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Systematic Evaluation and Meta-analysis of the Effects of Phase I Cardiac Rehabilitation on Heart Function of Patients after Percutaneous Coronary Intervention

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Abstract: *Objective*: To systematically evaluate the impact of phase I cardiac rehabilitation exercise prescriptions on cardiac function levels in patients after coronary intervention. *Methods*: Seven Chinese and English databases, including Cochrane Library, PubMed, Web of Science, ESC (European Society of Cardiology), and CNKI, as well as professional association websites, were searched using computers, with manual searching as a complement. Relevant literature published from the establishment of the database to February 2025 was retrieved. Two researchers independently screened the literature, extracted data, and evaluated the quality of the literature. Meta-analysis was performed using RevMan 5.3 software. *Results*: A total of 8 articles were included, involving 843 patients. Meta-analysis results showed that compared with routine nursing, phase I cardiac rehabilitation exercise prescriptions helped increase the 6-minute walking distance in patients after coronary intervention [*MD* = 0.84, 95% *CI* (0.57, 1.10), $P < 0.001$], increase the level of left ventricular ejection fraction in patients after coronary intervention [*MD* = 0.67, 95% *CI* (0.33, 1.00), $P < 0.001$], and cardiac rehabilitation combined with respiratory rehabilitation exercise could improve the level of left ventricular ejection fraction in patients after coronary intervention [*MD* = 0.58, 95% *CI* (0.40, 0.76), $P < 0.001$]. *Conclusion*: The implementation of phase I cardiac rehabilitation exercise prescriptions can help improve cardiac function levels in patients after coronary intervention. However, the standardization of outcome evaluation indicators needs to be improved, and the long-term effects of rehabilitation still require verification through a large number of high-quality studies.

Keywords: Cardiac rehabilitation; PCI; Exercise; Cardiac function; Systematic evaluation

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1. Introduction

Cardiovascular disease (CVD) is one of the leading causes of death and disability worldwide, and the prevalence and mortality rates of CVD in China have been increasing year by year [1]. The "Report on Cardiovascular Health and Diseases in China 2023" estimates that there are 330 million people currently suffering from CVD, including 11.39 million with coronary heart disease (CHD). According to data from the Global Burden of Disease Study (GBD), the age-standardized incidence rate of CVD among people aged 1–79 in China increased from 646.2 per 100,000 person-years in 1990 to 652.2 per 100,000 person-years in 2019 [2]. Globally, it is estimated that the total cost of CVD will rise to an astonishing $1,044 billion by 2030 [3]. The "China Health Statistics Yearbook 2022" indicates that cardiovascular disease (CVD) accounts for the highest proportion of deaths from diseases among urban and rural residents, with 48.98% and 47.35% of deaths in rural and urban areas, respectively, in 2021 [4]. Acute coronary syndrome (ACS) is an important component of CVD, and percutaneous coronary intervention (PCI) is a crucial treatment method for ACS that has been widely used in China in recent years [5]. PCI can quickly restore coronary blood flow, improve symptoms of myocardial ischemia, and reduce the risk of cardiovascular events [6]. However, despite successful PCI, patients still face high cardiovascular risks such as restenosis, arrhythmia, and heart failure [7]. Additionally, there are various issues such as the impact of bed rest, decreased exercise capacity, and large individual differences. Therefore, postoperative rehabilitation treatment is crucial [8].

Cardiac rehabilitation is a comprehensive medical measure designed to help patients with CVD restore heart function and improve quality of life through various means such as exercise training, nutritional support, psychological intervention, and drug treatment [9]. As an essential component of secondary prevention of CVD, a reasonable exercise prescription can enhance myocardial contractility, improve blood circulation to the heart, and increase the heart's reserve function [10, 11]. Cardiac rehabilitation can effectively reduce the recurrence rate and mortality of CVD [12]. Many countries have developed guidelines and standards for cardiac rehabilitation, emphasizing its importance in the prevention and treatment of CVD [13, 14]. China's cardiac rehabilitation industry has also made significant progress in recent years [15]. China has released the "Chinese Expert Consensus on Coronary Heart Disease Rehabilitation and Secondary Prevention" and the "Guidelines for Cardiovascular Disease Rehabilitation/Secondary Prevention in China (2015 Edition)", further standardizing the process and methods of cardiac rehabilitation [16, 17].

Phase I cardiac rehabilitation refers to early cardiac rehabilitation treatment that patients undergo during hospitalization, typically beginning 2–3 days after PCI [18]. It mainly promotes patients' physical recovery, prevents the occurrence of complications, and improves patients' self-confidence and ability to live independently [19]. Phase I cardiac rehabilitation effectively improves heart function, increases left ventricular ejection fraction (LVEF), and reduces left ventricular end-diastolic diameter (LVEDD) in patients after PCI [20, 21]. Additionally, it can improve myocardial metabolism and remodeling, reduce myocardial cell apoptosis and necrosis, and enhance myocardial endurance and anti-ischemic ability [22, 23]. By developing personalized exercise prescriptions, patients' exercise intensity and volume are gradually increased, improving their cardiopulmonary function and exercise endurance [24–26].

The burden of CVD in China is heavy. Acute coronary syndrome (ACS) is a significant component of CVD, and percutaneous coronary intervention (PCI) is a crucial treatment method for ACS [27]. Despite advancements in PCI technology, the rehabilitation outcomes for postoperative patients remain unsatisfactory, with high recurrence rates and mortality rates of cardiovascular events [28–30]. Therefore, postoperative cardiac rehabilitation based on exercise is particularly important for patients after PCI. Currently, there are still some issues in cardiac rehabilitation treatment for patients after PCI, such as non-standardized cardiac rehabilitation programs and

unscientific rehabilitation training [31, 32]. Specifically, further evidence-based medical evidence is needed to support the specific effects and measures for improving patients' heart function levels. Therefore, this study systematically and comprehensively evaluates the impact of Phase I cardiac rehabilitation exercise prescriptions on the heart function levels of patients after coronary intervention through a systematic review method, providing a reference for continuous improvement in early rehabilitation nursing for patients after coronary intervention.

2. Materials and methods

2.1. Inclusion and exclusion criteria

Inclusion and exclusion criteria are determined based on the PICOS principle.

Inclusion criteria are as follows: (1) Study population (P) consisted of patients aged ≥ 18 years who underwent coronary intervention; (2) Intervention (I) involved the implementation of a phase I cardiac rehabilitation exercise prescription; (3) Control intervention (C) included patients receiving routine care or no cardiac rehabilitation measures; (4) Outcome measures (O) included left ventricular ejection fraction, 6-minute walk test distance, and left ventricular end-diastolic diameter; (5) Study design (S) was randomized controlled trials to enhance the reliability of the research findings.

Exclusion criteria are: (1) Non-Chinese and non-English literature; (2) Duplicate publications or literature with incomplete data; (3) Literature where the full text was unavailable.

2.2. Literature search strategy

Computer searches are conducted in Chinese databases, including CNKI, WanFang Database, and VIP Database, as well as English databases such as Cochrane Library, PubMed, Web of Science, and the European Society of Cardiology (ESC). The search period is from the establishment of the databases until February 2025. Manual searches are also performed to trace the references of included literature. A combination of subject headings and free-text terms is used. For example, in PubMed, the search strategy is: ("Percutaneous Coronary Intervention"[Mesh]) AND [("Exercise"[Mesh]) OR ("Cardiac Rehabilitation"[Mesh])] AND (("Heart Function Tests"[Mesh]) OR ("Walk Test"[Mesh]) OR (Left ventricular end-diastolic diameter) OR (left ventricular ejection fraction)).

2.3. Literature screening and data extraction

After removing duplicates using Zotero 7.0 software, two graduate students trained in evidence-based nursing independently screened the literature by reading titles and abstracts, excluding clearly irrelevant articles. They then read the full texts for further screening and data extraction. A third researcher intervened in case of disagreement. Extracted information included: author, publication year, country, basic characteristics of the study population, intervention measures (experimental and control groups), intervention duration, and outcome measures.

2.4. Literature quality evaluation

The two researchers who extracted data independently evaluated the quality of the literature using the Cochrane Collaboration's risk of bias tool for randomized controlled trials. The tool consists of seven items, each rated as "low risk," "uncertain," or "high risk." Studies that fully met the criteria are considered to have the lowest risk of bias (quality grade A). Those that partially met the criteria are considered to have a moderate risk of bias (grade B).

Studies that did not meet the criteria are considered to have a high risk of bias (grade C) and are excluded.

2.5. Statistical methods

Statistical analysis is performed using RevMan 5.3 software. Continuous data are expressed as mean differences (*MD*) with 95% confidence intervals (*CI*). The chi-square test is used to determine the presence of heterogeneity among studies, with $P > 0.05$ and $I^2 < 50\%$ as the criteria for homogeneity. If both statistical conditions are met, a fixed-effects model is used for analysis. If one of the conditions is not met, indicating heterogeneity among studies, a random-effects model is applied. A $P < 0.05$ is considered statistically significant.

3. Results

3.1. Literature screening results

Initially, 1352 articles were retrieved. After screening, 8 articles were finally included, including 3 in English and 5 in Chinese [33–40]. The literature screening process and results are shown in **Figure 1**.

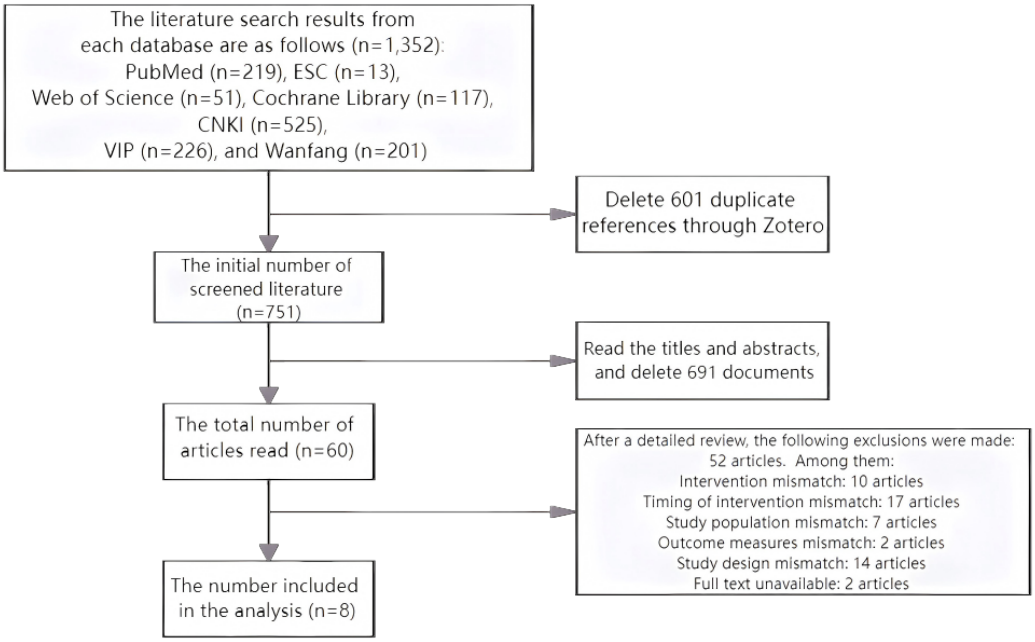

Figure 1. Flowchart of literature screening

3.2. Basic characteristics of included literature

The publication dates of the included literature ranged from 2017 to 2023, involving a total of 843 patients who underwent coronary intervention, with 422 in the experimental group and 421 in the control group. The basic characteristics of the included literature are shown in **Table 1**.

Table 1. Basic characteristics of included literature (n=8)

Included literature	Year	Country	Intervention group				Control group intervention	Outcome measures
			Sample size (E/C)	Intervention measures	Intervention method	Intervention duration		
Firoozeh Abtahi *et al.* [33]	2017	Iran	25/25	Comprehensive Cardiac Rehabilitation Program	Exercise training	Starting post-PCI, lasting 8 weeks	Risk factor management guidance only	LVEF, LVESD, LVM
Ming-Gui Chen *et al.* [34]	2020	China	48/48	Baduanjin Exercise Training	Inpatient: Seated Baduanjin; Post-discharge: Standing Baduanjin	Starting the second day post-PCI, lasting 24 weeks	Routine care	Quality of life, LVEF, BNP, BMI, Waist circumference
Liao Y [35]	2020	China	43/43	Individualized Cardiac Rehabilitation Training	Including respiratory training, rehabilitation exercises	Starting the second day post-PCI, lasting 24 weeks	Routine care	Exercise compliance, Cardiac function, Cardiovascular adverse events
Bai FF *et al.* [36]	2020	China	125/125	Cardiac Rehabilitation Content	Health education, exercise rehabilitation & daily activity guidance, psychological intervention, smoking cessation management, nutritional management	Starting post-PCI, lasting 12 months	Routine drug therapy	Cardiopulmonary assessment, Psychological assessment, Quality of life, Smoking cessation rate, Cardiovascular event rate
Chen Q *et al.* [37]	2020	China	54/ 53	Cardiac Rehabilitation Therapy	Phase I (in-hospital), Phase II (1st month post-discharge), Phase III (1-6 months post-discharge)	Starting post-PCI, lasting 6 months	Routine rehabilitation therapy	Vascular endothelial indicators, Cardiac function indicators, Psychological cognitive status
Minghui Jiang *et al.* [38]	2021	China	49/49	Progressive Kinetic Exercise	Including bed mobility assistance, respiratory training, stretching exercises, etc.	Starting post-PCI, lasting 6 months	Routine intervention	Cardiac function and Quality of life, Adverse event rate and Motor function
Zhou Y *et al.* [39]	2023	China	30/30	Early Cardiac Rehabilitation Training	Exercise Training	Starting post-PCI	Routine drug therapy	LVEF, 6MWD, Quality of life score, Major adverse cardiovascular event (MACE) rate
Xu Y *et al.* [40]	2023	China	48/48	Phase I Cardiac Rehabilitation Exercise	Respiratory training, Exercise training		Routine care	Cardiac function, Adverse reaction rate, Activities of daily living (ADL)

3.3. Methodological quality evaluation results of included literature

All 8 articles included were graded as B in quality, indicating a relatively high overall quality of the included literature. The methodological quality evaluation results of the included literature are shown in **Figure 2**.

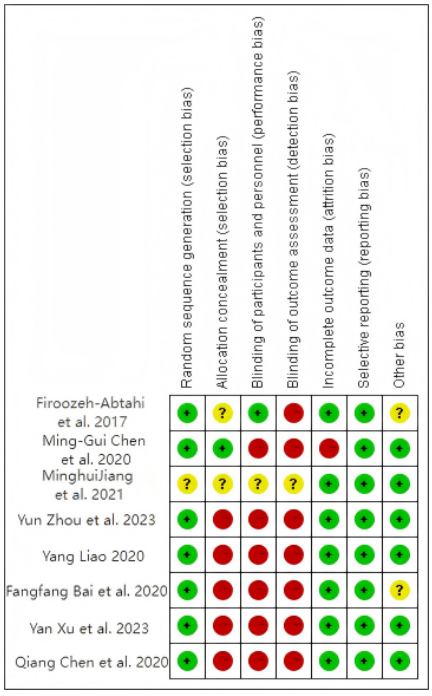

Figure 2. Methodological quality evaluation results of included literature (n=8)

3.4. Meta-analysis and descriptive analysis results

3.4.1. Left ventricular end-diastolic diameter

Data from 5 articles [33,36–38,40] were included in the analysis. A random effects model was used for analysis (P < 0.01, I^2 = 94%). The results showed no statistically significant difference in left ventricular end-diastolic diameter between the two groups [MD = 0.13, 95% CI (-0.61, 0.87), P = 0.73], as shown in **Figure 3**.

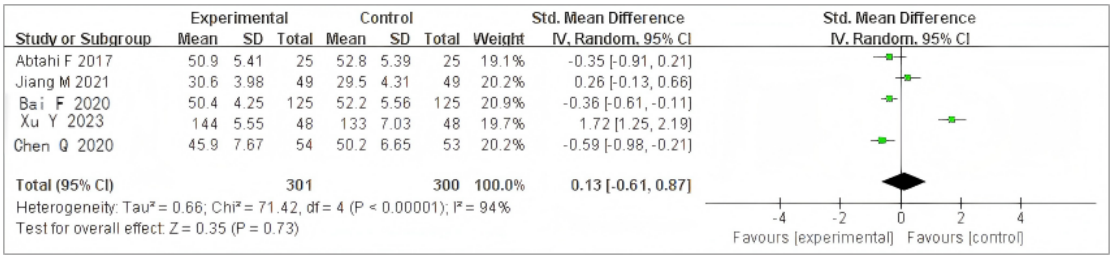

Figure 3. Forest plot of left ventricular end-diastolic diameter

3.4.2. 6-minute walk test distance

Data from 3 articles were included in the analysis [35,39, 40]. A fixed effects model was used for analysis (P = 0.44, I^2 = 0%). The results showed that the 6-minute walk distance in the experimental group was higher than that in the control group, and the difference was statistically significant [MD = 0.84, 95% CI (0.57, 1.10), P < 0.01], as shown in **Figure 4**.

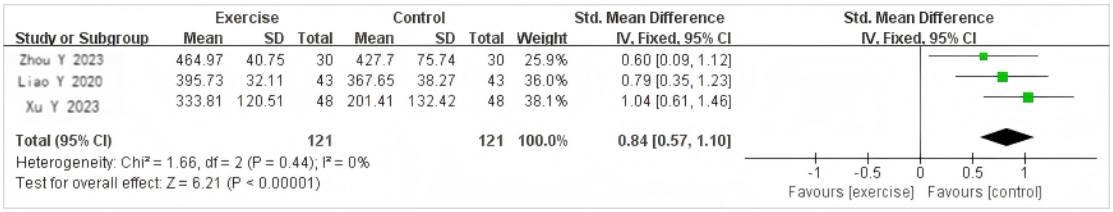

Figure 4. Forest plot of 6-minute walk test distance

3.4.3. Left ventricular ejection fraction

Data from 8 articles were included in the analysis [33–40]. A random effects model was used for analysis ($P < 0.01$, $I^2 = 81\%$). The results showed that the left ventricular ejection fraction in the experimental group was higher than that in the control group, and the difference was statistically significant [*MD* = 0.67, 95% *CI* (0.33, 1.00), $P < 0.01$], as shown in **Figure 5**. Among them, 4 articles adopted cardiac rehabilitation combined with respiratory rehabilitation training and could be combined for analysis [35–37, 39]. The heterogeneity among subgroups was moderate ($P = 0.18$, $I^2 = 39\%$). A random effects model was used for analysis. The subgroup analysis results showed that the left ventricular ejection fraction in the experimental group was higher than that in the control group, and the difference was statistically significant [*MD* = 0.58, 95% *CI* (0.40, 0.76), $P < 0.01$], as shown in **Figure 6**.

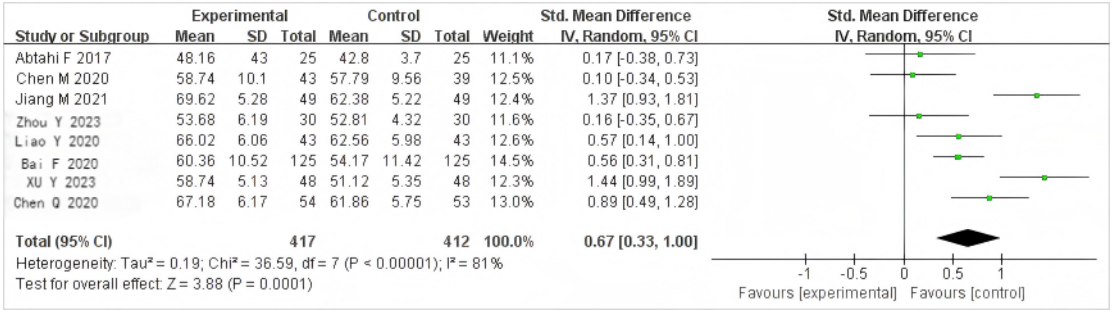

Figure 5. Forest plot of left ventricular ejection fraction

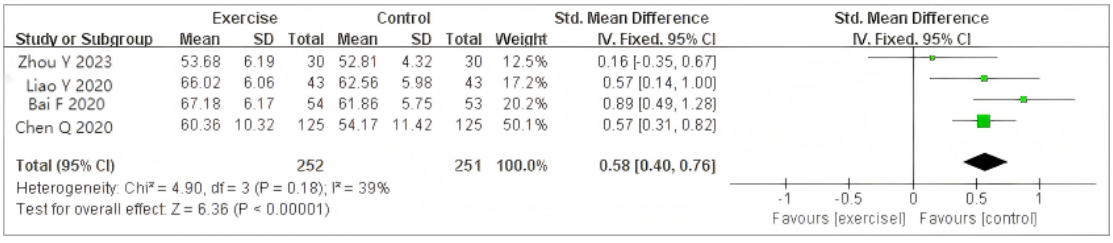

Figure 6. Subgroup analysis forest plot of left ventricular ejection fraction

3.5. Publication bias

In this study, less than 10 articles were included, so a funnel plot was not drawn.

4. Discussion

4.1. Phase I cardiac rehabilitation exercise prescription helps improve 6-minute walk test distance for patients after coronary intervention

The 6-minute walk distance (6MWD) is not only a commonly used indicator reflecting the cardiopulmonary

function of patients after coronary intervention, but also an objective evaluation index of patients' rehabilitation progress and treatment effect. Research has shown that Phase I cardiac rehabilitation focuses on evaluating and training patients' exercise capacity [24]. By developing personalized exercise prescriptions, patients' exercise intensity and volume are gradually increased, improving their cardiopulmonary function and exercise endurance. Study indicates that Phase I cardiac rehabilitation can significantly improve the 6-minute walk distance (6MWD) and cardiopulmonary exercise test indicators, such as maximal oxygen uptake and anaerobic threshold, for patients after PCI [25]. This study found that in improving the 6-minute walk test distance after coronary intervention, the Phase I cardiac rehabilitation exercise prescription is superior to traditional care. However, due to the limited number of studies that can be combined and analyzed under this outcome indicator, high-quality research is still needed for further verification.

4.2. Phase I cardiac rehabilitation exercise prescription contributes to improving left ventricular ejection fraction levels for patients after coronary intervention

According to research, early cardiac rehabilitation can alleviate myocardial ischemia, increase exercise tolerance, inhibit myocardial necrosis and apoptosis, reverse ventricular remodeling and myocardial remodeling, and enhance patients' heart function [22]. The results of this study suggest that the Phase I cardiac rehabilitation exercise prescription is beneficial for improving the left ventricular ejection fraction level of patients after coronary intervention. Based on the subgroup analysis results, it is hinted that combining cardiac rehabilitation exercise prescriptions with respiratory rehabilitation has a better effect on enhancing the left ventricular ejection fraction level for patients after coronary intervention. Future research can explore the integration of cardiopulmonary rehabilitation training and develop more personalized rehabilitation strategies to enhance the rehabilitation outcomes for patients after coronary intervention.

4.3. Limitations and prospects of this study

This study has certain limitations. For instance, the searched databases are limited, and the existing Chinese and English databases and professional association websites are not fully covered. The sample sizes in the included literature are all limited, and the subjects come from different countries and regions with age variations. The specific implementation process of the cardiac rehabilitation exercise prescription is difficult to ensure homogeneity. Based on the results of this study, it is suggested to optimize the exercise prescription of the cardiac rehabilitation program, improve the quality of cardiac rehabilitation, and promote the clinical application of Phase I cardiac rehabilitation for patients after PCI.

5. Conclusion

This study comprehensively evaluated the impact of the Phase I cardiac rehabilitation exercise prescription on the cardiac function levels of patients after coronary intervention. It initially confirmed that the Phase I cardiac rehabilitation exercise prescription can promote the improvement of the 6-minute walk distance and left ventricular ejection fraction. Combining it with respiratory rehabilitation training can be more effective than conventional nursing care, which can promote the clinical application of the Phase I cardiac rehabilitation exercise prescription to a certain extent.

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Disclosure statement

The authors declare no conflict of interest.

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