Cardiovascular Reviews, 2026, Volume 4, Issue 1
http://ojs.bbwpublisher.com/index.php/CR
Online ISSN: 2981-8109
Print ISSN: 3083-4880

Research Advances in Cardiac Rehabilitation Following Coronary Interventions

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Abstract: Coronary heart disease (CHD) is a common chronic cardiovascular condition that significantly impacts public health. With the accelerating trend of population aging in China, the prevalence of CHD continues to rise. Currently, percutaneous coronary intervention (PCI) serves as the primary method for revascularization in CHD, effectively improving patient prognosis and quality of life. However, cardiac rehabilitation nursing, a crucial component of the PCI system, remains underemphasized and underutilized in clinical practice. This paper systematically reviews research advances in post-PCI cardiac rehabilitation and nursing, aiming to integrate existing evidence and provide scientific, standardized references for clinical practice, thereby promoting the standardized implementation of secondary prevention for CHD.

Keywords: Coronary heart disease; Percutaneous coronary intervention; Cardiac rehabilitation; Precision exercise intervention; Telemedicine; Integrated Chinese and Western medicine; Multidisciplinary collaboration

Online publication: March 19, 2026

1. Introduction

Data from the 2023 China Cardiovascular Health and Disease Report indicates that China currently has 11.39 million people living with coronary heart disease, with over 1.5 million new cases annually. Percutaneous coronary intervention (PCI), as the core revascularization method, exceeded 1.28 million procedures nationwide in 2024.While PCI rapidly relieves mechanical coronary artery stenosis and restores myocardial perfusion, it addresses only localized lesions and cannot reverse the pathophysiological progression of coronary atherosclerosis. Consequently, long-term major adverse cardiovascular events (MACE) remain high postoperatively, with a 1-year myocardial infarction recurrence rate of 3.2%,and a cardiac mortality rate of 1.5%. Additionally, 42% of patients experience reduced exercise tolerance, and 35% develop psychological disorders such as anxiety and depression. Cardiac rehabilitation (CR), a multidimensional intervention encompassing exercise training, psychological support, health education, nutritional guidance, and medication adherence management, is listed as a Class I

recommendation (Grade A evidence) in the Percutaneous Coronary Intervention Guidelines (2025) for post-PCI care. While PCI rehabilitation participation rates exceed 70% in Western countries, China's rate remains below 15%, with significant regional disparities in rehabilitation quality and a lack of standardized implementation pathways. Recent breakthroughs in cardiopulmonary exercise testing (CPET), remote monitoring technologies, and evidence-based research integrating Chinese and Western medicine have substantially enhanced the precision and accessibility of cardiac rehabilitation interventions. This paper systematically reviews the core intervention model innovations, clinical efficacy mechanisms, evidence-based systems, and implementation challenges of post-PCI cardiac rehabilitation based on high-quality literature retrieved from databases such as CNKI over the past five years. It aims to provide theoretical foundations and practical pathways for promoting standardized and homogeneous development of post-PCI cardiac rehabilitation in China.

2. Core intervention models and research advances in post-PCI cardiac rehabilitation

2.1. Exercise rehabilitation: From standardization to individualized precision guidance

As a core component of cardiac rehabilitation, exercise rehabilitation achieves dual objectives: enhancing exercise tolerance and reducing adverse event risks by regulating myocardial energy metabolism, improving vascular endothelial function, and balancing autonomic nervous system activity. Traditional exercise protocols often rely on heart rate reserve (HRR) or the Borg scale of perceived exertion, which meet basic rehabilitation needs but carry risks of "over-rehabilitation" or "under-rehabilitation" due to insufficient consideration of individual myocardial ischemia thresholds, mitochondrial function, and comorbidities. In recent years, with advancing medical research, the application of evidence-based cardiac exercise rehabilitation quality improvement programs in patients undergoing percutaneous coronary intervention for coronary heart disease has become a research focus. Yang *et al.* demonstrated through clinical trials that implementing evidence-based cardiac exercise rehabilitation quality improvement programs during hospitalization for acute myocardial infarction patients following PCI significantly enhances healthcare providers' knowledge of cardiac rehabilitation [1]. This approach effectively promotes early clinical exercise rehabilitation practices, prevents exercise phobia in patients, and accelerates postoperative recovery. Gu *et al.* observed the effects of cardiac rehabilitation exercise therapy on cardiac function and health-related fitness in patients with acute myocardial infarction (AMI) undergoing percutaneous coronary intervention (PCI) [2]. They found that PCI-treated AMI patients receiving cardiac rehabilitation exercise therapy benefited from improved cardiac function, enhanced health-related fitness, increased 6-minute walk distance, and reduced major adverse cardiovascular events (MACE) during the intervention period. Zhang *et al.* emphasized that effective exercise rehabilitation outcomes for 130 PCI-treated AMI patients were achieved through close collaboration among healthcare teams [3].

2.2. Remote cardiac rehabilitation: An innovative approach to addressing accessibility challenges

Traditional outpatient cardiac rehabilitation faces limitations due to geographical constraints, high time costs, and poor adaptability for specific populations (elderly and mobility-impaired patients). Consequently, the national rehabilitation participation rate among PCI patients is only 12.8%, significantly lower than levels in Europe and the United States. Telecardiac Rehabilitation (TCR), leveraging internet technology and mobile health (mHealth) platforms, establishes a rehabilitation model combining "home-based training + remote guidance + real-time

monitoring," offering an effective solution to accessibility challenges. Studies by Pan *et al.* investigated the effects of home-based exercise rehabilitation under remote ECG monitoring guidance on exercise tolerance and quality of life in patients after PCI [4]. Their findings concluded that home-based exercise rehabilitation with remote ECG monitoring significantly improves cardiopulmonary exercise capacity and left ventricular function, stabilizes angina episodes, reduces anxiety and depression levels, enhances sleep quality, and ultimately elevates overall quality of life. Jiang *et al.* developed a remote ECG monitoring system that uses built-in algorithms to identify abnormal waveforms such as ventricular premature beats and ST-segment depression in real time [5]. Upon detecting malignant arrhythmias, it can simultaneously push alert notifications to patients, family members, and attending physicians within 15 seconds. This reduces the intervention response time for adverse events in high-risk patients from 4 hours in traditional models to 15 minutes, and elevates intervention success rates to 92%. This demonstrates that integrating real-time ECG monitoring with intelligent alert technology is a critical enabler for enhancing TCR safety.

2.3. Integrative Chinese-western medicine rehabilitation: Establishing a Chinese-characteristic rehabilitation protocol

The application of traditional Chinese medicine (TCM) in post-PCI rehabilitation has transitioned from empirical practice to evidence-based medicine. The 2025 Guidelines for Percutaneous Coronary Intervention, grounded in high-quality evidence such as the HEARTRIP study, have for the first time incorporated integrated Chinese-Western rehabilitation into the standard post-PCI recovery pathway. This explicitly recognizes the superior role of qi-tonifying and blood-activating TCM formulas in improving exercise tolerance and psychological well-being.

TCM theory posits that the core pathogenesis in PCI patients is "Qi deficiency and blood stasis." While the procedure restores blood flow, it depletes vital energy, leading to insufficient heart Qi and impaired blood circulation. This manifests as dyspnea on exertion, chest tightness, fatigue, and concomitant emotional disturbances like anxiety and depression. Modern research confirms that post-PCI patients commonly exhibit elevated inflammatory markers (IL-6, TNF-α), oxidative stress (increased MDA, decreased SOD), and vascular endothelial dysfunction. These findings objectively correlate with the TCM pattern of "Qi deficiency and blood stasis," where Qi deficiency corresponds to impaired immunity and energy metabolism, while blood stasis relates to microcirculatory disorders and inflammatory responses.

Based on this, integrated Chinese-Western rehabilitation adopts the core principle of "tonifying Qi and activating blood circulation to address both symptoms and root causes." It combines modern rehabilitation with TCM interventions such as herbal medicine and traditional exercises to form a rehabilitation program with Chinese characteristics. Commonly applied interventions include Qi-tonifying and blood-activating Chinese patent medicines, traditional exercises like Baduanjin, and acupoint massage. Among these, research on Chinese patent medicines combined with exercise rehabilitation is the most extensive. Su investigated the clinical efficacy of integrated Chinese and Western medicine therapy on the "dual-heart effect" in patients undergoing coronary stenting for coronary heart disease [6]. The study revealed significant improvements in lipid profiles and marked alleviation of adverse psychological conditions such as anxiety and depression.

Zhang *et al.* compared early rehabilitation indicators of exercise capacity and cardiac function between conventional rehabilitation nursing and an integrated Chinese-Western rehabilitation model in PCI patients [7]. The intervention group demonstrated superior 6MWT and LVE scores at 6 months, higher SF-36 scores for physical functioning, bodily pain, general health, and mental health, and lower MACE incidence during follow-up.

2.4. Multidisciplinary team collaboration in rehabilitation: Achieving comprehensive management

Modern cardiac rehabilitation has evolved from singular exercise guidance to a multidisciplinary team (MDT) model grounded in the biopsychosocial medical paradigm. The core team comprises cardiologists, cardiac rehabilitation specialists, clinical nutritionists, psychologists, specialized nurses, and pharmacists. Through regular consultations (1–2 times weekly), this team delivers comprehensive management of patients' physiological, psychological, nutritional, and pharmacological needs. The core strength of MDT rehabilitation lies in "individualized program development": cardiologists assess myocardial ischemia risk and adjust baseline medications; rehabilitation specialists create exercise prescriptions based on CPET results; nutritionists design personalized dietary plans considering lipid and glucose levels; psychologists intervene for exercise phobia and disease-related anxiety; pharmacists oversee standardized use of antiplatelet drugs and statins while monitoring adverse reactions. Research by Liu *et al.* on post-PCI coronary patients demonstrated that a mobile health-based multidisciplinary collaboration model effectively optimizes rehabilitation outcomes [8]. Through coordinated interventions by cardiologists, rehabilitation specialists, and specialized nurses, combined with mobile device-enabled management covering rehabilitation guidance, medication reminders, and condition monitoring, this approach significantly improves postoperative cardiac function metrics, enhances rehabilitation adherence, while reducing the incidence of adverse cardiovascular events, providing a viable intervention pathway for cardiac rehabilitation in post-PCI patients. Li *et al*.'s study established a multidisciplinary collaborative nursing team integrating expertise from cardiology, nursing, nutrition, and rehabilitation [9]. Tailored collaborative care plans were developed addressing the characteristics of elderly patients, such as diminished physiological function, multiple comorbidities, and poor rehabilitation tolerance. Results demonstrated that this model effectively improved postoperative quality of life and nursing satisfaction among elderly patients while reducing postoperative complications, providing robust practical support for rehabilitation care in elderly patients undergoing coronary intervention.

3. Specific measures for cardiac rehabilitation nursing after interventional treatment for coronary heart disease

Reviewing existing research reveals that specific measures for cardiac rehabilitation nursing after coronary artery disease intervention include the following aspects:

(1) Health awareness intervention: Even after intervention, patients retain multiple risk factors affecting long-term outcomes. Nurses should use plain language to systematically explain the etiology, symptoms, and risk factors of CHD to patients and families, emphasizing the importance of postoperative rehabilitation care to enhance disease awareness and compliance;

(2) Phased rehabilitation exercises: Following coronary intervention, patients remain in the recovery phase. Cardiac rehabilitation nursing during this period must adhere to the principle of gradual progression. Starting on Day 2, gradually introduce resistance limb exercises for approximately 15 minutes, 3 times daily, alongside self-care training (eating, personal hygiene) in bed. On Day 3, patients may practice sitting up with assistance. By Day 4, progress to standing at the bedside and slow walking (50–100 meters) 2–3 times daily. Starting on Day 5, patients may walk 100–200 meters within the ward and gradually incorporate stair climbing exercises. After Day 6, exercise volume and intensity should be progressively increased based on tolerance;

(3) Psychological support and lifestyle guidance: Actively engage patients in communication, truthfully convey surgical outcomes, and identify existing psychological concerns; Provide timely feedback on surgical results through dialogue, address negative emotions, and bolster confidence using successful case examples. Simultaneously, guide patients to adjust dietary patterns by limiting salt and fat intake while increasing fruit and vegetable consumption. In the meantime, establish regular sleep schedules, avoid staying up late, and foster a lifestyle conducive to recovery [10].

4. Future directions for cardiac rehabilitation nursing after coronary artery disease intervention

4.1. Establishing a tiered standardized rehabilitation pathway

Based on the "Guidelines for Percutaneous Coronary Intervention (2025)" and the "Three-Phase Postcardiac Surgery Rehabilitation Guidelines," establish a three-tier rehabilitation pathway: "Hospitalization Phase–Recovery Phase–Maintenance Phase." During hospitalization, initiate early mobilization to reduce deep vein thrombosis risk. In the recovery phase, implement CPET-guided precision exercise combined with remote monitoring. The maintenance phase focuses on home-based rehabilitation, delivering personalized plans via mobile applications. Concurrently, establish training and certification standards for rehabilitation therapists, requiring all practitioners to pass specialized cardiac rehabilitation assessments to ensure program quality.

4.2. Advancing intelligent rehabilitation technology development

Wearable devices, artificial intelligence (AI), and big data technologies should be actively integrated to establish an intelligent rehabilitation platform characterized by smart assessment, dynamic prescription, real-time alerts, and outcome feedback. This platform would enable continuous monitoring of physiological indicators and rehabilitation progress while automatically adjusting exercise intensity to optimize training outcomes. For patients experiencing exercise-related fear or anxiety, virtual reality (VR)-based rehabilitation scenarios may be developed to provide immersive experiences that help reduce psychological resistance and enhance engagement in rehabilitation programs.

4.3. Enhance policy support and public awareness

Expanding medical insurance coverage to include the entire cardiac rehabilitation cycle (three phases) and increasing reimbursement rates to over 70% would help improve patient participation and accessibility. In addition, a "rehabilitation outcomes-linked insurance payment" mechanism should be established, providing subsidies to institutions that demonstrate significant rehabilitation outcomes. Furthermore, research should focus on specialized rehabilitation for vulnerable populations, such as personalized programs for elderly patients (≥ 75 years old) and those with comorbidities such as diabetes or chronic kidney disease. Implementing "Internet + Rehabilitation" models in remote areas will further promote equitable access to rehabilitation services.

5. Conclusion

Post-PCI cardiac rehabilitation has evolved from an adjunct therapy to a core intervention for improving outcomes. To address the current quadruple challenges of insufficient awareness, inconsistent quality, low adherence, and inadequate insurance coverage, solutions include establishing tiered standardized pathways, advancing intelligent

technology applications, strengthening evidence-based research on integrated Chinese and Western medicine, and improving policy safeguards. Looking ahead, the establishment of a "precision-driven, intelligent, and comprehensive" rehabilitation system is expected to elevate post-PCI rehabilitation participation rates to over 60%. This will enable more patients to benefit from standardized rehabilitation treatment, providing critical support for reducing the burden of cardiovascular disease in China.

Funding

Baoding Municipal Science and Technology Plan Project (Project No.: 2541ZF263)

Disclosure statement

The authors declare no conflict of interest.

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