# Impact of Cardiac Rehabilitation on Functional Capacity in Patients After Coronary Angioplasty

# Impact de la réadaptation cardiaque sur la capacité fonctionnelle des patients après une angioplastie coronaire

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## Summary

**Introduction** : Cardiovascular diseases, predominantly ischemic heart disease, represent the leading cause of morbidity and mortality worldwide. Despite advances in coronary angioplasty, many patients continue to have reduced functional capacity after revascularization. Cardiac rehabilitation therefore plays a key role in improving exercise tolerance and quality of life, highlighting the importance of evaluating its impact on the functional capacity of post-angioplasty patients.

**Methods:** This was a retrospective, observational, descriptive, single-center study conducted at the Cardiac Rehabilitation Center of La Rabta Hospital. It included patients who had undergone successful percutaneous coronary angioplasty, were able to perform physical exercise, and participated in a cardiac rehabilitation program between September 2023 and September 2025. Clinical and paraclinical data were collected, and changes in functional capacity were monitored throughout the rehabilitation program.

**Results:** A total of 31 patients were included, with a mean age of 54.74 years and a predominance of males. The cardiac rehabilitation program led to a significant improvement in functional symptoms, with complete resolution of chest pain ($p = 0.008$) and a marked reduction in dyspnea ($p < 0.001$). Significant decreases in systolic ($p = 0.024$) and diastolic blood pressure ($p = 0.001$), as well as an improvement in left ventricular ejection fraction ($p < 0.001$), were observed, while resting heart rate remained stable ($p = 0.707$). Functional capacity also improved significantly, with increases in maximal tolerated exercise and distance covered during the six-minute walk test ($p < 0.001$).

**Conclusion:** Cardiac rehabilitation after coronary angioplasty significantly improves patients' symptoms, hemodynamic parameters, and functional capacity. Despite certain methodological limitations, these results underscore the importance of systematically integrating cardiac rehabilitation into the management of coronary patients.

## Keywords

Cardiac rehabilitation; Functional capacity; Coronary angioplasty; Post-infarction recovery

## Résumé

**Introduction:** La cardiopathie ischémique représente la principale cause de morbidité et de mortalité dans le monde. Malgré les avancées de l'angioplastie coronaire (ATC), de nombreux patients continuent à présenter une capacité fonctionnelle réduite après la revascularisation. La réadaptation cardiaque (RC)a un rôle clé dans l'amélioration de la tolérance à l'effort et de la qualité de vie.

**Objectif :** Evaluer l'impact de la RC sur la capacité fonctionnelle des patients post-angioplastie.

**Méthodes :** Etude rétrospective, observationnelle, descriptive, monocentrique, menée au Centre de réadaptation cardiaque de l'Hôpital La Rabta. Elle a inclus des patients ayant subi une ATC ayant participé à un programme de RC entre septembre 2023 et septembre 2025.

**Résultats :** Trente et un patients ont été inclus, avec un âge moyen de 54,74 ans et une prédominance masculine. Le programme de RC a entraîné une amélioration significative des symptômes, avec une résolution complète de la douleur thoracique ($p = 0,008$) et une réduction marquée de la dyspnée ($p < 0,001$). Une diminution significative de la pression artérielle systolique ($p = 0,024$) et diastolique ($p = 0,001$), ainsi qu'une amélioration de la fraction d'éjection ventriculaire gauche ($p < 0,001$), ont été observées, sans modification de la fréquence cardiaque au repos ($p = 0,707$), avec parallèlement une amélioration de la capacité fonctionnelle marquée par l'augmentation de l'effort maximal toléré et de la distance au test de marche de six minutes ($p < 0,001$).

**Conclusion :** La réadaptation cardiaque après angioplastie coronaire améliore significativement l'état clinique et la capacité fonctionnelle des patients coronariens, justifiant son intégration systématique dans leur prise en charge.

## Mots-clés

Réadaptation cardiaque ; Capacité fonctionnelle ; Angioplastie coronaire ; Récupération post-infarctus

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## INTRODUCTION

Cardiovascular diseases are the leading cause of morbidity and mortality worldwide, with ischemic heart disease being the most prevalent (1). Despite advances in coronary revascularization, particularly percutaneous coronary intervention (PCI), many patients continue to experience reduced functional capacity after the procedure. This limitation, often related to physical deconditioning, persistent cardiovascular risk factors, and fear of exertion, can impair daily activities and increase the risk of recurrent events (2).

Cardiac rehabilitation (CR) is a key component of comprehensive care for coronary patients (3). Multidisciplinary programs combining exercise training, therapeutic education, optimized medical therapy, and risk factor management have been shown to improve exercise tolerance, functional capacity, quality of life, and long-term prognosis(4). Functional capacity, commonly assessed by tests such as the six-minute walk test or exercise testing, is an important prognostic marker and a measure of rehabilitation effectiveness(5).

Despite its proven benefits, local data on the impact of cardiac rehabilitation post-angioplasty remain limited. Evaluating its effects is therefore crucial for clinical practice and for promoting its systematic integration into patient care.

The present study aims to assess the impact of cardiac rehabilitation on the functional capacity of patients following successful coronary angioplasty.

## METHODS

### Study population

This was a prospective, monocentric, observational study, conducted from September 2023 to September 2025 in the Cardiac Rehabilitation Center of the Cardiology Department, La Rabta University Hospital, Tunisia.

Patients were included if they underwent successful PCI of one or more native epicardial coronary arteries, were clinically stable, able to perform exercise, and participated in a cardiac rehabilitation program. Patients with acute instability or major complications (cardiogenic shock, severe periprocedural myocardial infarction, or significant arrhythmias), contraindications to exercise (severe musculoskeletal, pulmonary, or neurological disorders), uncontrolled comorbidities, prior coronary artery bypass grafting, or incomplete follow-up or rehabilitation were excluded.

Patients were not included if they were on peritoneal dialysis, dialyzed via a central venous catheter, or required emergency dialysis. Patients with a history of cardiomyopathy, coronary artery disease, arrhythmia, more than moderate mitral or aortic valvular disease, a history of chemotherapy, congenital heart disease, intra-cardiac devices or cardiac surgery were also not included;

**Tableau 1**. General characteristics

| | General population (n=31) |
|---|---|
| Age (years) | 55±11 |
| Gender (Male/Female) | 27/4 |
| Hypertension (n, %) | 13 (42) |
| Diabetes (n, %) | 8 (26) |
| Dyslipidemia (n, %) | 11 (36) |
| Obesity (n, %) | 10 (32) |
| Smoking (n, %) | 20 (65) |
| Heart failure (n, %) | 11 (36) |
| Atrial fibrillation (AF) (n, %) | 1 (3) |
| Chronic obstructive pulmonary disease (COPD) (n, %) | 1 (3) |
| **Coronary angioplasty (stent site)** | |
| Left Main (LM) (n, %) | 1 (3) |
| Left Anterior Descending (LAD) (n, %) | 27 (87) |
| Diagonal (n, %) | 4 (13) |
| Circumflex (CX) (n, %) | 6 (29) |
| Marginal (n, %) | 2 (7) |
| Ramus Intermedius (n, %) | 1 (3) |
| Right Coronary Artery (RCA) (n, %) | 7 (23) |
| **Clinical data** | |
| Asymptomatic (n, %) | 5 (16) |
| Chest pain (n, %) | 8 (26) |
| Dyspnea NYHA Class I (n, %) | 8 (26) |
| Dyspnea NYHA Class II (n, %) | 13 (42) |
| BMI < 25 kg/m² (Normal weight) (n, %) | 13 (42) |
| BMI25–30 kg/m² (Overweight) (n, %) | 14 (45) |
| BMI 30–35 kg/m² (Moderate obesity) (n, %) | 8 (26) |
| BMI ≥ 35 kg/m² (Severe obesity)(n, %) | 1 (3) |
| Systolic BP (mm Hg)before rehabilitation (Mean ± SD) | 112 ± 15 |
| Diastolic BP (mm Hg)before rehabilitation (Mean ± SD) | 68 ± 10 |
| Systolic BP (mm Hg)after rehabilitation (Mean ± SD) | 107 ± 12 |
| Diastolic BP (mm Hg)after rehabilitation (Mean ± SD) | 64 ± 10 |
| Heart rate (bpm) before rehabilitation (Mean ± SD) | 69 ± 9 |
| Heart rate (bpm) after rehabilitation (Mean ± SD) | 68 ± 10 |
| **Additional Diagnostic Tests** | |
| Heart rate (bpm) in Holter Monitoring (Mean ± SD) | 65± 9 |
| Maximal Theoretical Heart Rate (MTHR, %) before rehabilitation in Exercise Stress Test (Mean ± SD) | 71± 10 |
| Maximal Theoretical Heart Rate (MTHR, %) after rehabilitation in Exercise Stress Test (Mean ± SD) | 88± 8 |
| Target Heart Rate (THR, bpm) (Mean ± SD) | 110± 15 |
| Left Ventricular Ejection Fraction (LVEF, %) %) before rehabilitation in (Mean ± SD) | 45± 13 |
| Left Ventricular Ejection Fraction (LVEF, %) %) after rehabilitation in (Mean ± SD) | 50± 12 |
| 6-Minute Walk Distance (m) before rehabilitation (Mean ± SD) | 425± 102 |
| 6-Minute Walk Distance (m) after rehabilitation (Mean ± SD) | 522± 10 |

Abbreviations: BMI: body mass index, BP: Blood pressure, SD: standard deviation

## Clinical evaluation

The study encompassed the collection of patient demographic and anthropometric information, cardiovascular risk factors, and comorbidities.

Functional symptoms were assessed, including exertional dyspnea using the New York Heart Association (NYHA) classification and exertional angina. Physical examination data included body weight (kg), height (cm), systolic and diastolic blood pressure, heart rate (HR), peripheral oxygen saturation ($SpO_2$), cardiac auscultation findings, and signs of right or left heart failure.

All patients underwent transthoracic echocardiography (TTE) before and after cardiac rehabilitation to assess left ventricular ejection fraction (LVEF) calculated using the biplane Simpson method, systolic pulmonary artery pressure (sPAP) with sPAP ≥35 mmHg considered pulmonary hypertension and the presence of valvular heart disease.

Holter Monitoring was performed in all patients before rehabilitation, recording mean heart rate and the presence or absence of excitability or conduction abnormalities.

## Exercise Testing

Exercise testing is central to functional evaluation in cardiac rehabilitation, allowing assessment of exercise tolerance, objective measurement of functional limitations, detection of residual ischemia or exercise-induced arrhythmias, and individualization of training parameter.

In this study, testing was performed on a standardized cycle ergometer protocol under continuous medical supervision. Workload increased progressively according to the patient's clinical status and baseline functional capacity. Continuous electrocardiographic monitoring was maintained throughout, with repeated heart rate and blood pressure measurements.

During the test, the following were systematically recorded: subjective symptoms (dyspnea, chest pain, fatigue), heart rate and blood pressure response, occurrence of electrocardiographic abnormalities (ventricular repolarization changes, ventricular or supraventricular arrhythmias, conduction disorders), and abnormal hemodynamic responses (e.g., hypotension, pallor, or cold sweating indicating low cardiac output). Key outcomes included total exercise duration, maximal workload achieved, peak heart rate (PHR), exercise blood pressure, and any ECG abnormalities.

Results of the exercise test were used for risk stratification and to determine the target heart rate (THR) for individualized exercise training, calculated using the Karvonen formula(6):

THR = resting HR + (max HR – resting HR) × target intensity

Target intensity was set at 60–80% of HR reserve based on the patient's clinical profile and exercise tolerance, enabling personalized CR and monitoring of functional capacity progression.

Six-Minute Walk Test (6MWT):In this study, the 6MWT was conducted according to the American Thoracic Society (ATS) guidelines(7). The test took place in a clearly marked, flat, straight 40-meter corridor. Patients were instructed to walk as far as possible for six minutes at their own pace, with the option to slow down, stop, or resume walking as needed, without running.

The 6MWT was used to assess the patients' baseline functional capacity and to monitor changes throughout the CR program.

## Cardiac Rehabilitation

Our CR facility is equipped with devices designed to monitor and train patients' functional capacity. It includes:

- Ergometers (stationary bicycles): Allowing progressive cyclic exercise tailored to each patient's level.
- Treadmills and exercise platforms: For controlled walking during supervised sessions.
- Physiological monitoring systems: Including devices for heart rate, blood pressure, and oxygen saturation ($SpO_2$) during physical activity.
- Functional testing equipment: Such as six-minute walk setups and benches to assess exercise tolerance and capacity.
- Stress echocardiography equipment: Recently acquired, used to visualize cardiac response to progressive exercise and refine functional assessment.

Patient care was provided by a specialized multidisciplinary team including cardiologists, nurses trained in CR, and physiotherapists or exercise specialists, with initial risk stratification performed to guide individualized exercise prescription and the level of supervision and monitoring. Exercise prescription involves defining the mode, intensity, frequency, and duration of activity. Patients followed a structured program combining endurance and resistance training.

- Endurance exercises : Performed on treadmill, bicycle, or hand crank, each session includes 5 minutes of warm-up, 30 minutes of training (starting at 30 W with progressive increments of 5–10 W every two sessions, up to 90 W, including interval training), and 5 minutes of recovery.
- Resistance exercises : Ground-based gymnastics adapted to individual capabilities.

All sessions were conducted under continuous monitoring of HR and blood pressure, and training load was adjusted to ensure patient safety.

Dietary sessions are included to assess weight, BMI, and eating habits, and to guide patients toward ideal weight through interactive workshops and nutrition education tailored to their condition.

Psychological support sessions, led by a psychologist or trained mental health professional, were included to improve adherence and reduce anxiety after coronary events or angioplasty. They also aimed to enhance quality of life and reinforce therapeutic education on lifestyle and medication adherence.

The effects of the program were evaluated qualitatively through interviews and standardized questionnaires to complement the overall assessment of CR.

### Statistical analysis

Data were analyzed using IBM SPSS Statistics 27. Qualitative variables were expressed as frequencies and percentages, while quantitative variables were reported as mean ± standard deviation or median and interquartile range according to distribution. Comparisons were performed using Student's t-test for means and Chi-square or Fisher's exact test for proportions; paired non-parametric comparisons were assessed using the Wilcoxon signed-rank test and dichotomous paired variables with the McNemar test. A p-value < 0.05 was considered statistically significant.

## RESULTS

The study cohort included 31 consecutive patients, with a mean age of 55 ± 11 years, predominantly male (87%). Smoking was the most common cardiovascular risk factor (65%) followed by diabetes (26%) . PCI was performed mainly on the left anterior descending artery in 87% of cases. Dyspnea and chest pain were the most frequent baseline symptoms. Normal BMI was found in 26% of patients, 45% were overweight, and 29% were obese. Hypertension was present in 10% of patients. Mean heart rate was 69 ± 9 bpm before rehabilitation and 68 ± 10 bpm after rehabilitation.

All patients maintained sinus rhythm on Holter monitoring, with hyperexcitability observed in 19% and no conduction abnormalities; mean Holter heart rate was 65 ± 9 bpm. Maximal theoretical heart rate increased from 71 ± 10% before to 88 ± 8% after rehabilitation, while mean target heart rate before rehabilitation was 109 ± 15 bpm. Mean left ventricular ejection fraction improved from 45 ± 13% to 50 ± 12%, with pulmonary hypertension observed in 2 patients but no right ventricular dysfunction or significant valvular abnormalities. Functional capacity also improved, with six-minute walk distance increasing from 425 ± 102 m to 522 ± 100 m. The median CR program duration was 53 days (IQR: 46–59, range 30–262), with patients completing a mean of 20 ± 3 sessions (range 8–30).

### Impact of Rehabilitation on Functional Symptoms

The CR program led to a significant improvement in functional symptoms. Chest pain, reported by 8 patients before rehabilitation, was completely resolved in all cases after the program (p = 0.008, McNemar's exact test). Similarly, the number of patients experiencing dyspnea decreased markedly from 21 to 1 after rehabilitation (p < 0.001, McNemar's exact test).

### Impact of Cardiac Rehabilitation on Hemodynamic Parameters

Following the CR program, several physiological and functional parameters showed significant improvements. Systolic blood pressure (SBP) decreased significantly, from 112 ± 15mmHg before rehabilitation to 107± 12 mmHg after the program, with a mean reduction of 5 mmHg (95% CI: 0.73–9.59, p = 0.024, paired t-test). Similarly, diastolic blood pressure (DBP) decreased from 68.23 ± 9.54 mmHg to 64 ± 10 mmHg, with a mean reduction of 4 mmHg (95% CI: 1.69–6.37, p = 0.001).

In contrast, resting HR did not change significantly, from 68.61 ± 9.4 bpm to 68 ± 10 bpm (mean difference = 0.71 bpm, 95% CI: −3.11–4.53, p = 0.707).

### Impact on Echocardiographic Parameters

LVEF increased significantly, from 45 ± 13 % before rehabilitation to 50 ± 12% after (mean difference = −5.03%, 95% CI: −6.42–−3.65, p < 0.001).

### Impact on Functional Parameters

Maximal tolerated heart rate (MTHR) improved significantly following rehabilitation, from 71 ± 10% before to 88 ± 8% after (mean difference = −17.65%, 95% CI: −20.81–−14.48, p < 0.001, paired t-test).

Similarly, the six-minute walk distance (6MWD) increased significantly, from 425 ± 102 m to 522 ± 100 m after rehabilitation (mean difference = −96.13 m, 95% CI: −114.23–−78.03, p < 0.001).

In summary, the CR program led to significant improvements in hemodynamic parameters, left ventricular systolic function, and functional performance, while resting HR remained stable. The results are summarized in table 2.

**Table 2.** Changes in Functional Capacity Before and After Cardiac Rehabilitation

| | Before Rehabilitation (Mean ± SD) | After rehabilitation (Mean ± SD) | Mean Difference (95% CI) | P |
|---|---|---|---|---|
| Chest pain (n) | 8 | 0 | | 0,008 |
| Dyspnea (n) | 21 | 1 | | < 0.001 |
| Systolic BP (mm Hg) | 112±15 | 107±12 | 5.16 (0.73–9.59) | 0,024 |
| Diastolic BP (mm Hg) | 68±10 | 64±10 | 4.03 (1.69–6.37) | 0,001 |
| Heart rate (bpm) | 69±9 | 68±10 | 0.71 (−3.1–4.53) | 0,707 |
| Maximal Tolerated Heart Rate (%) | 71±10 | 88±8 | −17.65 (−20.81–−14.48) | < 0.001 |
| Left Ventricular Ejection Fraction (%) | 45±13 | 50±12 | −5.03 (−6.42–−3.65) | < 0.001 |
| 6-Minute Walk Distance (m) | 425±102 | 522±100 | -96,13 (-114,23—78,03) | < 0.001 |

Abbreviations: BP: blood pressure, CI: confidence interval, SD: standard deviation

## DISCUSSION

### Epidemiological and Clinical Characteristics

In our study, the mean age of patients was 55 ± 11 years reflecting a relatively young population. This age distribution aligns with literature data showing lower participation rates of elderly patients in CR programs. For example, Witt et al. (4), including 1821 post-myocardial infarction patients, reported that individuals aged ≥70 years were significantly less likely to participate in CR than those under 60 years (OR = 0.23; 95% CI: 0.16–0.33). Ghannem et al. (8) also demonstrated that CR programs for autonomous elderly patients are comparable to those for younger patients; however, for dependent elderly patients, the primary goal is functional independence. Advanced age should not preclude cardiovascular risk factor modification or therapeutic education, and involvement of family support is critical in patients with cognitive limitations.

In our cohort, males predominated (27 patients, 87%), consistent with the widely reported underutilization of CR in women despite strong evidence of its benefits. Multiple studies have shown that CR significantly reduces cardiovascular morbidity and mortality. Ghannem Cazaubiel (9) highlighted that, despite proven benefits on major clinical endpoints, CR remains under prescribed, particularly among women. These findings emphasize the need to increase access to CR for female patients and to adapt programs to their specific needs.

A large French national study by Grave et al. (5), based on 134 846 patients hospitalized for acute coronary syndrome, showed that only 22% participated in CR within six months of discharge, with a mean age of 62 years among participants. Male sex and younger age (35–64 years) were significantly associated with higher CR utilization. Between 2009 and 2019, CR participation increased from 15.9% to 22.3%, with women's participation remaining lower than men's (14.8% vs. 25.8%), reflecting persistent gender disparities in access to CR.

In our study, smoking was the most common cardiovascular risk factor, observed in 20 patients (65%), of whom 11 had quit (36%). This prevalence is consistent with literature emphasizing the detrimental impact of smoking on functional recovery after coronary events. Noguchi et al. (10) reported that smokers had significantly impaired cardiorespiratory function compared with non-smokers after CR ($\beta = -3.29$; SE = 1.40; 95% CI: −6.04 to −0.54; $p = 0.02$).

Other metabolic comorbidities, particularly diabetes, also play a key role in prognosis and CR response. In our cohort, 26% of patients were diabetic, with only one requiring insulin. This proportion remains relatively low considering the high prevalence of diabetes among coronary patients. Beacco et al. (11), in a database of 700 CR patients, identified 105 patients (15%) with glucose metabolism disorders, suggesting that diabetic patients remain underrepresented in CR programs despite clear benefits for this high-risk population.

### Importance of Cardiac Rehabilitation After Percutaneous Coronary Intervention

PCI is a cornerstone in managing acute coronary syndromes and stable ischemic heart disease. While PCI restores coronary blood flow and improves short-term survival, it does not address underlying pathophysiological mechanisms such as diffuse atherosclerosis, chronic inflammation, and persistent cardiovascular risk factors.

CR is therefore essential post-PCI to enhance functional capacity, reduce ischemic recurrence, improve quality of life, and decrease long-term cardiovascular mortality. International guidelines (ESC, AHA) recommend CR as a class I indication after myocardial infarction (12). Randomized trials, meta-analyses, and registries report a 20–30% reduction in morbidity and mortality with CR. Exercise training not only improves physical capacity but also optimizes risk factors, including lipid profile, blood pressure, smoking cessation, glycemic control, and weight management, thereby limiting atheroma progression.

Functional capacity itself is prognostic: the higher the exercise tolerance, the better the long-term outcome.

### Effects on Cardiovascular Risk Factors

Functional capacity improvement in our study reflects a broader reduction in cardiovascular risk. CR programs typically combine :

- Regular physical activity
- Therapeutic education
- Medical therapy optimization
- Smoking cessation
- Nutritional management

This comprehensive approach improves lipid, glucose, and blood pressure control, enhancing exercise tolerance and reducing ischemic recurrence risk (12). Denolle et al. (13), in 1091 coronary patients, reported significant improvements in risk factor control after CR, with more patients reaching blood pressure (≤140/90 mmHg), BMI (<30 kg/m$^2$), and LDL (<0.7 g/L) targets, while smoking prevalence dropped from 18% to 4%. However, these gains decreased after one year, underscoring the need for long-term follow-up strategies.

### Effects of Cardiac Rehabilitation on Functional Capacity

#### Improvement in Exercise Tolerance

Functional capacity, typically measured by exercise testing and the 6-minute walk test (6MWT), improves significantly after CR. In our study, structured CR led to notable functional gains, reflected in better exercise tolerance and earlier resumption of daily activities. These findings align with literature reporting increased 6MWT distances post-CR. For instance, the RER study by Pavy et al. (14) included 202 patients (mean age 63 ± 10 years; 93% male), showing an increase in 6MWT from 431 ± 90 m pre-CR to 511 ± 91 m post-CR, maintained at six months (513 ± 88 m).

Mechanisms underlying this improvement include:

- Enhanced cardiorespiratory efficiency
- Improved endothelial function
- Reduced heart rate during exercise
- Optimized peripheral oxygen extraction

Sabbahi et al. (15) highlighted the central role of aerobic training in CR programs and emphasized individualized exercise prescription. High-intensity interval training (HIIT) has also been shown to be safe and effective in various clinical populations, significantly enhancing functional capacity. Hambrecht (16) conducted a prospective study comparing an exercise intervention group (n = 29) with a usual care group (n = 33). After one year, the intervention group showed a 7% increase in oxygen consumption at the ventilatory threshold ($p < 0.001$) and a 14% increase in peak $VO_2$ ($p < 0.05$), whereas the control group declined, demonstrating the sustained benefits of structured exercise.

#### Reduction of Physical Deconditioning

Post-coronary hospitalization, many patients experience physical deconditioning due to bed rest, fear of exertion, and anxiety. CR allows a gradual, safe, and supervised return to activity, breaking the sedentary–deconditioning–exercise intolerance cycle. Sandu-Marinescu et al. (17) evaluated CR in very elderly patients (mean age 87 years) and found a significant increase in 6MWT distance (mean +68.5 m, $p < 0.001$) and reduced anxiety, facilitating safe return home.

#### Impact on Angina and Quality of Life

CR is crucial for reducing residual angina post-PCI. Supervised exercise improves endothelial function, myocardial perfusion, and coronary microcirculation while lowering heart rate and blood pressure, thereby reducing myocardial oxygen demand and increasing ischemic threshold. Similarly, Saeidifard et al. reported reduced angina frequency after CR in a meta-analysis (18).

Beyond physiological improvements, CR significantly enhances quality of life, reducing angina, exertional dyspnea, and fatigue. CR also promotes:

- Return to work
- Resumption of social activities
- Reduction in post-event anxiety and depression

Psychological benefits indirectly enhance functional capacity by alleviating fear of exertion and increasing patient confidence in physical abilities.

#### Comparison with Literature Data

Our results are consistent with those of several large studies and meta-analyses evaluating the impact of CR on mortality, cardiovascular complications, and risk factor management after PCI. Xingrong He et al. (2), in a systematic review and meta-analysis including 1,808 patients, demonstrated that the combination of five components of CR—exercise, nutrition, psychological support, smoking cessation, and medication optimization—significantly improves myocardial function and reduces cardiac complications following PCI. Similarly, Taylor et al. (19), in a systematic review and meta-analysis of 8,940 patients, reported that CR was associated with reduced all-cause mortality (OR = 0.80) and cardiac mortality (OR = 0.74), as well as improvements in total cholesterol levels, systolic blood pressure, and lower rates of self-reported smoking (OR = 0.64). In a study by Palatsi et al. including 180 patients, mortality during the second year was 3.6% in the exercise group compared with 5.5% in the control group. In the study by Maroto Montero et al. (20) involving 180 patients, all-cause mortality was significantly lower in the CR intervention group, with a 10-year survival rate of 91.8% versus 81.7% in the control group (P = 0.04). Cardiovascular mortality was also reduced, although not statistically significant (10-year survival 91.8% vs. 83.8%, P = 0.10). Furthermore, the incidence of non-fatal complications was lower in the CR group (35.2% versus 63.2%, P = 0.03), including unstable angina (15.7% vs. 33.9%, P = 0.02), heart failure (3.0% vs. 14.4%, P = 0.02), and the need for subsequent coronary interventions (8.4% vs. 22.9%, P = 0.02). Collectively, these findings from observational studies, clinical trials, and meta-analyses strongly support the beneficial role of cardiac rehabilitation in improving survival, reducing cardiovascular events, and optimizing risk factor control following PCI.

### Strengths of Our Study

Our study has several strengths: it was conducted under real-world conditions, included a homogeneous population of post-angioplasty patients, assessed functional capacity objectively, and focused on a clinically relevant and prognostic outcome. These factors enhance the clinical applicability of our findings.

### Limitations

Some limitations should be acknowledged: the sample size was relatively small, the study was monocentric and retrospective, and there is a potential selection bias due to voluntary participation in the cardiac rehabilitation program. These limitations may restrict the generalizability of the results and warrant cautious interpretation of the conclusions.

### Future Perspectives and Implications

This work opens several avenues for future research. Efforts should be made to expand access to cardiac rehabilitation, particularly post-angioplasty, promote home-based or tele-rehabilitation programs, identify patient profiles most likely to benefit functionally, and integrate rehabilitation early after PCI. Prospective multicenter studies with larger cohorts and longer follow-up are needed to better clarify the long-term impact of cardiac rehabilitation on functional capacity and mortality.

## CONCLUSIONS

In conclusion, cardiac rehabilitation after coronary angioplasty significantly improves symptoms, functional capacity, and left ventricular function. Despite the study's limitations, these findings support the integration of CR into routine post-angioplasty care, with further prospective studies needed to confirm long-term benefits and optimize program delivery.

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