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*NARRATIVE REVIEW*

# Return to Sports in Patients with Coronary Artery Disease: A Narrative Review

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## ABSTRACT

**Introduction:** Coronary artery disease (CAD) is a leading cause of mortality and morbidity, often limiting physical activity due to myocardial ischemia and ventricular dysfunction. Cardiac rehabilitation (CR) reduces cardiovascular risk, improves functional capacity, and enhances quality of life. While CR supports a safe return to sports (RTS), determining appropriate exercise intensity and type remains challenging. Guidelines from cardiology associations recommend risk assessment before RTS, often using cardiopulmonary exercise testing, but implementation varies, and research on RTS after CR in CAD patients is limited. This review explored physical activity and CR in facilitating safe RTS, addressing benefits, risks, screening, assessment, and exercise recommendations.

**Methods:** A literature search was conducted using PubMed, ScienceDirect, and CINAHL with keywords like "return to sport" and "coronary artery disease." Inclusion criteria encompassed original research on RTS in CAD patients, available in full text, and focused on adults. A multi-step screening process included title, abstract, and full-text evaluations.

**Results:** Seventeen articles addressed the risks and benefits of physical activity in CAD patients, eleven focused on pre-participation screening and assessments, and four examined RTS recommendations. Findings were synthesized into a narrative review with tables for clarity.

**Conclusion:** Physical activity benefits CAD patients by improving endothelial function, autonomic balance, and plaque stability, reducing cardiovascular risk. However, high-intensity exercise may trigger acute events, necessitating pre-participation screening. Risk stratification guides safe RTS, with tailored exercise programs optimizing benefits while minimizing risks. Individualized prescriptions and periodic evaluations ensure long-term safety.

**Keywords:** Coronary Artery Disease, Cardiac Rehabilitation, Return to Sport, Quality of Life, Exercise Therapy

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# INTRODUCTION

Coronary artery disease (CAD) is recognized as one of the leading causes of mortality and morbidity worldwide.[1] Patients with CAD often experience physical limitations due to myocardial ischemia, ventricular dysfunction, and an increased risk of arrhythmias, which may heighten the likelihood of recurrent cardiovascular events. [2] However, various studies have demonstrated that engaging in controlled and structured physical activity as part of a cardiac rehabilitation (CR) program can enhance functional capacity, lower the risk of cardiovascular complications, and improve patients' quality of life (QoL).[3,4]
Physical activity is a key aspect in CR and plays a crucial role in improving the QoL in patients with CAD.[5,6]

Nevertheless, determining the appropriate intensity and type of safe exercise for these patients remains a clinical consideration.[7,8] CR is a multidisciplinary intervention that promotes cardiovascular health by combining structured exercise training, lifestyle education, and medical therapy optimization.[4] This program is vital in preparing patients to safely and gradually resume physical activity, including sports.[4,9] However, one of the primary challenges in returning to sports for patients with CAD lies in determining the safe intensity, duration, and type of exercise while ensuring that patients are physiologically prepared to participate in sports without elevating the risk of adverse cardiovascular events.[7,10-12]

Several global health associations, including the American Heart Association (AHA) and European Society of Cardiology (ESC), have established CR guidelines that incorporate risk assessment before patients return to sports (RTS).[9,13,14] Cardiopulmonary exercise testing (CPET) is commonly utilized to measure aerobic capacity and ischemic thresholds, aiding safe physical activity levels.[15-17] However, the implementation of these guidelines varies across healthcare facilities, and the available literature specifically addressing RTS following CR in CAD patients remains limited.[18-20]

Therefore, this review aimed to explore physical activity and CR in facilitating a safe RTS for patients with CAD. Specifically, this review explored the risks and benefits of physical activity and exercise in CAD patients, pre-participation screening, pre-participation rehabilitation assessment, and recommendations and exercise prescriptions for RTS in this population.

# METHODS

A data synthesis was conducted using articles retrieved from PubMed, ScienceDirect, and CINAHL. The search strategy involved the use of specific keywords, including “return to sport” and “coronary artery disease,” either individually or in combination, to ensure a broad yet targeted selection of relevant studies. The inclusion criteria encompassed original research articles from any study design that explored aspects of return to sport in patients with CAD. To maintain the relevance of the review, the focus was restricted to studies conducted in adult patient populations. Articles were excluded if they were published in languages other than English or if full-text versions were not available.

The authors conducted a systematic screening of the search results through a multi-step process. Initially, article titles were carefully reviewed to identify relevant studies. Titles that appeared to align with the study objectives were then further assessed by examining their abstracts. If both the title and abstract indicated that the article was relevant to the scope of this review, the full text was then evaluated to ensure its suitability for inclusion. Furthermore, the references of the selected articles, as well as studies that cited them, were further explored. This approach allowed for the identification of additional relevant literature, thereby enriching the comprehensiveness and depth of the review.

# RESULTS

The article search was conducted with a primary focus on the research objectives. A total of seventeen articles were identified as relevant in discussing the risks and benefits of physical activity in patients with CAD. Additionally, eleven articles were reviewed to explore exercise pre-participation screening and pre-participation rehabilitation assessments for CAD patients. To formulate recommendations for returning to sports and exercise prescriptions for CAD patients, four key articles were analyzed and summarized.

The selected studies were then synthesized into a narrative review, detailing various aspects and considerations related to returning to sports for individuals with CAD. The findings are also illustrated through figures and tables for clarity and comprehensive presentation.

**REVIEW**

## The Risks and Benefits of Physical Activity and Exercise in CAD Patients

Sudden cardiac death (SCD) or acute myocardial infarction (AMI) can be the first clinical manifestation of CAD related to exercise.[21,22] The primary pathophysiological mechanism behind SCD is the rupture of non-obstructive coronary plaques, which accounts for the lack of prior symptoms like angina that are usually present in individuals with obstructive CAD. Additionally, superficial plaque erosion and intraplaque hemorrhage contribute to coronary plaque instability and ischemia, resulting from an imbalance between oxygen demand and supply. These factors play a significant role in triggering cardiac arrest during strenuous physical activity. During exercise, plaque rupture most frequently happens in the central area of the fibrous tissue, where the vasa vasorum are densely concentrated. In contrast, when at rest, plaque rupture is more likely to occur peripherally, at the interface between the fibrous tissue and the wall of the artery.[2,23,24]

## Risk of Physical Activity and Exercise in CAD

Exercise has been proven to provide beneficial effects in preventing the occurrence of CAD and reducing mortality in individuals with CAD. However, excessive exercise may have negative impacts on individuals, such as a sudden cardiac arrest (SCA) or SCD, particularly in those with a history of CAD, which manifests clinically in both symptomatic and asymptomatic cases.[25] (**Table 1**) **Conditions and Pathologies Associated with an Increased Risk of MACE or Death Related to Physical Activity**.[6,13,20,25-28]

Major adverse cardiovascular events (MACE) triggered by exercise are unexpected occurrences that have detrimental effects on the cardiovascular system. Events classified under this category include supraventricular tachyarrhythmia, acute coronary syndrome (ACS), cerebrovascular accidents (CVA), and transient ischemic attacks (TIA), including ischemia, myocardial infarction, and cardiac arrest.[13]

CAD can manifest as angina pectoris, and in some patients, it may be asymptomatic, referred to as silent ischemia. Myocardial infarction occurring during exercise is not caused by coronary stenosis but rather by the rupture of unstable coronary plaques. Another cause of SCD in CAD patients is exercise-induced ventricular arrhythmia, which is often observed during exercise testing.[20] Non-coronary causes such as myocardial bridging, drug abuse, or doping may also lead to unstable angina, potentially resulting in SCD in athletes or physically active individuals.[25]

The timing of SCA and SCD occurrences is categorized into three groups: during exercise, within one hour post-exercise, and between one and 24 hours post-exercise.[13] Cardiac abnormalities leading to SCD in athletes aged ≤35 years are classified into three categories: structural, electrical, and acquired abnormalities. Structural and electrical abnormalities are predominantly hereditary and contribute to approximately 5% of SCD cases in the United States. Acquired abnormalities include commotio cordis, myocarditis, environmental factors, and anabolic steroid use.[27]

The prevalence of SCD among athletes varies significantly, with reported rates ranging from 1 in 40,000 to 80,000, and the highest incidence reaching 1 in 3,000. In athletes under 35 years old, the leading cause of SCD is hypertrophic obstructive cardiomyopathy, affecting approximately 1 in 500 individuals and occurring more frequently in males. Coronary artery anomalies rank as the second most common cause, impacting around 1.2% of the population. In contrast, CAD is the primary cause of SCD in athletes over 35 years old.[26,28]

Cardiac abnormalities may lead to arrhythmia and an inability of the heart to pump blood effectively. Hypertrophic obstructive cardiomyopathy results in stiff ventricular walls, causing obstructive blood flow and increasing left atrial pressure and left ventricular end-diastolic pressure. This increase in pressure leads to pulmonary congestion.[28] This process also occurs due to left ventricular hypertrophy induced by anabolic steroids, which raises the risk of heart failure. Ventricular rhythm disorders involve fatty infiltration in the right ventricle, making the heart susceptible to premature ventricular contraction and frequent ventricular arrhythmias, especially during intense exercise. Ion channel disorders cause the malformation of channel proteins, disrupting electrolyte balance, particularly potassium, calcium, sodium, and magnesium, which regulate heart rate and rhythm. Stimulants can acutely affect the cardiovascular system by inducing arrhythmias with long-term hypertensive and inotropic effects. In older athletes, CAD increases susceptibility to atherosclerosis, posing a risk of plaque rupture in the coronary arteries during intense exercise.[26]

External environmental conditions may also have negative effects. Exercise performed at high altitudes carries a risk of MACE. The lower atmospheric oxygen levels at high elevations lead to reduced oxygen levels in the blood (hypoxia). This condition causes pulmonary arterial vasoconstriction, resulting in pulmonary hypertension and pulmonary edema. Hypoxia also triggers an increase in heart rate. Another environmental factor with adverse effects is extreme cold temperatures. In such conditions, the body attempts to maintain its core temperature by increasing its metabolism and reducing peripheral circulation. Physical activity under these conditions places additional strain on the cardiovascular system.[6]

## Benefits of Physical Activity and Exercise in CAD

Regular physical activity and physical fitness improvement are often associated with reduced risk of nonfatal and fatal cardiovascular events in young adults.[29,30] The beneficial effects of physical activity are significantly mediated through the modification of several risk factors for CAD, including metabolic syndrome, particularly insulin sensitivity, lipid profile, and blood pressure.[6,31]

Physical activity (exercise) has been shown to improve endothelial function, autonomic nervous system balance, and blood coagulation. Exercise enhances nitric oxide (NO) production in the vasculature, leading to vasodilation. NO is essential for vascular protection, as it prevents platelet aggregation, reduces the expression of adhesion molecules, inhibits leukocyte infiltration into the tunica intima and media, and minimizes lipid oxidation. These functions help prevent vascular injury and lipid accumulation within the vascular wall. In addition to increasing NO levels in the vasculature, exercise is also believed to reduce the degradation of NO by reactive oxygen species (ROS).[6,31] Exercise-induced physiological stress promotes the activity of antioxidant enzymes, thereby reducing ROS production. Another factor contributing to decreased ROS levels is the inhibition of ROS-generating enzymes.[32,33]

Long-term exercise influences the expression of cytokines and growth factors, which enhance smooth muscle and endothelial cell proliferation, leading to arteriolization of capillaries. Moreover, NO stimulates the mobilization of circulating progenitor cells, which play a role in endothelial repair and angiogenesis.[6,34]

Regular exercise is not only a primary preventive measure against CAD but also serves as a secondary prevention modality to reduce complications in individuals with established CAD. A study has shown that routine exercise can reduce mortality by 20% in individuals diagnosed with CAD.[6]

Exercise improves autonomic nervous system balance by reducing sympathetic nerve activity, enhancing vagal activity, and stimulating baroreflex sensitivity. This leads to decreased blood pressure, reducing cardiac afterload and improving left ventricular diastolic function.[6,31] Another study examined the effects of exercise based on heart rate variability (HRV) and HR recovery, demonstrating that exercise exerts positive effects by modulating parasympathetic nervous system activity.[31]

The mortality-reducing effects of exercise in CAD patients are not solely attributed to improved cardiac function but also to the stabilization of atherosclerotic plaques. This is mediated by increased collagen and elastin deposition, along with reduced macrophage concentration within the vasculature. Stable atherosclerosis minimizes the risk of plaque rupture, thereby preventing life-threatening events.[6]

## Pre-participation Screening

Athletes are defined as amateur or professional individuals who undergo intensive and regular training to participate in competitive sports activities. Athletes can be categorized into two groups: professional and recreational. Professional athletes are individuals who engage in intensive training for at least ≥10 hours per week, whereas recreational athletes are individuals who engage in physical activity for ≥4 hours per week. Research data indicate that extremely intense physical activity (18 hours per week or 7 times per week) increases the risk of death in CAD patients.[13]

Pre-participation screening focuses on the initial identification of cardiovascular risk before a patient or athlete with CAD returns to sports. This screening includes medical history assessment, physical examination, cardiac imaging, exercise testing, and risk stratification based on guidelines such as those from the ESC and AHA (**Table 2**). **The objective is to detect factors that may increase MACE risk during exercise**.[13,35]

Pre-participation screening in athletes starts with a thorough medical history assessment. The most frequently reported symptoms of cardiovascular complications include chest pain (both typical and atypical), breathlessness, heart palpitations, and episodes of syncope. It should also be noted that symptoms in athletes may not always be typical. Decreased performance and reduced exercise capacity may occur even in the absence of the common symptoms mentioned above. Lower risk of cardiovascular complications is associated with the absence of symptoms during strenuous physical activity, despite underlying pathological conditions.[20]

New imaging modalities in cardiovascular, which include coronary artery calcium scoring, cardiac magnetic resonance (CMR) imaging, and coronary computed tomography angiography, can diagnose subclinical CAD. However, these modalities could not provide information on coronary artery flow and reserve, which are significantly associated with the risk of exercise-induced SCD. Additional diagnostic evaluations may include exercise testing, stress echocardiography, adenosine or dobutamine stress CMR, single-photon emission computed tomography (SPECT), or positron emission tomography (PET). These assessments are essential for pre-participation screening, with exercise testing particularly useful for evaluating maximal exercise capacity, blood pressure response, and the presence of exercise-induced arrhythmias.[36]

## Pre-Participation Rehabilitation Assessment

Pre-participation rehabilitation assessment is a crucial step in determining the readiness of patients with CAD to return to sports. This process involves a comprehensive evaluation that integrates cardiovascular risk stratification, functional capacity assessment, and individualized rehabilitation planning.[13]

Patients with CAD must undergo thorough cardiovascular risk stratification before resuming sports activities. According to the diagnostic testing results, risk stratification of athletes-patients with proven CAD (**Table 3**) is divided into high and low probability for adverse cardiac events induced by exercise.[20]

Evaluating functional capacity is essential to determine the patient's ability to tolerate physical exertion. This can be assessed using: 1) CPET to evaluate peak oxygen uptake ($VO_2$ peak), offering an objective measurement of aerobic capacity and cardiovascular adaptation to physical exertion; 2) The six-minute walk test (6MWT) to evaluate response to submaximal exercise, especially in patients not capable in performing maximal test; or 3) HR recovery and blood pressure response during and after exercise testing to assess autonomic function and cardiovascular fitness.[37-39]

A structured rehabilitation program must be tailored to the cardiovascular condition, fitness level, and sports goals of the patients. Wearable devices and remote monitoring tools can be used to track cardiovascular responses and detect abnormal heart rhythms during rehabilitation. The program typically includes: 1) Aerobic training: Low- to moderate-intensity endurance exercises such as walking, cycling, or swimming, progressing based on the patient's tolerance; 2) Resistance training: Light to moderate weight training to improve muscular strength while avoiding excessive strain on the heart; 3) Flexibility and balance exercises: To enhance mobility and reduce injury risk.[40]

Psychological factors play a significant role in an athlete's RTS. Fear of re-injury, anxiety about cardiac events, and reduced confidence in physical abilities can impact performance and adherence to rehabilitation. Psychological support, counseling, and gradual exposure to physical activity can help athletes regain confidence and safely reintegrate into sports.[41,42]

Patients should undergo regular follow-up assessments to monitor progress and detect any signs of recurrent ischemia or arrhythmias. Serial exercise testing, echocardiography, and biomarker monitoring (e.g., high-sensitivity troponin, NT-proBNP) can help guide long-term sports participation decisions.[10,43]

## Recommendations and Exercise Prescriptions for RTS in CAD Patients

## Recommendations for RTS

Different RTS recommendations apply to each group of CAD, categorized into asymptomatic athletes without clinical evidence of CAD, athletes with confirmed CAD, and athletes undergoing revascularization procedures (**Table 4**).[20]

It is recommended to conduct a stepwise evaluation, risk management, and close monitoring before allowing athletes with CAD to return to competition. Since CAD develops gradually and becomes more detectable over time, clinical evaluation includes exercise testing as the primary tool for assessing an athlete's readiness to compete. If the exercise test reveals abnormal thresholds, such as ST depression $\geq 0.15$ mV or atypical ST-segment elevation, additional assessments such as stress echocardiography, SPECT, PET, or CMR are required. Maximal exercise SPECT is recommended as an initial diagnostic step for athletes. However, the choice of method should consider diagnostic accuracy, equipment availability, and the presence of skilled specialists. If the exercise test is positive, further evaluation with computed tomography (CT) or coronary angiography is necessary to assess CAD progression.[20]

Athletes with CAD are classified into high and low-risk groups based on clinical evaluation. Athletes categorized as low-risk may still compete under strict selection criteria, while those classified as high-risk are not advised to participate in competitive sports. Additionally, age is an important consideration for athletes with CAD. Athletes over the age of 60, even with a low-risk profile, require special attention. Previous studies have shown that the risk of sudden cardiac arrest is significantly higher in men over 60 years old during physical activity.[20]

In athletes with CAD, ischemia can be induced by exercise. If substantial ischemia arises during exercise, anti-ischemic treatment should be adjusted for optimal management. If ischemia persists despite adequate medical therapy, revascularization is required, particularly for athletes aiming to return to competitive sports.[20]

Athletes who have undergone revascularization are advised to enter a structured training program promptly. Training should begin gradually with short, low-intensity sessions and be progressively intensified and extended over time. For athletes recovering from AMI or ACS, the rehabilitation period is determined by the severity of the infarction and the extent of myocardial remodeling, necessitating serial assessments for at least three months post-rehabilitation. In contrast, those with stable CAD or non-ST elevation myocardial infarction (NSTEMI) without ischemic symptoms may progress through training at a faster pace.[20]

## Exercise Prescription for RTS

Precisely classifying sports is challenging, as each sport involves distinct components in terms of muscle movement, methodology, volume, and intensity. Some sports are predominantly static, while others are more dynamic. Certain sports require optimal muscle movement and skill proficiency, whereas others demand high-intensity performance (**Table 4.**). The classification system in (**Table 5.**) provides an overview of different sports based on their static and dynamic physical intensity, which can help guide exercise prescription and RTS decisions for athletes, particularly those with cardiovascular concerns. [44]

Several key aspects should be considered when prescribing exercise for RTS in patients with CAD: 1) Exercise Adjustment Based on Maximum Capacity: Before designing an exercise program, an evaluation of maximal exercise capacity should be conducted through an exercise test; 2) Utilization of Exercise Test Results: heart rate reserve (HRR), $VO_2$ reserve, ventilatory threshold, and rating of perceived exertion (RPE) should be determined by the exercise test as the basis for exercise prescription; 3) Exercise Intensity Limits: The recommended exercise intensity for improving cardiorespiratory health ranges between 40-85% VO2max or 64-93% HRmax; 4) Safety Threshold for CAD Patients: Patients with CAD should not exceed their ventilatory threshold or 85% HRmax to prevent the risk of ischemia and arrhythmias; 5) Guidelines for Patients with Angina or Arrhythmias: If a patient experiences angina or arrhythmia, exercise intensity should be limited to a maximum of 10 beats below HRmax; 6) Impact of β-Blockers on Cardiac Response: Patients taking selective beta-1 blockers experience a reduction in HRmax and VO2max of up to 10%. While the relationship between HRmax and VO2max remains linear, target heart rate adjustments are necessary; and 7) Use of the Borg Scale (RPE) as an Alternative: The Borg Scale (RPE) can be used as an alternative method to determine exercise intensity, as it is not influenced by β-blockers.[13,25] Exercise intensity determination can be guided by (**Figure 1**).[13]

The principles of exercise prescription for RTS in CAD patients are: 1) Frequency, type, intensity, and duration should be tailored to the patient's condition; 2) Exercise should remain below the ventilatory threshold, with the maximum heart rate determined based on individual exercise test results; and 3) The exercise program should be progressive to prevent the risk of silent ischemia, angina, and arrhythmias.[13]

The optimal range for cardiorespiratory health is 40-85% VO2max or 64-93% HRmax**.** However, for CAD patients, the maximum limit is 85% HRmax to reduce cardiovascular risk.[13]

## Limitations of this Review

This narrative review has several limitations that should be acknowledged. First, due to its narrative nature, an interpretative bias from the authors cannot be entirely avoided. Second, the literature search was limited to PubMed, ScienceDirect, and CINAHL databases, which may have resulted in the omission of relevant studies indexed in other databases. Third, the included literature comprised heterogeneous study designs, including observational studies, clinical guidelines, and expert consensus, leading to substantial variability in the definitions of RTS, characteristics of patients with CAD, and types and intensities of physical activity. Fourth, literature specifically addressing RTS following cardiac rehabilitation in patients with CAD remains limited, with many recommendations relying on clinical guidelines and expert opinion rather than prospective clinical trials. Fifth, only English-language publications were included, raising the possibility of language and publication bias, particularly regarding studies with neutral or negative findings. Sixth, patients with

CAD were analyzed as a general group without detailed stratification into stable CAD, post-ACS, or post-revascularization status, which may affect the precision of RTS recommendations for specific subpopulations. Finally, most of the reviewed studies focused on acute or short-term risks, while long-term outcomes such as disability, quality of life, and recurrent cardiovascular events following RTS were not explored.

**Table 1. Conditions and Pathologies Associated with an Increased Risk of MACE or Death Related to Physical Activity**

| Condition/Pathology Group | Main Condition/Pathology | Description of Risk for MACE/Death |
|---|---|---|
| Ischemic Heart Disease (Coronary Artery Disease) | Symptomatic and asymptomatic CAD, silent ischemia, angina pectoris | Intense exercise may trigger SCA/SCD; CAD is the leading cause of SCD in individuals aged >35 years |
| | Unstable coronary plaque rupture | Causes myocardial infarction during exercise, independent of the degree of coronary stenosis |
| Arrhythmias and Electrical Pathologies | Exercise-induced ventricular arrhythmias, supraventricular tachyarrhythmia | Exercise may trigger fatal arrhythmias and falls within the spectrum of MACE |
| | Channelopathies (ion channel disorders) | Electrolyte imbalance predisposes to fatal arrhythmias, particularly during high-intensity exercise |
| Structural Heart Disease (Hereditary) | Hypertrophic obstructive cardiomyopathy | The leading cause of SCD in athletes ≤35 years; causes outflow obstruction and arrhythmias |
| | Coronary artery anomalies | The second most common cause of SCD in young athletes |
| Acquired Heart Disease | Myocarditis | A non-hereditary condition that increases the risk of SCD during physical activity |
| Ventricular Pathology and Pump Dysfunction | Ventricular rhythm disorders with right ventricular fatty infiltration | Increases the risk of premature ventricular contractions and ventricular arrhythmias during intense exercise |
| | Left ventricular hypertrophy induced by anabolic steroids | Increases ventricular filling pressures and the risk of heart failure |
| Pharmacological and Substance-Related Factors | Stimulants, drug abuse, and doping | Trigger acute arrhythmias and exert long-term hypertensive and inotropic effects |
| Environmental Factors | High altitude (hypoxia) | Hypoxia induces tachycardia, pulmonary vasoconstriction, and increases the risk of MACE |
| | Extreme cold exposure | Peripheral vasoconstriction and increased metabolic demand impose additional cardiovascular strain |

CAD, coronary artery disease; MACE, major adverse cardiovascular event; MI, myocardial infarction; PVC, premature ventricular contraction; SCA, sudden cardiac arrest; SCD, sudden cardiac death

**Table 2. Key Components of Pre-Participation Screening**

| Components | Purpose |
|---|---|
| Medical History Assessment | Evaluating personal and family history to identify potential cardiovascular abnormalities |
| Physical Examination | Conducting thorough physical examinations to detect signs of cardiovascular diseases |
| Cardiac Imaging | Utilizing modalities like echocardiography to assess cardiac structure and function. |
| Exercise Testing | Performing exercise stress tests to evaluate the cardiovascular response to physical activity |
| Risk Stratification | Applying guidelines from organizations, including ESC and AHA, to determine the major adverse cardiovascular events during exercise |

AHA, American Heart Association; ESC, European Society of Cardiology

**Table 3. Risk Stratification Before Resuming Sports Activities in Athletes-Patients with Proven CAD**

| Low-probability | High-probability |
|---|---|
| If all the following criteria apply | |
| • Ejection fraction ≥50% based on echocardiography, CMR, or angiography (with no wall motion abnormalities).<br>• Absence of critical coronary stenosis (i.e., <70%) in major coronary arteries or <50% in the left main stem based on coronary angiography.<br>• No inducible ischemia on maximal exercise testing.<br>• No major ventricular tachyarrhythmias (i.e., non-sustained ventricular tachycardia, polymorphic ventricular tachycardia, or very frequent ventricular ectopic beats) at rest or during maximal exercise testing<br>• Normal, age-adjusted exercise capacity. | • Ejection fraction <50% based on echocardiography (or other diagnostic tests).<br>• Presence of at least one critical coronary stenosis in a major coronary artery (>70%) or the left main stem (>50%) based on coronary angiography.<br>• Dyspnea at low exercise intensity (equivalent to angina).<br>• Exercise-induced ischemia, with ST depression >0.1 mV (horizontal or down-sloping at 80 ms after the J point) in two chest leads, or ST elevation >0.1 mV (in a non-Q-wave lead and not related to aortic valve replacement), or new-onset left bundle branch block at low exercise intensity or immediately post-exercise.<br>• Extensive myocardial scarring was detected by CMR imaging<br>• Syncope or dizziness during exertion.<br>• Relevant ventricular tachyarrhythmias (such as non-sustained ventricular tachycardia, polymorphic ventricular tachycardia, or very frequent ventricular ectopic beats at any time). |

**Table 4. Return to Sports Recommendation in CAD Patients**

| Category | Evaluation & Considerations | Return to Sport Recommendations |
|---|---|---|
| **Asymptomatic Athletes Without Clinical Evidence of CAD** | • Evaluation of functional ischemia and cardiovascular risk assessment.<br>• Exercise testing as the primary assessment tool.<br>• If exercise test results are normal and the cardiovascular risk profile is low → no further testing is required.<br>• If abnormalities are detected in the exercise test → further assessment (stress echo, CMR, PET, SPECT) is needed.<br>• If the exercise test is positive → further evaluation with CT or coronary angiography is needed. | • If the normal result in the exercise test and the risk is low, → Unrestricted participation in competitive sports.<br>• Routine annual risk factor management is recommended.<br>• If significant lesions are detected, coronary angiography should be performed before determining sports eligibility. |
| **Athletes with Confirmed CAD** | • Diagnosis based on CT scan or coronary angiography.<br>• Consideration of myocardial ischemia induced by exercise, arrhythmias, myocardial dysfunction, individual fitness level, type of sport, and cardiovascular risk profile.<br>• Risk stratification into low- and high-risk categories. | • Low-risk: May participate in competitive sports with careful selection.<br>• High-risk: Competitive sports are not recommended.<br>• Extreme strength or high-endurance sports should be avoided.<br>• Athletes >60 years old require special attention due to a significantly higher risk of sudden cardiac arrest during exercise.<br>• If ischemia persists despite optimal medical therapy → revascularization should be considered. |
| **Athletes Undergoing Revascularization Procedures** | • Immediate initiation of a structured training program post-procedure is recommended.<br>• Initial phase: Gradual training starting with low intensity and limited duration.<br>• Progressive increase until unrestricted training is achieved.<br>• In athletes with ACS or AMI, evaluation is required at least 3 months after rehabilitation, depending on infarct size and myocardial remodeling.<br>• In athletes with NSTEMI or stable CAD without ischemic symptoms, training can progress more rapidly. | • If rehabilitation has been completed successfully, → return to competition may be considered.<br>• Close monitoring is essential, particularly after myocardial infarction.<br>• Serial evaluations are crucial to ensure safety before returning to competitive sports |

ACS, acute coronary syndrome; AMI, acute myocardial infarction; CAD, coronary artery disease; CMR, Cardiac Magnetic Resonance; CT, Computed Tomography; NSTEMI, non–non-ST-segment elevation myocardial infarction; PET, Positron Emission Tomography; SPECT, Single Photon Emission Computed Tomography

**Table 5. Sports Classification by Physical Intensity**

| Dynamic/ Static Component | Low (<40% $VO_2$ max) | Moderate (40-70% $VO_2$ max) | High (>70% $VO_2$ max) |
|---|---|---|---|
| **Low (<20% MVC)** | Curling, Riflery, Billiards, Cricket, Golf, Bowling | Volleyball, Baseball/Softball, Table Tennis, Fencing | Soccer, Running (Long Distance), Badminton, Tennis, Race Walking, Field Hockey, Orienteering, Racquetball/Squash, Cross-Country Skiing (Classic Technique) |
| **Moderate (20-50% MVC)** | Diving, Equestrian, Archery, Auto Racing, Motorcycling | Surfing, Running (Sprint), American Football, Rugby, Figure Skating, Field Events (Jumping), Rodeo, Synchronized Swimming | Running (Middle Distance), Swimming, Basketball, Ice Hockey, Team Handball, Lacrosse, Cross-Country Skiing (Skating Technique) |
| **High (>50% MVC)** | Weightlifting, Martial Arts, Gymnastics, Sport Climbing, Water Skiing, Bobsledding/Luge, Field Events (Throwing), Sailing, Windsurfing | Bodybuilding, Skateboarding, Wrestling, Downhill Skiing, Snowboarding, | Cycling, Triathlon, Boxing, Canoeing/Kayaking, Speed Skating, Decathlon, Rowing, |

MVC, maximal voluntary contraction

**Figure 1. Exercise Intensity Categories Based on VO2max, HRmax, HRR, and RPE Scale**
Adopted from: Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, et al. 2020 ESC Guidelines on sports cardiology and exercise in patients with cardiovascular disease. Eur Heart J. 2021;42(1):17–96

| Intensity | $VO_2max$ (%) | HRmax (%) | HRR (%) | RPE Scale | Training Zone |
|---|---|---|---|---|---|
| Low intensity, light exercise[a] | <40 | <55 | <40 | 10–11 | Aerobic |
| Moderate intensity exercise[a] | 40–69 | 55–74 | 40–69 | 12–13 | Aerobic |
| High intensity[a] | 70–85 | 75–90 | 70–85 | 14–16 | Aerobic + lactate |
| Very high intense exercise[a] | >85 | >90 | >85 | 17–19 | Aerobic + lactate + anaerobic |

HRmax, maximal heart rate; HRR, heart rate reserve; RPE, rating of perceived exertion; VO2max, maximal oxygen uptake.

## CONCLUSION

Exercise and physical activity provide significant benefits for patients with CAD, including improved endothelial function, autonomic nervous system balance, and stabilization of atherosclerotic plaques, which can reduce cardiovascular events. Regular exercise has been shown to decrease mortality by up to 20% in CAD patients by enhancing aerobic capacity, optimizing blood pressure responses, and reducing oxidative stress through the activation of antioxidant enzymes. However, high-intensity exercise may trigger acute cardiovascular events such as SCD or AMI, primarily due to the rupture of unstable coronary plaques or exercise-induced ventricular arrhythmias. Therefore, pre-participation screening is essential to assess individual risk before resuming physical activity. This screening involves evaluating medical history, conducting physical examinations, performing cardiac imaging, and exercise testing to identify potential cardiovascular events that may be triggered by physical exertion.

A pre-participation rehabilitation assessment aims to evaluate a patient's readiness to return to exercise through cardiovascular risk stratification and functional capacity evaluation using CPET or the 6MWT. Patients are categorized into low- or high-risk groups, which determine recommendations for participation in competitive or recreational sports. To ensure safe exercise, rehabilitation programs should be tailored to the patient's condition and include aerobic exercise, resistance training at light to moderate intensity, and flexibility exercises to reduce the risk of injury. An exercise prescription is based on individual maximal capacity, considering HRR, $VO_2$ max, and ventilatory thresholds to optimize cardiovascular benefits without increasing the risk of ischemia or arrhythmia. Periodic evaluations, including serial exercise testing and cardiovascular biomarkers, are essential for maintaining the long-term safety of physical activity for patients with CAD.

## Conflict of Interest

The authors declare there is no conflict of interest in producing this study.

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