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Review Article

Contemporary Cardiac Rehabilitation: Evolution of Approaches and Remaining Challenges

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Abstract

Cardiovascular Diseases (CVDs) are the leading cause of death globally, with growing prevalence driven by modifiable risk factors including hypertension, dyslipidemia, poor diet, and sedentary lifestyles. A proven multidisciplinary strategy, Cardiac Rehabilitation (CR) enhances survival, functional capacity, and quality of life in patients with CVD. Phase 2, the traditional center-based program, delivers structured, supervised exercise and education immediately after cardiac events, significantly improving cardiovascular fitness. Phase 3 CR emphasizes long-term maintenance, fostering self-directed exercise and lifestyle modification; however, participation often declines without structured support. Exercise modalities, including aerobic, resistance, and high-intensity interval training, produce multi-system physiological adaptations. Beyond exercise, behavioral counseling, psychosocial support, nutritional guidance, smoking cessation, and medication adherence are essential to comprehensive CR. Emerging delivery model such as home-based CR, hybrid, telehealth, and app-supported programmes, address barriers such as accessibility, travel constraints, and adherence while maintaining clinical efficacy. Despite these innovations, challenges persist, including low referral rates, socioeconomic disparities, digital literacy gaps, and limited long-term data on outcomes. Future CR strategies aim to integrate precision medicine, digital monitoring, wearable technologies, and artificial intelligence to personalize interventions. This review synthesizes contemporary evidence on CR evolution, highlights persistent barriers, and explores strategies for maximizing accessibility, equity, and long-term effectiveness, offering a roadmap toward the next generation of patient-centered, technology-enabled CR.

Keywords: Cardiovascular disease, Cardiac rehabilitation, Telerehabilitation, Digital health, Psychosocial support.

1. Introduction

Cardiovascular diseases (CVDs) are considered one of the primary causes of death. Globally, around 20 million fatalities are reported, with a reported increase in mortality from 19.6 to 20.5 million between 2019 and 2021, accounting for 33% of all global deaths (Di Cesare et al. 2024). In Global Burden Disease (GBD) analysis 2023, CVDs accounted for 437 million years of healthy life were lost globally due to CVD (95% uncertainty interval [UI]: 401-465 million). This indicates substantial global health loss. When compared with 320 million in 1990, the number of deaths from CVDs increased from 13 million to 20 million, reflecting a substantial rise over three decades. More than doubled prevalence in 2023 reports around 600 million cases of CVDs in 2023 (Amaravadi et al. 2025). Although age-standardized prevalence rates are projected to remain relatively stable, the total number of individuals affected by CVDs is expected to increase substantially due to population growth and aging, particularly in low-and middle-SDI regions. Hypertension, hyperlipidemia, pollution, and dietary risks are shown as modifiable risk factors for 79% of the total burden. Based on projections, the prevalence of

CVD in 2025 would rise by around 90% by 2050, while the age-standardized prevalence is predicted to remain relatively stable (Chong et al. 2025). Ischemic heart disease and stroke are the leading causes, accounting for over 85% of CVD-related deaths. Although the frequency has increased, age-standardized mortality rates exhibit a lower over time (Soler and Ruiz 2010).

Despite the improvements in prevention and management of disorder, more than three-quarters of CVD-related deaths occur in Low- and Middle-Income Countries (LMICs), where reductions in mortality have been slower compared to high-income countries. Consequently, CVDs remain the primary contributor to premature mortality from Non-Communicable Diseases (NCDs) worldwide (Di Cesare et al. 2024). Cardiac Rehabilitation (CR) is regarded for its widespread efficacy in improving human health. This program is designed exclusively for those who have CVD, endured a heart attack, or have undergone heart surgery. It is known as a comprehensive program because its therapeutic focus extends beyond the heart and improves overall health (Taylor, Dalal, and McDonagh 2021). In this multidisciplinary program, core components include managing risk factors such as dyslipidemia, diabetes, hypertension, and smoking cessation, as well as patient assessment. Other elements, such as nutritional counseling, program outcomes evaluation, and psychosocial support, work together to improve the quality of life, hospital readmissions and reduce mortality in CV patients (Brown et al. 2024).

Despite the evident benefits of CR program, global doctor referral and patient participation rates are not meeting the optimal criteria. The addressed issues are relevant in older patients, who are at higher risk of cardiovascular complications. Patients with less strength and physiological reserve, are more vulnerable to stress, a high risk factor of CVD. Multimorbid patients, having more than one chronic condition also complex management needs (Nichol et al. 2024).

Evidence suggests that new delivery modes, including Home-Based Cardiac Rehabilitation (HBCR), and telerehabilitation, are promising strategies. However, gaps remain in understanding their long-term effectiveness, optimal delivery protocols, and patient adherence across diverse populations (Karisa et al. 2026).

Continuity of CR across the patient's life is important, yet many patients disengage after Phase II. Dropouts are influenced by physical health issues, exercise difficulty, and personal stress, highlighting a need for extended, tailored interventions to sustain secondary prevention beyond formal CR programs (Daly et al. 2002). Structured approaches to sustain lifestyle changes and manage associated risk factors are limited, and further research is needed to guide effective secondary prevention. Although CR is proven beneficial, evidence on alternative delivery modes, digital interventions, Artificial Intelligence (AI)-guided rehabilitation, and cost-effective models is still insufficient, and disparities persist across gender, age, and socio-economic groups. Figure 1 demonstrates **the** evolution of CR models from traditional centre-based programs to emerging home-based, hybrid, and AI-guided interventions. Addressing these gaps requires high-quality research to optimize access, adherence, and long-term outcomes. This narrative review aims to provide a comprehensive overview of CR, highlighting evolving approaches, persistent challenges, and knowledge gaps in referral, and long-term secondary prevention beyond Phase 2. It examines emerging delivery models and evaluates the evidence on cost-effectiveness and equity in access.

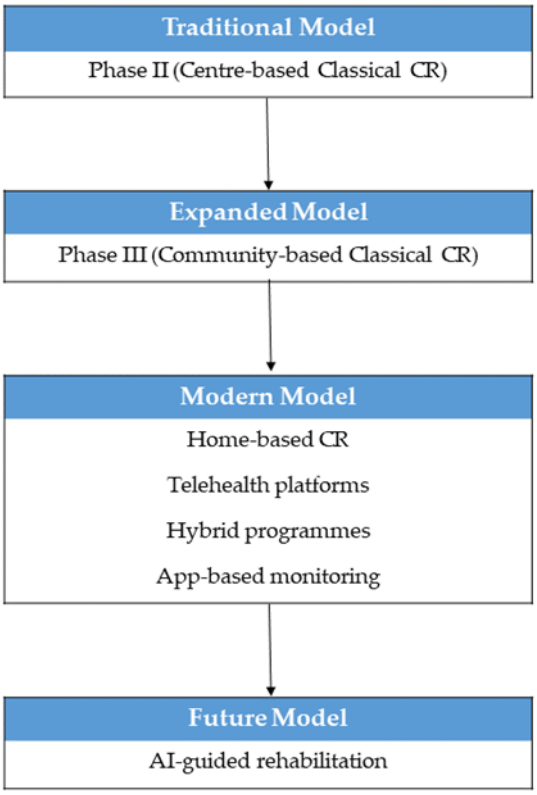

Figure 1: Evolution of Cardiac Rehabilitation Models

2. Phase 2 CR (Classical Model)

Phase 2 CR is a classical and center-based model in which outpatient programs following a cardiac event are supervised in hospital settings. This focused program demonstrates improving maintenance of physical activity where interventions are delivered soon after phase 2 CR. Following structured exercise training, education, and lifestyle modification, variations exist in program length, intensity and duration of services, influencing long-term outcomes (Andersen et al. 2022). Patient-centered approaches, including consistent communication and cognitive-behavioral strategies, serve as the foundation for long-term secondary prevention.

Research evidence supports the effectiveness of phase 2 CR, where it improves functional capacity, CVD risk profiles, and quality of life. Supervised rehabilitation programs is proven to significantly enhance exercise tolerance and improve metabolic risk factors such as blood pressure, lipid levels, and glucose regulation (Reich et al. 2020).

3. Phase 3 CR (Maintenance Phase)

Following the end of the phase 2 program, phase 3 CR is administered to maintain lifestyle changes with minimal oversight. The primary objective of phase 3 CR is to promote long-term adherence to physical activity and cardiovascular risk-reduction behaviors. Patients are encouraged to continue regular aerobic exercise, strength training, and flexibility activities while maintaining healthy lifestyle practices such as balanced nutrition, smoking cessation, stress management, and adherence to prescribed medications. Continuous self-management promotes the lowering of long-term cardiovascular risk. Aside from risk control measures, regular physical activity and behavioral self-management is highly sustained.

Long-term participation in maintenance programs has been associated with sustained improvements in exercise tolerance, cardiovascular fitness, and psychosocial well-being. However, patient participation reduces over time, in addition to program design, duration, and follow-up strategies varying, emphasizing the need for standardized procedures (Winnige et al. 2021).

4. Evidence-based Rehabilitation

Exercise training under supervision is the main part of CR, where its effectiveness is evident in improving patients' functional capacity and physiological reserve. In condition of percutaneous coronary intervention (PCI), CR improves long-term survival and recovery of patient. In study on modest improvements in cardiorespiratory fitness (CRF), the metabolic equivalents (METs) measured for shifts in CRF shows association with mortality rate in a dose-response manner, where 1-MET increase is found to reduce 17% of mortality risk (Ezzatvar et al. 2021). Exercise training induces multi-system adaptations, including improved left ventricular function, enhanced endothelial vasodilation, increased skeletal muscle capillary density and mitochondrial capacity, and favorable metabolic effects on glucose, lipids, blood pressure, body composition, and inflammation (Adam et al. 2025). In this section, the exercise prescription following PCI is clearly explained, including the parameters of dose, intensity, and modality. For exercise, aerobic exercise of 4-7 sessions per week is recommended to improve CRF. It is typically recommended to work at 40-79% of VO^2 peak and 55-70% of maximum heart rate (HRmax) (Franklin et al. 2022). A resistance training frequency of 2-3 non-consecutive days per week is recommended in addition to aerobic training, which improves the strength of muscles and enhances quality of life. These resistance exercises, performed with 1-3 sets of 8-15 repetitions, are recommended to achieve an appropriate training volume, performed dynamically through a full range of motion to maximize functional benefits. When combined, these multimodal training sessions of aerobic training and resistance training, they were shown to have enhanced outcomes, with improved VO^2 peaks. This also enhances the muscles strength and improves overall quality of life (Nazir et al. 2025). Another form of exercise, High-Intensity Interval Training (HIIT) with HRmax of more than 85%, lasts 35 seconds to few minutes. Following three phases of HIIT, where exercise at near maximal effort follows recovery phase of low-intensity activity and repeated multiple times cycle improves VO2 faster than moderate continuous training.

In post-PCI CR, it is evident to stimulate collateral circulation and enhance endothelial function via nitric oxide-mediated vasodilation. This training is evident to achieve benefits efficiently. HIIT sessions involves 1 minute of cycling at 90% of HRmax, followed by 2 minutes of recovery through easy cycling, and repeated 8 times, for a total duration of approximately 25 minutes (Kumar et al. 2024). Overall exercise-based CR post-PCI should be tailored according to individual risk stratification and patient preferences.

5. Beyond Exercise: Behavioral, Psychosocial, Nutritional, Smoking Cessation, and Medication Adherence

CR extends beyond structured exercise to encompass behavioral, psychosocial, nutritional, and pharmacological interventions, all of which play crucial roles in improving long-term outcomes for post-PCI patients. Figure 2 illustrates the components of comprehensive CR. In modern medical literature, the role of behavioral and psychosocial factors are highlighted where studies have reported acute emotional stress as a known factor of sudden cardiac death.

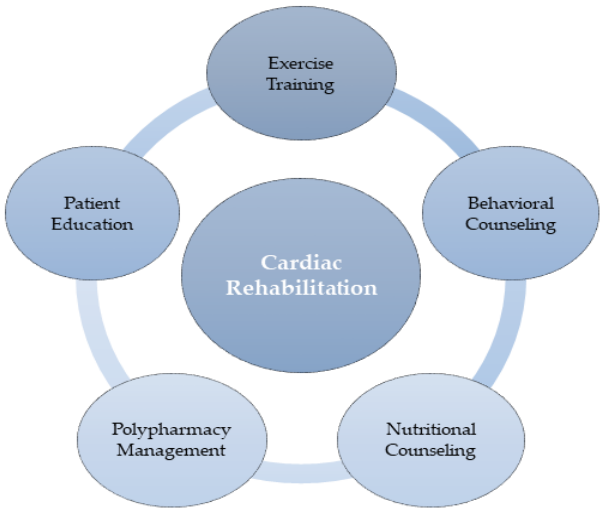

Figure 2: Components of Comprehensive Cardiac Rehabilitation

Depression has been associated with an increased risk of recurrent cardiovascular events and death in post-PCI patients. Patients with CVD who also suffer from depression are clearly at an increased risk of developing serious heart issues. The severity of depressive symptoms after a heart attack or unstable angina raises the risk of death over the next five years. Post-PCI patients often experience depression, which has been linked to a higher risk of recurrent cardiovascular events and death (Saini et al. 2022). Studies confirms that the depressive symptoms are common after PCI, affecting about one-third of CVD patients (Rawashdeh et al. 2021). Comprehensive CR also involves psychosocial assessment. This intervention includes stress management and patient education (Hughes, Serber, and Kuhn 2022). Nutritional counseling is also evident as a secondary preventive measure. The Mediterranean diet (MD) is evident in primary and secondary prevention of CVD, where diet constituents are monosaturated and polyunsaturated fats, omega fats, and bioactive nutrients with anti-oxidant properties. This diet is evident in regulating lipid profiles, lowering inflammation, and inhibiting platelet aggregation. Adherence to the MD is associated with lower CVD incidence, reduced mortality, improved metabolic and inflammatory profiles in primary prevention, and with slower atherosclerosis progression, reduced inflammation, and fewer recurrent cardiac events in secondary prevention (Mlynarska et al. 2025).

These findings support the MD as an effective non-pharmacological nutritional strategy to improve cardiovascular outcomes alongside standard therapy. Another critical factor is smoking, where it is evident to be associated with significant higher risk of major adverse cardiovascular events after PCI. In studies of patients who quit smoking after PCI with a cumulative exposure of less than 20 pack-years, the risk is comparable to that of non-smokers. Whereas in quitters with less than 20 pack-years, the risk remains similar to that of persistent smokers (Ki et al. 2023). Randomized trial evidence in CVD patients demonstrates that varenicline combined with counseling significantly increases continuous abstinence rates compared with placebo (Rigotti et al. 2010).

Table 1: Comparison of Cardiac Rehabilitation Delivery Models

CR Model	Key Features	Perks	Limitations	References
Hybrid CR	Integrated center-based sessions with remote components	Maintains supervision with more flexibility and convenience	Requires digital literacy; coordination between center and remote care; technology cost and maintenance	(Damery et al. 2025)
Centre-based CR	Supervised programs with structured exercise and lifestyle guidance	Highly supervised, ensures protocol adherence, with immediate healthcare support.	Limited access, travel constraints, inflexible schedules, non-adherence	(Pagnoni et al. 2025)
Community-based CR	Post-Phase self-management under minimal supervision which focuses on lifestyle maintenance	Promotes self-efficacy, long-term risk reduction, and flexible participation	Declining adherence, variable duration and follow-up, less structured	(Bayuo et al. 2025)
HBCR	Exercise and interventions performed at home with remote instructions	Greater accessibility, suitable for rural and underserved areas, flexible schedule	Limited supervision, loss of motivation, potential safety concerns	(Thomas et al. 2019)
Telerehabilitation	Remote monitoring via apps and wearables	Boosts participation, real-time monitoring, behavioral support	Technology access needed, digital literacy, setup cost, limited long-term data	(Maita et al. 2024)

In contemporary CR, polypharmacy is common; in one study, 84.6% of patients took up to six medications with risk increasing with age and presence of other diseases, though the exact number of disorders did not further elevate polypharmacy levels. High-risk drug interactions, particularly involving Clopidogrel with Aspirin or Proton-pump Inhibitors (PPIs), highlight the importance of post-prescription monitoring and educational awareness. Serious and moderate polypharmacy is required to be managed under supervision in clinical settings, while minor polypharmacy is manageable at home with prescriptions follow-up. This emphasizes the careful prescription of drugs such as in case of using polypills to confirm accurate medication intake with minimal side effects or complications (Al-Amin et al. 2012).

6. New and Emerging Delivery Models

Modern research in CR suggests to introduce effective and non-traditional models to overcome barriers such as limited centre capacity, work-life challenges, and transportation issues. Less participation rates due to these barriers needed an alternative,

where hybrid, digital, and remote programmes can act as viable alternatives to improve adherence and accessibility. Table 1 summarizes the comparison of CR delivery models. In case of hybrid models of centre-based sessions and remote components, flexible options are available without compromising supervision. Hybrid models in CR are evident for improvements in exercise capacity, modifying risk factors, and improving overall quality of life. These improvements facilitates the patients in terms of convenience and are comparable to traditional in-person programmes (Mueller and Kim 2025). The other traditional centre-based CR is HBCR, which is reported for non-compromised outcomes, where CVD patients can perform exercises and activities mentioned in prescription at their own pace, providing accessibility. The comparative systematic review findings suggests the long-term lifestyle modification in patients with CVD, where it overcome transportation barriers with minimal improvements noted in VO^2 peaks. Overall, HBCR represents a flexible and efficient approach to maximum participation while addressing barriers in CR. Its greater benefits are notable for patients in rural or underserved areas, where access to facility-based programs is limited and only minimal supervision and expert guidance may be available (Karisa et al. 2026). Digital platforms also serves to deliver real-time solutions focused on personalized care. Its secondary prevention outcomes are noticed, where regular bi-directional interaction between healthcare providers and patients is an important key factor. The option for remote monitoring through wearable devices and monitoring systems serves to track patient's progress and provide targeted guidance. This can enhance the quality of clinical information that eases the decision-making. In addition, telehealth platforms increase the accessibility of CR by allowing patients to participate from home, thereby overcoming traditional barriers such as travel distance, time constraints, and limited access to specialized rehabilitation centres. (Gallegos-Rejas et al. 2024). App-supported programmes increase accessibility and enable patients to follow rehabilitation protocol at home. Application in mobile phones when integrated with activity monitors, serves for individualized rehabilitation. These digital solutions also promote self-directed recovery, help reduce sedentary behavior through activity tracking and reminders, and support hybrid CR delivery models. Overall, such technologies play an important role in expanding participation and supporting the long-term management of CVD (Hatch and Davies 2022).

7. Discussion

In this review, strongest contemporary evidence from meta-analysis and randomized trial demonstrating the telehealth benefits, recent paradigm shifts, implementation barriers, cost-effectiveness and unresolved issues are discussed in detail. In many researches, contemporary CR demonstrated robust benefits across diverse populations, where it reduced mortality rate, re-hospitalization, and improved overall quality of life. Phase 2 CR as compare to phase 3 provides the structured training with defined intensity, dose, and progression (Torres-Saavedra and Winter 2022). Literature suggests extended gains of phase 3, where usually self-direct exercise with more flexible schedules is implemented to sustain the habits instead of rapid improvements. In phase 2 CR, patient engagement was found highly supervised, whereas Phase 3 sees declining participation, with long-term adherence depending on program design, follow-up, and patient self-efficacy. Community-based programs are evident for delivering with long-term engagement. A central to these approached, exercise-based CR is evident for physiological benefits with different training types such as aerobic, resistance and combined training (Monturo et al. 2025). In PCI patients, studies report improved muscle strength and CRF

through regular aerobic training several times per week at moderate intensity, combined with resistance training on non-consecutive days. Greater improvement in VO2 peaks were found evident in HIIT, where short, repeated near-maximal efforts interspersed with recovery, enhancing endothelial function and collateral circulation (Hong and Liu 2025). Research suggest that the personalized and tailored exercise prescriptions optimizes the outcomes (Gao et al. 2023). Adoption to telehealth, HBCR, and app-supported programmes introduces a paradigm shift in CR covering last 5-10 year studies. HBCR when combined with remote monitoring and personalized feedback was found to improve flexibility, adherence, and access (Gao et al. 2023). The COVID-19 pandemic data on feasibility and acceptability of remote and hybrid CR models revealed their innovatory role where the CR programmes reached travelers and rural population (Sestayo Fernandez et al. 2022). App-supported programmes facilitates the individualized exercise delivery, self-directed recovery, and behavioral reinforcement, helping reduce sedentary time and enabling real-time communication with healthcare teams (Daryabeygi-Khotbehsara et al. 2021). Despite the advancements in CR, challenges persists, where implementations remains difficult and uptake remains suboptimal, with women, older adults, socioeconomically disadvantaged groups, and patients with multimorbidity underrepresented in clinical trials. Barriers in CR includes limited clinical engagement, reimbursement constraints, and digital literacy gaps. Cost-effectiveness is evident through analysis, where potential societal savings from remote and HBCR. However initial investment for technology, training, and maintenance is needed. Additionally, heterogeneity in designing of programs and reporting standard limits direct comparability, and evidence remains limited for long-term clinical outcomes beyond several months. Emerging research addresses personalized CR by tailoring exercise intensity, modality, and digital support to patient preferences. Populations such those with cognitive or sensory impairments, and individuals with complex situation of more than one disease complex remain clearly underserved, emphasizing the need for tailored and inclusive strategies (Wu et al. 2026). Addressing these gaps is critical to maximize the reach, equity, and effectiveness of contemporary CR, moving toward precision rehabilitation that integrates digital health, long-term behavior change, and value-based care principles.

8. Future Directions

CR provides personalized and precision-based approaches that account for individual variability in genetics, clinical phenotypes, and lifestyle factors. Advances in genomics can allow tailored rehabilitation strategies to be implemented upon patient's genetic predisposition and disease characteristics. In addition, digital biomarkers can serve as wearable devices to check continuous heart rate, sleep patterns, and quality. This fills the gap by providing real-time data, allowing individualized monitoring and adjustments of rehabilitation programs according to personalized needs. These kind of precise measures in CR has the potential to optimize exercise prescription, risk-factor management, and patient adherence. Integration of CR programs with AI and adaptive closed-loop systems gives a promising solution, where AI-driven algorithm can analyze huge patient data from electronic health records and mobile applications. This can allow to predict patient responses to dynamically modify exercise duration, frequency, and intensity. Closed-loop digital platforms could automatically adjust rehabilitation plans based on physiological feedback, thereby improving safety, personalization, and long-term engagement. A major challenge in CR is to achieve sustainable long-term behavior change. Although CR

programs typically last 8 - 12 weeks, CVD requires lifelong risk-factor management. Therefore, future models should promote continued physical activity, healthy diet, smoking cessation, and medication adherence beyond the formal program, supported by digital health tools, remote monitoring, and community-based maintenance programs to facilitate lifelong cardiovascular self-management.

Furthermore, integration with primary care systems and digital public health initiatives will be essential for expanding CR reach and continuity of care. By combining precision medicine, digital innovation, and community-based support systems, CR can evolve from a time-limited intervention into a lifelong strategy for cardiovascular health maintenance and disease prevention.

Conflict of Interest

All the authors declare no conflicts of interest.

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Study Approval

NA

Consent Forms

NA

Authors Contributions

Aimen Shahid contributed to the conceptualization and initial drafting of this review article, while Maha Amin contributed to critical revision and refinement of the manuscript. Both authors approved the final version.

Data Availability

All the data relevant to this study is with the authors.

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