



Cardiac Rehabilitation: Integrated Approaches in Physical Therapy, Nursing, and Health Information Management

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Abstract

Background: Cardiovascular disease is the leading cause of death globally. Cardiac rehabilitation (CR) is an evidence-based, multidisciplinary intervention recommended for patients recovering from acute cardiac events or living with chronic cardiac conditions to improve functional capacity and reduce mortality.

Aim: The primary aims of CR are to reduce the physiological and psychological burdens of cardiovascular disease, lower all-cause and cardiovascular-specific mortality, restore cardiopulmonary function, and enhance quality of life through structured, supervised programming.

Methods: CR is delivered through phases, interprofessional programs integrating supervised, graded exercise training (aerobic and resistance), rigorous risk factor modification (e.g., lipid, blood pressure, and weight management), and structured psychosocial support and patient education. Programs are typically supervised and span approximately 12 weeks.

Results: Participation in CR leads to significant improvements in functional capacity (e.g., VO₂ max), modifiable risk factors, and psychosocial well-being (reducing anxiety and depression). It demonstrably reduces hospital readmissions and long-term mortality. Furthermore, CR has an exceptional safety profile, with severe adverse events being exceptionally rare during supervised sessions.

Conclusion: Cardiac rehabilitation is a cornerstone of cardiovascular secondary prevention, effectively improving clinical outcomes, functional status, and quality of life. Despite its proven benefits, utilization remains low due to systemic and patient-level barriers.

Keywords: Cardiac rehabilitation, cardiovascular disease, secondary prevention, exercise training, interprofessional team, risk factor modification, outcomes.

1. Introduction

Cardiovascular disease remains the leading cause of death worldwide and the principal cause of mortality in the United States [1][2]. Cardiac rehabilitation is a multifaceted interprofessional clinical intervention recommended for patients with chronic cardiac conditions including ischemic heart disease and congestive heart failure and for those recovering from acute cardiac events or revascularization procedures such as myocardial infarction percutaneous coronary intervention and coronary artery bypass grafting [3]. The aims of

cardiac rehabilitation include reduction of psychological and physiological burdens imposed by cardiovascular disease reduction of all cause and cardiovascular specific mortality risk and restoration or enhancement of cardiopulmonary function to improve quality of life [4]. Through methodical graded exercise and adjunctive therapeutic strategies cardiac rehabilitation increases myocardial reserve mitigates progression of atherosclerotic disease and restores functional capacity and self-efficacy [5].

As an evidence based element of contemporary cardiovascular care cardiac

rehabilitation is codified within clinical practice guidelines and organized as a coordinated program that integrates supervised exercise training systematic modification of cardiovascular risk factors and structured psychosocial support delivered by a multidisciplinary team. Conventional programs commonly span approximately 12 weeks and often comprise 36 supervised center based sessions an approach that has demonstrated reductions in rehospitalization rates and cardiovascular mortality while improving health related quality of life metrics [6]. Despite strong evidence of benefit utilization of cardiac rehabilitation services remains low. Epidemiological data show that only a minority of eligible patients enroll and that attrition among participants further limits the population level impact of these programs. Disparities in enrollment and completion are associated with sociodemographic determinants such as sex race and ethnicity socioeconomic position and geographic access to services which create inequitable uptake and attenuated benefit distribution across patient subgroups [7][8].

Professional bodies including the American Heart Association the American Association of Cardiovascular and Pulmonary Rehabilitation and the Agency for Health Care Policy and Research have defined core program elements to standardize and optimize delivery. A comprehensive cardiac rehabilitation model should include rigorous initial and serial patient assessment to stratify risk and tailor interventions targeted nutritional and weight management strategies systematic control of blood pressure and dyslipidemia evidence informed management of diabetes where present and integrated tobacco cessation interventions. Psychosocial evaluation and support must be embedded to identify and treat anxiety depression and other behavioral health comorbidities that impair adherence and outcomes. Structured physical activity counseling and individualized exercise training remain central components and should be delivered with physiological monitoring and progression plans designed to maximize safety and efficacy [9].

To realize the full potential of cardiac rehabilitation health systems must address barriers to referral and participation and expand delivery models beyond traditional center based formats to include home based and telehealth enabled modalities. Systems should implement data driven quality improvement mechanisms that track referral enrollment completion and outcome metrics. Paired with culturally competent outreach and pragmatic scheduling accommodations these system level adaptations can increase access for underserved populations and reduce disparities that currently constrain program reach. The synthesis of supervised exercise risk factor management behavioral interventions and coordinated interdisciplinary care positions cardiac rehabilitation as a cornerstone of

secondary prevention. Translating clinical trial efficacy into real world effectiveness requires coordinated action across clinical administrative and policy domains to ensure eligible patients are identified engaged and retained in programs that respond to individual needs and contextual constraints.



Figure-1: Cardiac Rehabilitation.

Anatomy and Physiology

The heart is a hollow muscular organ organized into four distinct chambers, two superior atria and two inferior ventricles, contained within the protective confines of the pericardial sac. The pericardium comprises an outer fibrous layer and an inner serous component that is divided into parietal and visceral layers, the latter constituting the epicardium. A physiologic volume of serous fluid, typically up to 50 milliliters, occupies the pericardial space and facilitates frictionless motion during the cardiac cycle. Structurally the heart wall is composed of three concentric layers. The outer epicardium provides a visceral serosal covering. The myocardium constitutes the intermediate and functionally dominant layer composed of specialized contractile cardiomyocytes organized in helical fiber arrays that optimize force generation and wall stress distribution. The endocardium lines the chamber interiors and valvular surfaces and contributes to intracavitary homeostasis through endothelial functions. Functionally, the right atrium receives systemic venous return and channels deoxygenated blood through the tricuspid atrioventricular valve into the right ventricle. The left atrium receives oxygenated pulmonary venous return and transmits blood through the mitral valve to the left ventricle. Semilunar valves regulate ventricular egress with the pulmonary valve directing flow from the right ventricle to the pulmonary arterial system and the aortic valve controlling outflow from the left ventricle to the systemic circulation. These anatomic elements operate in coordinated sequence during systole and diastole to effect forward flow, maintain unidirectional valvular competence, and preserve optimal pressure gradients that drive perfusion of end organs [10].

The biomechanical and electrophysiological milieu of the heart underpins its capacity to respond to physiologic demands. Cardiac contraction emerges from orchestrated excitation-contraction coupling. The specialized conduction apparatus comprising the sinoatrial node, atrioventricular node, bundle of His,

and Purkinje network imposes temporal order on atrial and ventricular activation and ensures atrioventricular synchrony under normal conditions. Hemodynamically cardiac output is determined by the product of stroke volume and heart rate. Stroke volume itself is a composite of preload which reflects venous return and end-diastolic volume, myocardial contractility which represents intrinsic inotropic state, and afterload which represents the arterial impedance the ventricle must overcome. Coronary perfusion is intimately tied to diastolic pressure, myocardial oxygen demand, and microvascular integrity. Endothelial cells lining the coronary and systemic vasculature modulate vascular tone by releasing vasoactive mediators, including nitric oxide, and maintain antithrombotic and anti-inflammatory properties that are essential for vascular health. Pathologic perturbations to any component of this integrated system can compromise forward flow, elevate filling pressures, precipitate arrhythmia, and promote maladaptive remodeling [10][11]. Physical activity exerts profound acute and chronic effects on cardiovascular physiology that mediate reductions in cardiovascular morbidity and mortality. The primary hemodynamic adaptation to exercise is an increase in cardiac output driven by concurrent rises in stroke volume and heart rate. During incremental aerobic exertion stroke volume augments through enhanced venous return and preload, facilitated by skeletal muscle pump activity and sympathetic venoconstriction, and through improved myocardial contractility mediated by increased intracellular calcium availability and adrenergic stimulation. Heart rate acceleration further elevates cardiac output and is coordinated by autonomic adjustments favoring sympathetic predominance during activity. These acute responses collectively optimize oxygen delivery to metabolize tissues and maintain perfusion despite increased metabolic demand [10].

With long term training repeated hemodynamic loading induces structural and functional myocardial adaptations frequently characterized as physiologic remodeling. Endurance-oriented training promotes eccentric myocardial hypertrophy with increases in end-diastolic chamber dimensions and augmented diastolic filling capacity, adaptations that expand stroke volume and enhance cardiac reserve. Strength-oriented training produces concentric changes that reflect pressure loading. These remodeling processes increase myocardial contractile reserve and improve early diastolic relaxation, effects that contribute to enhanced exercise tolerance and reserve capacity in trained individuals [11]. At the vascular level habitual physical activity counteracts age and disease related arterial remodeling. Regular exercise preserves endothelial function, maintains or increases nitric oxide bioavailability, and reduces arterial stiffness. Exercise training attenuates oxidative stress and downregulates proinflammatory

signaling pathways within the vascular wall, mechanisms that collectively lower systemic vascular resistance and arterial pressure. These vascular benefits manifest clinically as reductions in resting and ambulatory blood pressure and as improved indices of arterial compliance and microvascular perfusion [12]. The integrated cardiac and vascular adaptations to physical activity therefore operate at cellular molecular and organ system levels to confer protection against atherothrombotic disease progression and to improve functional capacity. Exercise induced improvements in preload handling contractile performance endothelial function and inflammatory milieu create a physiologic state that supports efficient cardiac work at lower filling pressures and with reduced wall stress. These mechanisms explain much of the empiric reduction in cardiovascular events observed with structured aerobic and resistance training and underscore the rationale for incorporating exercise prescription within preventive and rehabilitative cardiovascular care.

Indications:

Cardiac rehabilitation is indicated for a spectrum of clinical scenarios in which structured secondary prevention, functional restoration, and risk factor modification improve clinical outcomes. Foremost among these indications is the convalescent phase following an acute myocardial infarction or acute coronary syndrome. In this context rehabilitation facilitates graded restoration of aerobic capacity, mitigates ischemic symptoms, and reduces the risk of recurrent events through supervised exercise, optimization of pharmacotherapy, and behavioral interventions. For patients with chronic stable angina, cardiac rehabilitation serves as an adjunctive strategy to reduce symptom burden and enhance exertional tolerance. Tailored exercise programs increase ischemic threshold, while concurrent risk factor management and patient education promote better angina control and reduce angina-related disability [13].

In patients with symptomatic congestive heart failure, cardiac rehabilitation targets improvement in functional capacity and quality of life. Exercise-based interventions enhance peripheral muscle performance, improve ventilatory efficiency, and augment stroke volume during exertion. These physiologic gains translate into greater independence in activities of daily living and fewer heart failure related hospital admissions when programs are properly individualized and monitored. Cardiac rehabilitation is also a standard component of recovery pathways after major cardiac procedures. Following coronary artery bypass grafting or percutaneous coronary intervention, rehabilitation accelerates physical recovery, reduces postoperative deconditioning, and supports the transition from inpatient to community care. After valvular surgery, rehabilitation addresses both the hemodynamic

consequences of valvular correction and the deconditioning that accompanies prolonged hospitalization. In the setting of cardiac transplantation, structured rehabilitation is essential for rebuilding exercise capacity, reestablishing functional independence, and addressing the complex interplay between immunosuppression related complications and cardiovascular fitness [13].

Finally, cardiac rehabilitation has an established role in the long-term management of adult congenital heart disease. For these patients, individualized rehabilitation addresses residual hemodynamic lesions, arrhythmic risk, and exercise intolerance that persist into adulthood. Programs integrate risk stratification with tailored exercise prescriptions and ongoing surveillance to optimize functional capacity and to reduce the long-term sequelae of congenital defects. Across all indications, inclusion criteria reflect evidence linking rehabilitation to reductions in morbidity and mortality, improvements in exercise performance, and enhanced patient reported outcomes. Program selection and intensity must be matched to clinical stability, comorbid conditions, and procedural timing to maximize safety and benefit [13].

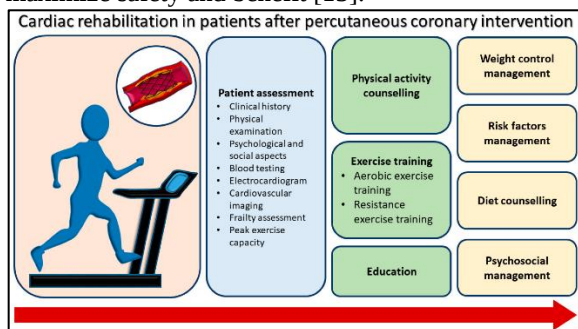


Figure-2: Cardiac Rehabilitation after percutaneous coronary intervention.

Contraindications

The exercise component of cardiac rehabilitation must be prescribed within a framework of clinical safety. Certain pathophysiological states render physical exertion hazardous, and recognizing these contraindications is essential to prevent hemodynamic instability, arrhythmogenic events, or structural cardiac injury. Unstable angina represents a primary contraindication, as fluctuating myocardial ischemia under exercise-induced stress can precipitate infarction or fatal arrhythmias. Exercise under these circumstances imposes excessive myocardial oxygen demand in the context of restricted coronary perfusion, heightening the risk of acute coronary decompensation. Similarly, acute decompensated congestive heart failure constitutes a prohibitive condition. The hemodynamic burden and elevated filling pressures during exacerbations impair cardiac output, and physical exertion can provoke further volume overload, pulmonary congestion, and circulatory collapse [14]. Complex ventricular arrhythmias are another absolute contraindication to

exercise-based rehabilitation. Sustained or polymorphic ventricular tachycardia, frequent ventricular ectopy, or episodes of ventricular fibrillation increase the likelihood of sudden cardiac arrest during exertion. Until these arrhythmias are stabilized pharmacologically or through device therapy, exercise must be deferred. Severe pulmonary hypertension, defined by a right ventricular systolic pressure exceeding 60 mm Hg, also precludes participation. In these patients, increased pulmonary vascular resistance and right ventricular strain predispose to syncope and acute right heart failure when cardiac output rises during activity. The presence of an intracavitary thrombus poses a significant embolic risk during exercise, as enhanced myocardial contraction and blood flow can dislodge the thrombus, leading to systemic or pulmonary embolization [14].

Recent thrombophlebitis, with or without pulmonary embolism, similarly contraindicates exercise until resolution or adequate anticoagulation is achieved, as muscular activity can exacerbate venous inflammation or mobilize thrombotic material. Severe obstructive cardiomyopathies, including hypertrophic forms associated with dynamic outflow tract obstruction, are also incompatible with exercise therapy, as increased contractility and decreased preload during exertion may precipitate obstruction, syncope, or sudden death. Severe or symptomatic aortic stenosis represents another exclusion, given the fixed outflow limitation and the risk of hypotension or ischemia during exercise. Active inflammatory or infectious conditions involving the myocardium, pericardium, or systemic circulation are additional contraindications, as exercise can intensify inflammatory responses, impair recovery, and provoke arrhythmia or heart failure. Finally, significant musculoskeletal disorders that limit mobility or prevent safe execution of exercise protocols also exclude participation until functional restoration is achieved. The presence of any of these contraindications necessitates individualized assessment and stabilization prior to initiation of exercise-based cardiac rehabilitation. Once underlying pathology is corrected or adequately controlled, graded physical activity may be introduced under close supervision to ensure safety and clinical benefit [14].

Equipment:

The equipment used in cardiac rehabilitation differs according to the phase of recovery, the patient's functional capacity, and the degree of medical supervision required. During the early postdischarge phase, generally within the first week after hospitalization, structured exercise sessions are conducted in a controlled clinical environment equipped to ensure both safety and continuous physiological monitoring. Typical facilities include exercise bicycles, treadmills, and step ergometers that enable graded aerobic conditioning while allowing

clinicians to regulate workload intensity. Telemetry monitoring systems are essential in this phase, providing continuous electrocardiographic and hemodynamic observation to detect arrhythmias, ischemic changes, or abnormal blood pressure responses during exercise. Strength training equipment, such as resistance bands or light free weights, is introduced gradually to enhance muscular endurance and peripheral conditioning without imposing excessive cardiac load. This early supervised stage typically extends for two weeks to one month, during which patients regain confidence in performing physical activity under controlled clinical oversight [15].

Once patients demonstrate clinical stability, functional improvement, and hemodynamic tolerance, they may transition from a hospital-based or specialized rehabilitation center to a community gym or a structured home-based exercise program. In these settings, equipment selection is tailored to individual needs and medical guidance. Recommended tools include stationary bicycles, walking treadmills, or step platforms for aerobic conditioning and lightweight resistance tools for muscular strengthening. Portable heart rate monitors and blood pressure devices allow ongoing self-monitoring, facilitating safe exercise progression. The use of digital applications or wearable technologies for heart rate and activity tracking is increasingly integrated into home-based programs, promoting adherence and feedback to healthcare teams. Proper equipment selection and maintenance ensure safety and efficacy throughout the continuum of cardiac rehabilitation. Whether in supervised or independent phases, the emphasis remains on achieving controlled, progressive conditioning with close adherence to prescribed intensity and duration parameters defined by healthcare professionals [15].

Personnel:

Cardiac rehabilitation achieves its optimal outcomes when delivered through an interprofessional framework that integrates the expertise of multiple healthcare disciplines. Evidence consistently demonstrates that a team-based approach enhances clinical outcomes, promotes adherence, and ensures continuity of care across all phases of recovery [15][16]. The patient and family form the central component of this team, as active engagement, understanding, and motivation determine the success of rehabilitation efforts. Education and counseling empower both the patient and family to manage lifestyle modification, medication adherence, and early recognition of warning symptoms, fostering long-term self-management and sustained health behavior change. Clinicians, including cardiologists, cardiothoracic surgeons, and physiatrists, provide diagnostic oversight, risk stratification, and medical supervision. They define the rehabilitation goals, monitor progress, and adjust treatment plans based on

individual cardiac status, comorbidities, and procedural outcomes. Pharmacists contribute by optimizing pharmacologic therapy, ensuring drug safety, managing potential interactions, and providing patient education on adherence to cardiovascular medications such as antiplatelets, beta-blockers, and lipid-lowering agents. Nurses play a pivotal role in coordinating care, monitoring vital parameters, and delivering education on disease management and lifestyle adjustment. Their continuous patient interaction positions them to identify psychosocial barriers and promote adherence to prescribed regimens [15][16].

Physical therapists design and supervise exercise programs tailored to cardiovascular capacity and individual limitations. They assess functional performance, prescribe graded aerobic and resistance exercises, and ensure progression within safe physiologic limits. Occupational therapists focus on facilitating return to work and daily activities, emphasizing energy conservation and functional adaptation to physical limitations. Speech and language pathologists may be involved in selected cases, particularly for patients recovering from stroke or cardiac procedures complicated by neurological deficits, ensuring safe swallowing and communication rehabilitation. Behavioral therapists address psychological factors including anxiety, depression, and adjustment difficulties that frequently accompany cardiac illness. Their interventions strengthen coping strategies and improve motivation for sustained participation. Dietitians provide individualized nutritional counseling, guiding patients in dietary modification aimed at lipid control, weight reduction, and blood pressure management. Case managers integrate the efforts of all disciplines, coordinate transitions between inpatient, outpatient, and community settings, and ensure adherence to follow-up care. Through this collaborative structure, cardiac rehabilitation functions as a unified continuum of medical, physical, and psychosocial interventions. The interprofessional team collectively ensures comprehensive management, continuity of care, and sustained improvements in functional capacity, risk reduction, and quality of life [15][16].

Preparation:

Preparation for cardiac rehabilitation begins with a detailed cardiopulmonary exercise assessment that evaluates cardiovascular fitness, respiratory efficiency, and hemodynamic response to graded physical exertion. This evaluation establishes a baseline for exercise tolerance and identifies potential risks or limitations that could influence program design. Parameters such as heart rate response, blood pressure behavior, oxygen consumption, and electrocardiographic changes during exertion guide the clinical team in determining appropriate exercise intensity and safety thresholds. Following this assessment, the interprofessional rehabilitation team

develops a personalized exercise and education plan tailored to the patient's medical condition, age, physical capacity, and personal goals. The plan integrates aerobic training, resistance conditioning, and educational components focused on risk factor modification, medication adherence, and self-monitoring techniques. Prior to each exercise session, participants perform a structured warm-up phase consisting of low-intensity movements designed to enhance blood flow, increase muscle temperature, and prepare the cardiovascular and musculoskeletal systems for activity, minimizing the risk of injury or hemodynamic instability [16].

Technique or Treatment

Cardiac rehabilitation is delivered through a phased, stepwise model that aligns therapeutic intensity and clinical oversight with patient recovery status, functional capacity, and specific procedural or disease-related considerations. The initial clinical phase, commonly designated Phase I, commences in the inpatient setting immediately after an acute cardiovascular event or invasive intervention. During this interval the rehabilitation team performs a comprehensive baseline assessment that addresses hemodynamic stability, functional capacity, comorbid conditions, psychosocial readiness, and safety for participation. Intervention goals during Phase I prioritize preservation of mobility, mitigation of hospital-associated deconditioning, preservation of musculoskeletal integrity, and the establishment of early adaptive behaviors that facilitate recovery. Multidisciplinary clinicians employ graded bedside mobilization protocols, respiratory incentive maneuvers, and low-intensity range-of-motion and ambulation activities tailored to the patient's tolerance. Concurrently, nurses and therapists instruct patients and families in activities of daily living with an emphasis on energy conservation, symptom recognition, wound and device care where applicable, and strategies for sleep and rest optimization during convalescence. Education regarding medication regimens, early warning signs of clinical deterioration, and basic lifestyle modification is initiated at this stage to promote a seamless transition to outpatient care. Where indicated, assessments for assistive devices, home safety, and early discharge planning are completed to minimize readmission risk and expedite functional recovery [17].

Outpatient cardiac rehabilitation, traditionally identified as Phase II, begins once medical clearance has been obtained and acute clinical risks have been ameliorated. Phase II comprises the core supervised exercise and education interval of rehabilitation and typically spans a minimum of three to six weeks, with many contemporary programs extending to 12 weeks to optimize physiologic and behavioral outcomes. The initial outpatient evaluation systematically quantifies exercise capacity, functional limitations, comorbid constraints, psychosocial factors, and specific activity restrictions. These data

inform an individualized exercise prescription that integrates progressive aerobic conditioning, resistance training where appropriate, and flexibility work, coupled with explicit intensity, duration, frequency, and progression parameters. Supervision in this phase involves continuous or intermittent physiologic monitoring, medication reconciliation, and iterative risk stratification to permit safe workload escalation. The therapeutic agenda of Phase II further encompasses structured educational modules addressing secondary prevention pharmacotherapy, dietary strategies for lipid and blood pressure control, tobacco cessation counseling, and behavioral techniques for stress reduction and adherence optimization. Relaxation techniques, cognitive behavioral interventions, and targeted counseling for depression and anxiety are frequently incorporated to address psychosocial determinants of recovery and participation. A core objective of the outpatient phase is to consolidate patient autonomy by fostering self-efficacy in exercise performance, symptom monitoring, and lifestyle modification in preparation for sustained community-based activity [17].

The long-term maintenance period, often termed Phase III or the postcardiac rehabilitation phase, emphasizes independent exercise adherence, ongoing risk factor surveillance, and periodic clinical reassessment. Phase III transitions responsibility for daily exercise execution to the patient while preserving structured follow-up with the rehabilitation team and specialty clinicians. Interventions within this stage focus on sustaining aerobic and resistance training gains, refining functional balance, preserving flexibility, and systematically preventing relapse into sedentary behavior. Patients are counseled on self-monitoring strategies including heart rate and symptom-guided intensity regulation, and they receive guidance on incorporating physical activity into occupational and recreational routines. Regular outpatient encounters enable medication adjustment, identification of recurrent or progressive symptoms, and reinforcement of dietary and behavioral modifications. Where available, community-based supervised exercise programs, cardiac fitness classes, or formally structured maintenance sessions provide an intermediate level of oversight that supports adherence among higher-risk individuals. The maintenance phase also serves as the locus for long-term outcome surveillance, allowing clinicians to track functional indices and to intervene when objective or subjective declines are observed [17][18].

A preoperative or presurgical optimization interval is sometimes integrated into the rehabilitation continuum for elective procedures; this phase aims to enhance cardiopulmonary reserve, correct modifiable risk factors, and educate patients regarding perioperative expectations and postoperative recovery trajectories. Preoperative conditioning may include tailored aerobic and inspiratory muscle training, anemia optimization, smoking cessation, and

nutritional support designed to reduce perioperative morbidity. Notwithstanding the theoretical advantages of prehabilitation, comparative data indicate variable tolerance and differential benefit depending on procedural urgency, baseline functional reserve, and the temporal window available prior to surgery, with some evidence suggesting superior tolerance of postoperative recovery pathways when preoperative conditioning is abbreviated or not feasible. Across all phases, rehabilitation extends beyond exercise prescription to encompass comprehensive management of comorbid medical conditions and modifiable cardiovascular risk factors. Integrated pharmacologic optimization, individualized nutritional planning, targeted tobacco cessation programs, and structured behavioral health services comprise the nonexercised pillars of rehabilitation. Behavioral interventions and psychosocial support address the complex interplay between mood disorders, health behaviors, and adherence, thereby enhancing the durability of physiologic gains. Successful cardiac rehabilitation therefore rests on a biopsychosocial model that combines graded physical conditioning with risk reduction, education, and longitudinal medical oversight to reduce morbidity, improve functional capacity, and support sustained recovery [17][18].

Complications:

Cardiac rehabilitation is designed to restore cardiovascular function through structured and closely supervised physical activity, minimizing clinical risks during recovery. The evidence consistently shows that cardiac rehabilitation maintains one of the safest profiles among exercise-based medical interventions. The programs are organized to match exercise intensity with the patient's cardiovascular capacity, medication profile, and comorbid conditions. Each session is conducted under clinical supervision, often with electrocardiographic and hemodynamic monitoring, which allows early detection and management of potential complications such as arrhythmia, angina, or hemodynamic instability. A large-scale United States analysis from the early 1980s, encompassing 167 rehabilitation programs, provided one of the earliest quantitative evaluations of safety outcomes. The study documented 1 cardiac arrest per 111,996 exercise hours, 1 acute myocardial infarction per 293,990 exercise hours, and 1 fatality per 783,972 exercise hours. These findings demonstrate the low probability of adverse cardiovascular events when exercise is conducted in a controlled and supervised environment [19]. Comparable results were observed in subsequent studies from Europe. A French investigation evaluating the safety of rehabilitation across multiple centers reported a cardiac arrest incidence of 1.3 per million patient exercise hours, confirming the negligible risk associated with modern cardiac rehabilitation [20].

Device-related complications have also been examined. Rakhshan et al studied patients with implanted heart rhythm devices who participated in an 8-week rehabilitation program. The study found no evidence of device malfunction or inappropriate shock delivery. On the contrary, participants demonstrated a reduced rate of musculoskeletal and cardiovascular complications compared with those who did not participate in the program [21]. These data reinforce the safety of rehabilitation for patients with pacemakers or implantable cardioverter-defibrillators when appropriate monitoring protocols are followed. Most adverse events reported during rehabilitation are transient and self-limited. Common examples include mild muscle soreness, fatigue, and brief episodes of asymptomatic arrhythmia. The occurrence of serious complications such as myocardial ischemia, heart failure exacerbation, or syncope is extremely low, particularly in programs adhering to standardized pre-session screening and gradual workload progression. Risk is further reduced by careful medication adjustment, patient education on symptom recognition, and adherence to individualized exercise prescriptions. Overall, cardiac rehabilitation demonstrates a consistently favorable safety record supported by extensive clinical evidence. Continuous supervision, real-time physiological monitoring, and individualized treatment planning make serious adverse events exceptionally rare. When delivered through a structured, multidisciplinary model, cardiac rehabilitation remains an effective and secure therapeutic pathway for cardiovascular recovery and secondary prevention [21].

Clinical Significance:

Cardiac rehabilitation plays a pivotal role in modern cardiovascular care, delivering measurable improvements in physical capacity, psychological well-being, and long-term clinical outcomes. It combines structured exercise, education, and lifestyle modification within a supervised framework, producing sustained health benefits and reducing healthcare resource utilization. Extensive evidence demonstrates that participation in cardiac rehabilitation enhances quality of life, lowers hospital readmission rates, and reduces overall healthcare costs associated with cardiovascular disease management [22]. The exercise component provides measurable physiological gains that translate into clinical improvements. Enhanced maximal oxygen uptake ($\text{VO}_2 \text{ max}$) reflects better aerobic efficiency and increased myocardial oxygen delivery, which collectively improve functional endurance and daily activity tolerance. Exercise training also enhances endothelial function through increased nitric oxide bioavailability, improving vascular reactivity and reducing arterial stiffness. These effects contribute to a favorable hemodynamic profile and greater myocardial reserve capacity during stress or exertion. Regular exercise participation reduces circulating

catecholamine levels, improves left ventricular function, and promotes efficient oxygen extraction at the muscular level [22].

Beyond the physiological domain, cardiac rehabilitation exerts substantial benefits on modifiable risk factors. Evidence shows consistent reductions in smoking rates, body weight, total cholesterol, triglycerides, and systolic and diastolic blood pressure among participants. The combined effect of these risk modifications significantly reduces the likelihood of recurrent cardiovascular events. Psychosocial well-being also improves as structured rehabilitation decreases anxiety, enhances motivation, and supports long-term adherence to lifestyle changes. Milani et al demonstrated that participation in cardiac rehabilitation programs leads to a marked decline in depression severity following major coronary events, contributing to improved emotional resilience and engagement in recovery [23]. A Cochrane systematic review further validated the broad impact of cardiac rehabilitation, identifying a reduction in hospital admissions and long-term all-cause mortality among patients with heart failure and preserved ejection fraction. While short-term mortality reduction was not evident within 12 months, sustained benefits over extended follow-up suggest the cumulative effect of continued exercise, education, and behavioral adherence. These findings underscore the importance of maintaining long-term participation to achieve durable cardiovascular and systemic improvements. Cardiac rehabilitation goals align with both immediate recovery and chronic disease modification. Short-term objectives focus on stabilizing cardiac symptoms, improving functional capacity, and minimizing the emotional and physiological consequences of acute cardiac illness. Programs aim to restore confidence, promote early mobilization, and enable patients to resume social and occupational roles safely. In contrast, long-term goals extend toward altering disease progression by stabilizing atherosclerotic plaques, improving vascular integrity, and mitigating inflammation. Through continued engagement, cardiac rehabilitation contributes to reducing reinfarction rates, sudden cardiac death risk, and the progression of ischemic heart disease [23].

Future research emphasizes the evolution of cardiac rehabilitation delivery models to enhance accessibility and personalization. A systematic review of 19 randomized clinical trials revealed that complex e-coaching—digital platforms integrating exercise tracking, feedback loops, and behavioral support—effectively improves physical capacity, clinical status, and psychosocial health. However, the absence of standardized intervention protocols limits the ability to identify which digital components yield the most significant outcomes [24]. This gap highlights the need for comprehensive trials that evaluate platform design, engagement strategies, and long-term adherence outcomes. Basic e-coaching interventions lacking individualized feedback or professional

supervision were shown to be ineffective, reinforcing the necessity for structured, evidence-based virtual models. Moreover, cardiac rehabilitation in populations with congenital heart disease remains underexplored. Adults and children with congenital conditions face unique physiological challenges, including altered hemodynamics and surgical sequelae, that may limit standard rehabilitation protocols. The limited body of randomized controlled trials in this area restricts the development of clear evidence-based guidelines. Expanding research to address exercise safety, optimal training intensity, and outcome measurement in congenital heart disease will enable more precise and inclusive rehabilitation frameworks [25]. In summary, cardiac rehabilitation remains an essential intervention in cardiovascular medicine. It not only improves physiological performance and psychosocial outcomes but also serves as a cornerstone for secondary prevention. The integration of technology, patient-centered approaches, and evidence-based customization represents the next phase in optimizing its clinical impact and extending its benefits to broader patient populations [23][24][25].

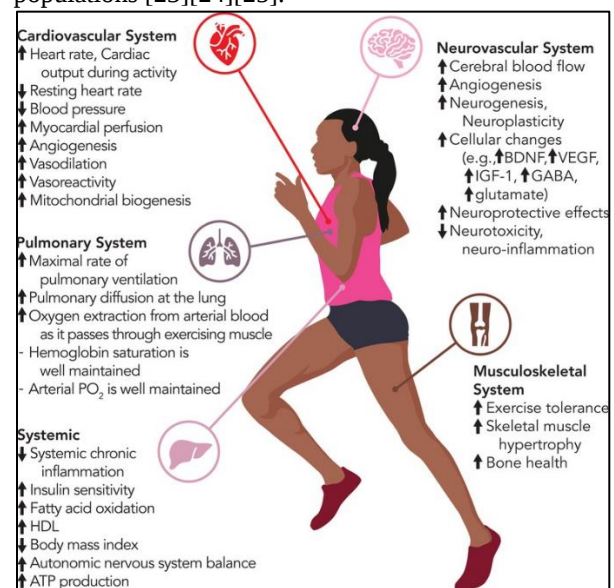


Figure-3: Clinical Significance of Cardiac Rehabilitation.

Enhancing Healthcare Team Outcomes

Although the benefits of cardiac rehabilitation are well-established, global participation rates remain insufficient to achieve widespread population-level impact. Data from Medicare and the Centers for Disease Control and Prevention reveal that only 14% to 35% of patients who survive a myocardial infarction and roughly 31% of those recovering from coronary artery bypass grafting enroll in structured cardiac rehabilitation or secondary prevention programs. These low participation rates significantly limit the potential of cardiac rehabilitation to reduce morbidity and mortality on a national scale. Leon et al identified multiple determinants contributing to

underutilization, including inconsistent referral practices, limited insurance coverage, inadequate patient motivation, socioeconomic barriers, and restricted access to rehabilitation facilities in rural or underserved regions [26]. The underuse of cardiac rehabilitation reflects both systemic and patient-level challenges. From a healthcare delivery perspective, many eligible patients never receive formal referrals at hospital discharge due to time constraints, fragmented communication between inpatient and outpatient providers, or the absence of standardized referral pathways. Even when referrals occur, barriers such as high copayments, limited transportation options, or scheduling conflicts prevent patients from participating. On the patient side, misconceptions about the purpose and safety of exercise following cardiac events can discourage engagement. Fear of symptom exacerbation or uncertainty about physical limits frequently leads patients to avoid structured programs. These factors highlight the importance of proactive team-based interventions to streamline referral systems, educate patients, and ensure financial and logistical support for sustained participation [26].

Psychosocial barriers also influence adherence to cardiac rehabilitation. A 2017 qualitative study exploring patients' perceptions identified major themes, including limited time availability, fear of exercise-induced complications, and emotional distress related to post-event vulnerability. Motivation to participate was closely associated with prior exercise experience, trust in the physiotherapist, and personal health goals after recovery [27]. Patients who received individualized education and clear communication from healthcare professionals demonstrated higher engagement and sustained attendance. Therefore, effective cardiac rehabilitation requires more than a prescriptive exercise plan—it demands consistent psychosocial assessment, empathetic communication, and personalized goal setting aligned with each patient's recovery trajectory. A strong interprofessional structure is central to addressing these multifaceted challenges. Cardiac rehabilitation teams that integrate primary care clinicians, cardiologists, cardiovascular surgeons, cardiac nurses, pharmacists, physical therapists, occupational therapists, and behavioral health specialists are better positioned to deliver comprehensive care. Each member contributes unique expertise that collectively enhances clinical outcomes. Cardiologists and surgeons provide medical oversight, adjusting pharmacologic therapies and monitoring recovery progress. Cardiac nurses play a critical role in patient education, symptom monitoring, and emotional support, ensuring adherence to medical and lifestyle recommendations. Pharmacists manage medication reconciliation, optimize cardiovascular pharmacotherapy, and identify drug-related issues that may affect exercise tolerance or hemodynamic stability. Physical and occupational therapists design

individualized activity programs that promote safe physical reconditioning and functional independence, while behavioral health specialists address psychological barriers such as anxiety and depression that often hinder adherence [27].

A growing area of interest involves integrating respiratory and diaphragmatic muscle training within cardiac rehabilitation frameworks. Diaphragm muscle rehabilitation has shown potential in enhancing exercise tolerance, improving respiratory efficiency, and optimizing hemodynamic stability, particularly in patients with chronic heart failure or postoperative respiratory compromise. However, current clinical guidelines offer limited direction on its standardized implementation, intensity, and duration. Further randomized trials are needed to establish evidence-based protocols that define its role within the broader rehabilitation continuum [28][29]. To enhance team effectiveness and patient outcomes, healthcare systems must adopt structured referral models, integrate technology-driven monitoring, and expand access through community-based or home-based programs. Tele-rehabilitation platforms that combine virtual supervision, biometric tracking, and behavioral support have demonstrated comparable safety and efficacy to traditional center-based models, particularly for patients facing logistical or socioeconomic barriers. Additionally, implementing automated referral systems within electronic health records can ensure that all eligible patients are consistently identified and enrolled before discharge. Ultimately, improving cardiac rehabilitation participation and outcomes requires alignment between interprofessional collaboration, patient-centered education, and systemic policy support. When teams function cohesively—sharing data, communicating transparently, and tailoring interventions—the benefits extend beyond individual patients to the broader healthcare system. Reduced readmissions, lower healthcare expenditures, and improved long-term survival rates all depend on the coordinated effort of the rehabilitation team in translating evidence-based cardiac care into consistent, accessible, and sustainable practice [28][29].

Nursing, Allied Health, and Interprofessional Team Interventions:

Cardiac rehabilitation represents a multidisciplinary model of care that depends on the collective expertise of healthcare professionals working in a coordinated framework to promote recovery, reduce recurrence, and improve long-term cardiovascular outcomes. The interprofessional team approach is central to this process, ensuring that each dimension of patient health—physical, psychological, and social—is addressed in a structured, evidence-based manner. The team integrates specialized contributions from cardiologists, nurses, physiotherapists, dietitians, psychologists,

pharmacists, social workers, and health information professionals, all functioning under a shared goal of optimizing patient function and quality of life after cardiac events. Cardiologists serve as the primary medical authority within cardiac rehabilitation programs. They conduct detailed assessments of cardiac function, monitor electrocardiographic changes, interpret diagnostic data, and tailor treatment plans according to the patient's recovery trajectory. Their oversight ensures the medical safety of all rehabilitation activities, particularly in patients with complex comorbidities or post-surgical complications. Cardiologists also play a pivotal role in determining exercise intensity thresholds, adjusting pharmacologic therapy, and coordinating follow-up assessments to track cardiovascular adaptation over time [30].

Exercise physiologists and physical therapists contribute by designing individualized training regimens that align with each patient's tolerance, physical limitations, and clinical objectives. They utilize graded exercise testing and functional assessments to prescribe aerobic, resistance, and flexibility exercises that enhance cardiac efficiency, muscular strength, and endurance. Continuous monitoring during sessions ensures safety and prevents adverse cardiac events. Their role also includes educating patients on maintaining independent physical activity post-program, facilitating a smooth transition to home-based exercise routines that sustain cardiovascular benefits over the long term. Nursing professionals form the backbone of day-to-day patient management in cardiac rehabilitation. Their responsibilities include monitoring vital signs, recognizing early warning signs of decompensation, and reinforcing adherence to therapeutic and lifestyle recommendations. Nurses deliver individualized education on medication adherence, blood pressure monitoring, and symptom recognition. They also act as the primary communication bridge between patients and the broader healthcare team, coordinating care transitions and ensuring that rehabilitation goals remain aligned with overall treatment plans. In addition, nurses provide emotional support, addressing anxiety or uncertainty that often accompany cardiac recovery, thus fostering motivation and patient engagement [30].

Dietitians integrate nutritional science into the rehabilitation process by designing individualized meal plans that promote lipid control, blood pressure regulation, and weight management. Their focus extends beyond calorie restriction to emphasize nutrient balance, sodium moderation, and appropriate macronutrient distribution. By helping patients adopt sustainable dietary behaviors, dietitians reduce modifiable cardiovascular risk factors and complement the physiological benefits of exercise and medication adherence. Mental health professionals, including psychologists and counselors, address the emotional and behavioral components of recovery. Post-cardiac event anxiety, depression, and stress are

common and can negatively influence adherence and outcomes. Through evidence-based interventions such as cognitive-behavioral therapy, stress reduction techniques, and motivational interviewing, they enhance emotional resilience and self-efficacy. Their involvement ensures that mental well-being remains a cornerstone of holistic rehabilitation. Pharmacists play an essential role in optimizing medication regimens by ensuring proper dosing, preventing drug interactions, and educating patients on pharmacologic adherence. They review cardiovascular drug profiles, including antiplatelets, beta-blockers, ACE inhibitors, and statins, to verify compatibility and minimize adverse effects. Pharmacists also collaborate with physicians and nurses to adjust medication plans based on exercise tolerance and blood pressure fluctuations during rehabilitation sessions. Social workers complement the clinical team by addressing non-medical barriers to participation. They assist patients in accessing community resources, navigating insurance coverage, and managing financial or logistical challenges related to attendance. Their advocacy supports equitable access to rehabilitation services and reduces disparities caused by socioeconomic constraints. Through this coordinated interprofessional structure, cardiac rehabilitation programs achieve higher adherence rates, better functional outcomes, and improved patient satisfaction. Communication among team members through case conferences, progress reports, and shared electronic documentation ensures continuity and consistency in care delivery [30].

Health information professionals hold an increasingly critical role in supporting cardiac rehabilitation operations. They manage patient data collection, ensure the accuracy of electronic health records, and track clinical progress across rehabilitation phases. By analyzing participation metrics, outcomes, and safety data, they provide essential insights that inform clinical decision-making and program evaluation. They also facilitate interoperability among healthcare systems, ensuring that relevant patient information is accessible to all team members. Moreover, health information specialists contribute to quality improvement by identifying trends in adherence, outcomes, and complication rates, enabling evidence-based refinement of rehabilitation protocols. In sum, cardiac rehabilitation thrives on the synergy between clinical expertise, patient-centered education, and data-driven management. The coordinated work of nurses, allied health professionals, and health information workers ensures a comprehensive, safe, and outcome-focused rehabilitation experience that strengthens recovery and enhances long-term cardiovascular health [30].

Conclusion:

In conclusion, cardiac rehabilitation stands as a pivotal, evidence-based intervention that significantly improves the prognosis and quality of life for patients with cardiovascular disease. By

integrating supervised exercise training, comprehensive risk factor management, and structured psychosocial support within an interprofessional team framework, CR produces demonstrable benefits. These include enhanced functional capacity, improved physiological and psychological well-being, and a definitive reduction in hospital readmissions and long-term mortality. Despite its proven efficacy and exceptional safety record, the widespread impact of CR is hampered by significant underutilization, driven by referral gaps, logistical barriers, and patient misconceptions. To realize the full potential of cardiac rehabilitation, healthcare systems must prioritize overcoming these barriers. This requires the implementation of automated referral protocols, the expansion of accessible delivery models such as home-based and telehealth programs, and persistent patient education. A coordinated, interprofessional approach is essential to ensure eligible patients are identified, engaged, and supported throughout their rehabilitation journey. Ultimately, enhancing participation in cardiac rehabilitation is critical for translating its robust clinical trial benefits into widespread, real-world effectiveness, solidifying its role as an indispensable component of comprehensive cardiovascular care.

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