Review Paper

Sudden cardiac death (SCD) in athletes: A mini-review

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Running head: Sudden death in athletes

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Abstract

Elite young athletes with clinically silent cardiovascular disorders are at risk of sudden cardiac death (SCD) in competitive sports activity. SCD is caused by a variety of conditions; in middle-aged/senior athletes, atherosclerotic coronary artery disease accounts for the vast majority of cases. In younger athletes, the spectrum of SCD causes is broader and includes inherited (cardiomyopathies) and congenital structural heart disease. Inherited ion channelopathies have been implicated also, with an apparently normal heart morphology identified at autopsy. SCD screening allows identification of athletes affected by occult conditions at a pre-symptomatic stage, and may lead to reduction of risk of SCD during sporting competition or training. The use of modern criteria for interpretation of the electrocardiogram (ECG) offers the potential to improve screening accuracy by reducing the number of false positives. Exercise testing in middle aged/senior athletes engaged in leisure sports activity is likely to be effective in screening significant coronary risk factors, while it is less effective in lower risk groups. Besides screening, the availability of automated external defibrillators at sporting environments is a preventative strategy to help intervene during unexpected cardiac arrest.

***Keywords**:* Athletes, death, cardiac, screening

Introduction

The occurrence of a young, apparently healthy athlete dying of sudden cardiac death (SCD) during a competitive sporting activity is a shocking and deeply emotive occurrence [1–4]. The leading cause of death in this population is an underlying structural cardiac disease [5], triggering SCD during physical exertion [6]. Less prevalent non-cardiac causes relate to asthma (or other pulmonary conditions), heat stroke, drug abuse, cerebral embolism, and ruptured cerebral artery, amongst other causes [7,8].

The athlete's heart is defined by the physiologic adaptation in heart structure during sports participation over time [9–11]. These physiologic adaptations can vary between athletes due to a multitude of factors including genetic differences, types of training, and age and sex [12–15]. These adaptations can be harmful in athletes with inherited congenital heart disease, and manifest as pathological as opposed to physiological adaptations. The aim of the present mini-review was to identify the main causes of SCD in young athletes during competitive sports activities.

Material & Methods

A literature search was conducted using PubMed and ISI Web of Science databases [16]. The following search terms were used: 'young athletes and cardiac', 'sudden death in young', 'cardiac death and sport', 'competitive sports and death'. Included reports and important reviews regarding sudden death and athletes were manually screened for additional relevant studies. Experts in the field, including authors from the included reports, were also requested to suggest any additional trials in order to ensure that the review was as comprehensive and up-to-date as possible. Only studies published in English were included.

1. Exercise and SCD

The risk of SCD in young athletes is twice as high as in young non-athletes [17]. The most prevalent congenital cardiac conditions which can lead to SCD include hypertrophic cardiomyopathy, arrythmogenic right ventricular cardiomyopathy, congenital coronary anomalies, and aortic rupture [18,19]. Preventive strategies and accurate decision-making are essential for reducing the incidence of SCD in young athletes. Primary prevention may be feasible using pre-competition assessments based on advanced screening methods according to international criteria [20,21]. These criteria are designed and developed for the evaluation of male athletes. In females, less developed criteria currently exist. Besides preventative strategies, availability of AED and trained medical staff in cardiopulmonary resuscitation during sporting events is essential for reducing the incidence of SCD [22,23] (Table 1).

2. Mortality reduction by pre-participation screening

Both the American Heart Association and the European Society of Cardiology consensus panel recommendations agree that cardiovascular screening for young competitive athletes is justifiable and compelling based on ethical, legal, and medical grounds [24]. Screening athletes solely on history and physical examination has limited sensitivity to identify the higher risk cases because most athletes with undetected cardiovascular disease are asymptomatic [25]. The addition of 12-lead ECG alongside history and physical examination enhances the power of screening for the detection of athletes with cardiomyopathies, channelopathies, and pre-excitation syndromes at rest or during exercise testing [26] (Table 1).

3. Undetected causes of SCD

Autopsy studies have reported that the cause of SCD in young athletes remains undetermined in up to 40% of cases [27]. Inherited ion-channel disease leading to ventricular fibrillation in the absence of structural heart abnormalities may be responsible for some of these unidentified cases.

Other representative examples of these 'hidden' causes include so-called 'non-ischemic, isolated left ventricular (LV) scar' and 'arrhythmic mitral valve pro-lapse'. The former of these conditions can be associated with life-threatening arrhythmias and SCD [28,29]. A recent autopsy study reported a prevalence of 25% in young athletes dying from SCD during exercise [30]. The diagnostic power of routine pre-participation screening for non-ischemic, isolated left ventricular (LV) scar is limited because ECG changes and echocardiographic LV systolic dysfunction, either regional or global, are not clearly identifiable in affected patients [30]. The lack of accurate pre-participation screening makes this condition one of the most challenging and unpredictable causes of SCD during sporting activities, as shown by the tragic loss of a professional Italian soccer player in 2012 [5,6,30] (Table 1).

4. SCD in older athletes

The risk of sports-related acute cardiovascular events, including SCD, increases exponentially in individuals aged ≥35 years. The main reason for SCD in this population is almost exclusively related to the development and progression of atherosclerotic coronary artery disease [30]. Identification of coronary artery disease in asymptomatic middle-aged and senior athletes may be challenging to detect through traditional screening methods [31]. The main causes of SCD are shown in Figure 1.

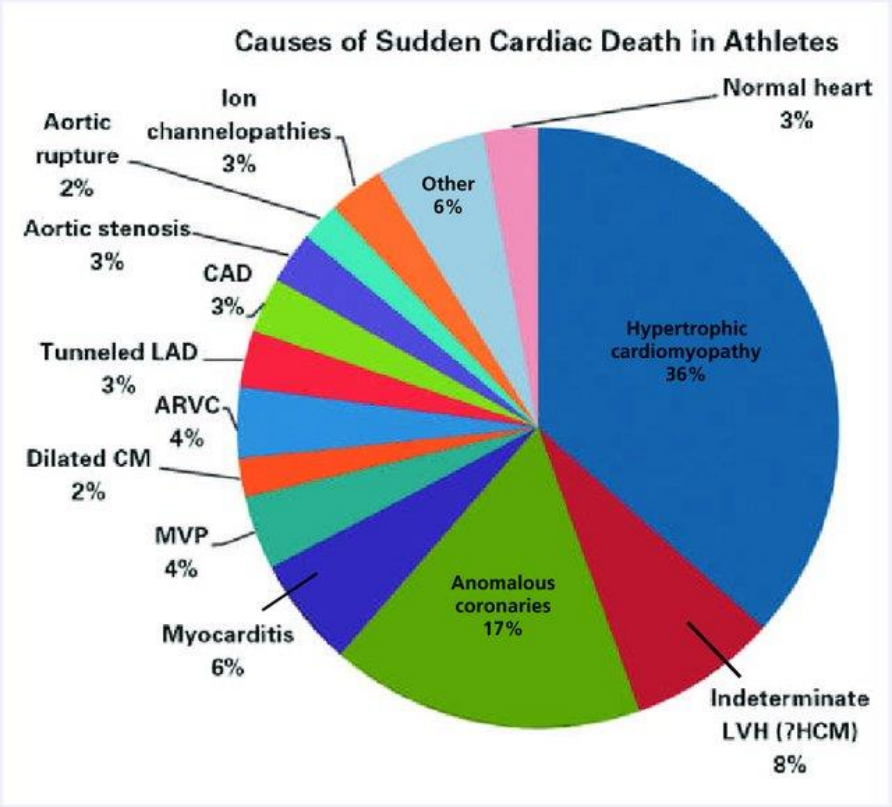

Figure 1. Causes of SCD in young athletes [32]

Exercise testing with ECG is perhaps the most commonly used test due to its widespread availability and relatively low cost [33,34]. However, test accuracy for detection of coronary artery disease is challenging within the general population. The test accuracy for identifying coronary artery disease increases if participants have multiple other cardiovascular risk factors. According to current recommendations for pre-participation cardiovascular evaluation, the assessment of risk is based on age, sex, blood pressure, blood cholesterol, and smoking history, using available scoring systems such as the ESC Systematic Coronary Risk Evaluation (SCORE) [35]. Maximal exercise testing (and possibly further cardiologic evaluations) should be reserved for those individuals embarking in moderate/intense physical activity who show an increased risk for coronary events [27,36] (Table 1).

Table 1: Brief summary of existing articles

Author/year	Title	Focus	Conclusions
Lampert & Zipes, 2018	Updated recommendations for athletes with heart disease	A review of current guidelines and recommendations for athletes	Risks associated with contact sports should be more thoroughly considered
Mavrogeni, Bacopoulou, Apostolaki, & Chrousos, 2018	Sudden cardiac death in athletes and the role of cardiovascular magnetic resonance imaging	A review of previous reports and position statements	Variety of factors that can lead to SCD
Catto, Dessanai, Sommariva, Tondo, & Dello Russo, 2019	S-ICD is effective for reducing the risk of sudden cardiac death in young athletes with arrhythmogenic cardiomyopathy	Two male elite athletes between 20-21 years old	Physical activity may increase the risk of SCD
Sweeting & Semsarian, 2018	Sudden cardiac death in athletes	A review of previous reports	The process/protocol for dealing with sudden cardiac events is key to positive outcomes
Post et al., 2019	A comparison of emergency preparedness between high school coaches and club sport coaches	A total of 769 coaches were included	Further work is required to raise the awareness of risks of sudden cardiac death in high schools and clubs
Vancini et al., 2019	Prevention of sudden death related to sport: The science of basic life support—from theory to practice	A review paper focused on risk factors associated with SCD	Increasing knowledge and education of coaches with regards basic life support may help reduce risks of SCD.
Cater et al., 2018	Perspectives on pre-participation cardiovascular screening in young competitive athletes	Twenty-three athletic therapists,12 coaches, six physicians, and five associated personnel participated in a survey	Pre participation cardiovascular screening is key to reducing risks associated with SCD.
Maron, Friedman, & Caplan, 2015	Ethics of preparticipation cardiovascular screening for athletes	An opinion paper with key recommendations	Screening should be undertaken for all groups to reduce risks of SCD
Van Brabandt, Desomer, Gerkens, & Neyt, 2016	Potential risks and benefits of screening young people to prevent SCD	Summary of risks and benefits associated with pre-participation screening for non-professional athletes	Do risks/costs outweigh the benefits of pre-participation cardiac screening?

Corrado & Zorzi, 2017	An overview of sudden cardiac death in athletes	Short communication based on previous reports	Understanding individual cardiac history could be useful to determine the potential risks of SCD.
Corrado & Zorzi, 2018	Sudden death in athletes	A short report based on previous research	Understanding individual cardiac history could be useful to determine the potential risks of SCD.
Barry et al., 2018	Incidence and predictors of clinically important and dangerous arrhythmias during exercise testing in young people with congenital heart disease	A retrospective review of exercise tests performed between 2013-2015	Pre-season screening is essential for all athletes
Morrison et al., 2016	Cardiovascular pre-participation screening and risk assessment in masters athletes: International recommendations and a Canadian perspective	International recommendations and a Canadian perspective on pre-participation cardiac screening	Pre-participation screening is accepted by Canada and is key to reducing the risk of sudden cardiac events
Sharma et al., 2017	International criteria for electrocardiographic interpretation in athletes	An international report based on experts opinion	Abnormal ECGs should be thoroughly investigated

Table 2: Main reasons of sudden cardiac death in young athletes

Young competitive athlete •Hypertrophic cardiomyopathy • Arrhythmogenic right ventricular cardiomyopathy • Idiopathic dilated cardiomyopathy • Myocarditis • Coronary artery anomalies • Aortic dissection	• Commotio cordis • Arrhythmic heart disease (including Wolff-ParkinsonWhite syndrome, long QT syndrome, short QT syndrome, Brugada syndrome) catecholaminergic polymorphic ventricular tachycardia	Masters athlete • Coronary artery disease • Dilated cardiomyopathy • Hypertensive heart disease • Myocarditis

Conclusion

Effective pre-participation screening strategies are essential for reducing the risk of SCD in young athletes. A combination of ECG, physical examination, and assessment of family history can help identify individuals who may be at greater risk of SCD. However, some cardiac conditions may be difficult to identify through traditional screening methodologies. Within a sporting context, continuing education and training of coaching and medical staff remain paramount to ensure that any occult cardiac cases are dealt with as effectively as possible.

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