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REVIEW ARTICLE

## Coronary artery disease in athletes: An adverse effect of intense exercise?

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### KEYWORDS

Veteran athletes;  
Dose of exercise;  
Coronary artery disease;  
Coronary computed tomography angiography

**Abstract** Regular physical exercise is responsible for various health benefits, and is recommended for primary and secondary cardiovascular (CV) prevention. Despite these recognized benefits, various clinical events can occur in athletes, including acute myocardial infarction and sudden cardiac death (SCD); the main cause of SCD in veteran athletes is coronary artery disease (CAD). The relationship between intense exercise training and CAD is controversial, and a U-shaped association has been hypothesized. If this is the case, screening for subclinical CAD in older athletes may be justified, and various different methodologies have been proposed. However, the methodology for screening veteran athletes is not consensual, and several markers of CAD, in addition to clinical CV risk factors, could improve risk stratification in this population. In the present paper we review the published data on CAD in athletes, focusing on the relationship between the dose of exercise and CAD, as well as the implications for pre-participation screening of veteran athletes.

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### PALAVRAS-CHAVE

Atletas veteranos;  
Dose de exercício;  
Doença das artérias coronárias;  
Angiografia coronária por tomografia computadorizada

### Doença coronária em atletas: «efeito adverso do exercício físico intenso?»

**Resumo** O exercício físico associa-se a múltiplos benefícios para a saúde, estando recomendado na prevenção cardiovascular (CV) primária e secundária. Apesar dos benefícios comprovados, diversos eventos clínicos podem ocorrer em atletas, incluindo enfarte agudo do miocárdio e morte súbita, nos atletas veteranos maioritariamente devido a doença das artérias coronárias (DAC). A relação entre exercício físico intenso e DAC permanece controversa, colocando-se a hipótese de associação tipo «curva em U». Neste contexto, a deteção subclínica de DAC em atletas veteranos pode ser justificada, estando propostas algumas metodologias.

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No entanto, a metodologia para a avaliação pré-competitiva dos atletas veteranos não é consensual e diversos marcadores de risco, adicionais aos fatores de risco CV clínicos tradicionais, poderão melhorar a estratificação de risco nesta população. Neste artigo revêm-se os dados publicados sobre DAC em atletas, com relevância para a relação entre a dose de exercício e DAC, bem como as implicações para a avaliação pré-competitiva de atletas veteranos.

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## Introduction

Regular physical activity and exercise training have various health benefits, and are recommended for primary and secondary cardiovascular (CV) prevention.<sup>1,2</sup> The benefits of exercise are mediated by multiple mechanisms, with favorable impact both in the general population and in patients with established CV disease in the context of cardiac rehabilitation. Among these effects are the prevention and control of various CV risk factors, including reduction in the incidence of obesity and diabetes and improved lipid and blood pressure profiles, as well as reduction of acute coronary events and increased survival.<sup>2</sup>

In response to the constant campaigns promoting the benefits of physical activity and exercise training, the number of people participating regularly in sports has grown in recent decades. Consequently, the spectrum of athletes has widened to include not only young adults, but also children and the elderly, with more individuals taking up regular exercise in middle age and continuing until late in life. Evidence of this tendency is the large number of veteran athletes involved in high dynamic component disciplines such as cycling, marathon, triathlon and Ironman races.<sup>3,4</sup>

Although much is now known about exercise-induced physiological cardiac adaptations, the long-term effects of prolonged and excessive intense exercise training remain unclear. Recent evidence points to a potential U-shaped relationship between the dose of exercise and the occurrence of clinical CV events, which could be related to the presence and severity of coronary artery disease (CAD). This is an important issue, since CAD is responsible for the greatest proportion (approximately 80%) of sudden cardiac death (SCD) in veteran athletes, a less studied athletic population.

The recent development of new CV imaging tests, including non-enhanced cardiac computed tomography (CT) with calcium scoring (CS) and enhanced cardiac CT (coronary CT angiography [CCTA]), has enabled non-invasive detection and better characterization of the presence and severity of CAD.<sup>5</sup> This could be a game-changer for risk stratification in veteran athletes, changing the paradigm from traditional stratification based on clinical CV risk factors and exercise electrocardiographic testing, which has well-known limitations.<sup>6</sup>

In the present paper we review the published data on CAD in athletes, focusing on the relationship between the dose of exercise and CAD, the potential mechanisms involved and the implications for pre-participation screening of veteran athletes, highlighting the role of CS and CCTA.

## The paradox of sudden cardiac death in athletes

Despite the proven benefits of regular physical exercise and although athletes are the paradigm of healthy individuals, this population is not risk-free and can suffer severe clinical conditions including SCD.<sup>5,7</sup> Although SCD is uncommon in young athletes (incidence 2-5/100 000 per year), it is a tragic event, with high visibility due to media attention. Most sports-related cardiac arrests occur in individuals not performing regular exercise, and in epidemiological terms, SCD during sports accounts for only a small proportion of cases in the general population.

Several studies have confirmed both the increased risk of exercise-associated myocardial infarction and SCD and the beneficial effect of regular exercise in risk reduction. Data from Italy revealed a 2.8-fold greater risk of SCD in young competitive athletes compared to non-athletes.<sup>8</sup> However, it should be stressed that exercise is not the cause of death, but is a precipitating factor in susceptible individuals with previously undiagnosed cardiac disease. It should also be recognized that the overall beneficial effects of exercise in the population outweigh the increased risk.

In young athletes the most common causes of SCD are hereditary diseases, mainly cardiomyopathies and primary arrhythmic diseases, while in veteran athletes the great majority is caused by CAD.<sup>5,9-12</sup> For the purpose of this paper, we define a veteran athlete as an individual more than 35 years old participating in sports at a competitive level or as a leisure activity. The majority of sports-related SCD occurs in older athletes, but as many of the deaths are unwitnessed, the magnitude of the problem is probably underestimated.<sup>12</sup> Beyond the difference in the athletes' age, other important epidemiological features of SCD in athletes are the higher frequency in males (9:1 to females) and occurrence during or immediately after exercise and mainly in high dynamic component sports.<sup>5</sup>

Identification of athletes with higher CV risk is a crucial goal of pre-participation screening.<sup>13,14</sup> Although controversial, due to the long-standing disagreement between Europe and the US, the methodology recommended by the European Society of Cardiology (ESC) for screening of young athletes includes medical history (personal and family), physical examination, and 12-lead electrocardiogram (ECG).<sup>13</sup> Central to the disagreement is the ECG, due to the high rate of false positive results. The main question is not whether the ECG should be included, but how it should be interpreted; the adoption of more restrictive criteria decreases the false-positive rate without reducing sensitivity and with

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