was not found between the two groups (I^2 22% quotient 0.28). Fixed effect model was selected for analysis. The forest map indicated that the rate of coronary restenosis in the test group was sharply lower than that in the control group [RR = 0.59, 95% CI (0.41, 0.87), $p < 0.05$]. Fig. 6 is presented as follows.

Revascularization Again

Four studies assessed the revascularization rate of the two groups of patients, and heterogeneity was not found between the two groups patients (I^2 34% recuperative 0.21). The fixed effect model was opted to analyze. The forest map implied that the revascularization rate in the test group was sharply lower than that in the control group [RR = 0.58, 95% CI (0.43, 0.79), $p < 0.05$]. Fig. 7 is presented as follows.

Recurrent Angina Pectoris

Five literatures studied the incidence of recurrent angina pectoris in the two groups of patients, and no heterogeneity was found between the two groups (I^2 34% quotient 0.87). Fixed effect model was selected to analyze. The forest map revealed that the incidence of recurrent angina pectoris in the test group was sharply lower than that in the control group [RR = 0.41, 95% CI (0.27, 0.62); Fig. 8].

Late Lumen Loss

Two literatures studied the degree of late lumen loss in the two groups of sufferers, and heterogeneity was not found between the two groups (I^2 0.00% quotient 0.62). Fixed effect model was opted for analysis. The forest map indicated that the degree of late lumen loss in the test group was sharply lower than that in the control group [RR = –0.60, 95% CI (–0.98, –0.23), $p < 0.05$]. See Fig. 9.

Discussion

PCI is the main therapy for coronary heart disease. The mature application of this method improves the clinical curative effect and prognosis of patients with coronary heart disease [20]. However, PCI cannot inhibit the process of coronary atherosclerosis, the life, health, and safety of patients remain under great threat; the 10-year mortality rate is still more than 30% [3,21]. Rehabilitation medicine experienced a spurt progress, and exercise-based cardiac rehabilitation therapy has entered people's field of vision and gradually applied to the postoperative rehabilitation of patients with PCI; related literature shows that this model can significantly enhance the cardiac function of patients after PCI [22–24].

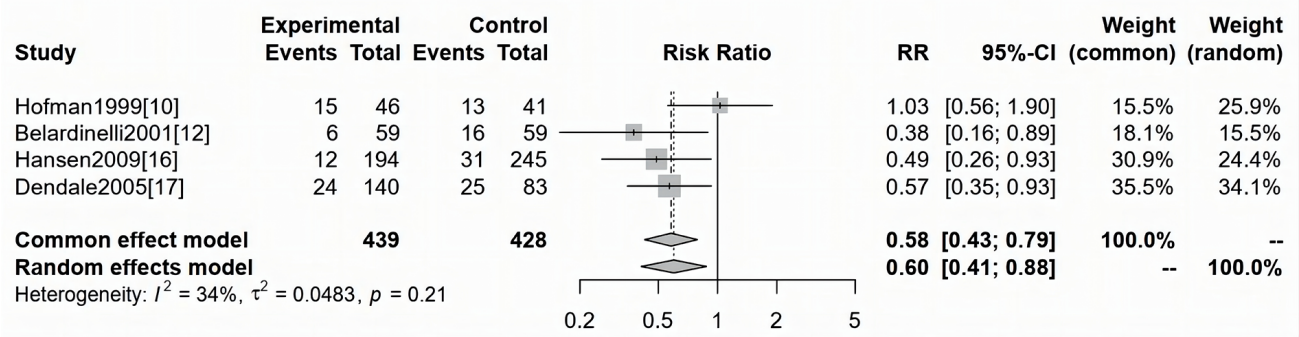

Fig. 7. Comparison of forest map of revascularization between two groups of patients.

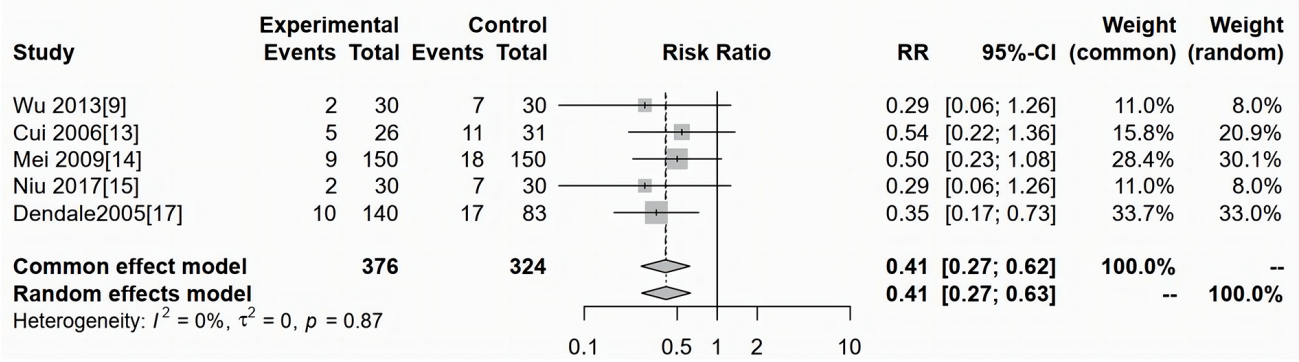

Fig. 8. Forest map of two groups of patients with recurrent angina pectoris.

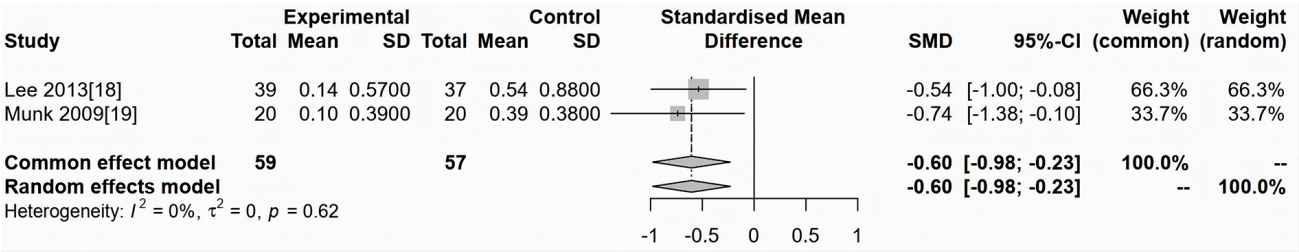

Fig. 9. Forest map of comparison of late lumen loss between two groups of patients. SD, Standard Deviation; SMD, Standardized Mean Difference.

Controversy exists with regard to the influence of exercise-based cardiac rehabilitation therapy for patients after PCI, and systematic analysis has not been conducted yet. The present study aims to analyze it to provide new ideas for clinical decision-making. This survey included 11 literatures with 1823 sufferers undergoing PCI. The meta-analysis indicated that cardiogenic mortality, coronary restenosis rate, revascularization rate, incidence of recurrent angina pectoris, and late lumen loss in the test group were sharply lower than those in the control group ($p < 0.05$). This finding is basically consistent with the research results of Fu C and others [25]. Exercise-based cardiac rehabilitation therapy is a multi-disciplinary cooperative intervention model that can significantly improve the systematic and scientific nature of PCI treatment for patients and help to maximize the advantages of multi-disciplines to promote the postoperative recovery of patients and reduce the risk of major adverse cardiovascular and cerebrovascular events [26,27]. This model can also effectively enhance the adaptability of patients after PCI to exercise and improve their exercise endurance. In addition, long-term exercise can enhance their cardiac tolerance, change the coronary blood flow velocity, promote the dissolution of lipid plaques, and carry a great deal of weight in improving the cardiac function of patients after operation [28,29]. However, this study also revealed that no obvious difference had been found in the recurrence rate of myocardial infarction between the test group and the control group ($p > 0.05$). Only a few previous studies and a short follow-up time from 3 to 38 months were reported so researchers do not have enough time to observe the recurrence of myocardial infarction in patients after PCI. However, according to the collected data, although no significant difference was found in myocardial infarction recurrence rate between the

two groups, exercise-based cardiac rehabilitation tends to decline the risk of myocardial infarction recurrence.

This study has some shortcomings: (1) the number of included literature is limited and the sample size is small, which may influence the analysis of the research outcomes; (2) the follow-up time of some literature is short, and its long-term effect remains to be further verified; and (3) differences in intervention time and outcome indicators included in the literature. Although the subjects are all patients after PCI, there are differences in medical level and intervention measures in different countries, regions and hospitals, resulting in certain bias.

Conclusion

Exercise-based cardiac rehabilitation therapy can effectively reduce the risk of major adverse cardiocerebrovascular events, such as cardiogenic death and coronary restenosis after PCI, reduce the late lumen loss of stent coronary segment, and has no obvious effect on the recurrence of myocardial infarction. However, according to the relevant data, this therapy tends to reduce the recurrence rate of myocardial infarction. In the future research, we will conduct higher quality research and increase the follow-up time to determine the clinical efficacy of exercise-based cardiac rehabilitation therapy on sufferers after PCI and offer new ideas to ameliorate the prognosis and quality of life of patients after PCI.

Availability of Data and Materials

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

Author Contributions

XB and WH designed the study; all authors conducted the study; WH and LF collected and analyzed the data; XB and LF 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

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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.7287.

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