JOURNAL OF EDUCATION, HEALTH AND SPORT
eISSN 2391-8306 · Open Access · Peer-reviewed
apcz.umk.pl/JEHS · Nicolaus Copernicus University in Toruń

Cite as: WASILEWSKI, Luiza, KOLADZYN, John, SŁODYCZKA, Anna, JANKOWSKI, Gabriela, MARGIELEWSKA, Weronika, JANKOWSKI, Marianna, BADRAN, Mahmoud, TWOMBLY, Gregory and SIEMASZKO, Kai. Pre-Participation Cardiovascular Screening in Competitive Athletes: An Evidence-Based Review of Strategies and Risk Stratification. Journal of Education, Health and Sport. 2026;91:70864. https://doi.org/10.12775/JEHS.2026.91.70864

ARTICLE TIMELINE
Received: 14.04.2026 Revised: 15.05.2026
Accepted: 16.05.2026 Published: 22.05.2026

INDEXING & EVALUATION
MEiN points: 40 Unique ID: 201159
Disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

The journal has been awarded 40 points in the parametric evaluation by the Polish Ministry of Higher Education and Science (Annex to the announcement of 05.01.2024, No. 32318). Unique Journal Identifier: 201159. Scientific disciplines: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).

Punkty Ministerialne z 2019 – aktualny rok 40 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).

Pre-Participation Cardiovascular Screening in Competitive Athletes: An Evidence-Based Review of Strategies and Risk Stratification

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Abstract:

Background: Competitive athletes are exposed to sustained physiological stress that may reveal previously unrecognized structural or electrical cardiac disease, thereby predisposing susceptible individuals to exercise-related sudden cardiac events. Pre-participation cardiovascular screening has become an established component of athlete care.

Aim: To review the rationale, components, strengths, and limitations of contemporary cardiovascular screening strategies in competitive athletes and to examine current controversies and future directions.

Material and methods: A narrative review of PubMed-indexed literature published between 2017 and 2025 was conducted, focusing on guideline statements, systematic reviews, and cohort studies addressing cardiovascular screening in athletes.

Summary: The reviewed literature indicates that structured screening based on history, physical examination, electrocardiography, and selective imaging facilitates early identification of occult cardiac disease and supports informed eligibility and management decisions. Variability in diagnostic performance, inconsistency in ECG interpretation, and differences in screening approaches remain areas of ongoing debate.

Conclusions: Cardiovascular screening in competitive athletes functions as a structured strategy for risk mitigation that supports early detection and informed clinical decisions. Its effectiveness depends on appropriate expertise, consistent implementation, and access to follow-up pathways. Continued refinement of screening criteria and implementation models is needed to optimize athlete safety while preserving participation.

Keywords: competitive athletes; cardiovascular screening; sudden cardiac death; electrocardiography; pre-participation evaluation.

1. Introduction

A competitive athlete is typically defined as an individual engaged in organized team or individual sports requiring systematic training, regular competition, and sustained high levels of physical exertion [1]. These physiological demands may unmask previously unrecognized structural or electrical cardiac disease, predisposing susceptible individuals to exercise-related arrhythmic events. Sudden cardiac death, although relatively uncommon, remains one of the leading medical causes of death in young competitive athletes and often occurs in individuals without a prior diagnosis [6]. Consequently, pre-participation cardiovascular evaluation has become an integral component of athlete care, aimed at identifying previously undetected cardiac abnormalities associated with increased risk of exercise-related arrhythmic events.

The American Heart Association/American College of Cardiology (AHA/ACC) Scientific Statement and the European Society of Cardiology (ESC) Sports Cardiology Guidelines support a structured screening strategy based on targeted cardiovascular history-taking and physical examination, with consideration of electrocardiographic assessment when appropriate expertise and follow-up resources are available [1,3]. The 2017 International Criteria for Electrocardiographic Interpretation in Athletes further standardized ECG analysis, enhancing differentiation between physiological athletic adaptation and pathological findings [2].

Despite consensus regarding the importance of cardiovascular assessment in athletes, debate persists concerning optimal screening strategies and implementation models. This review examines the rationale, components, strengths, and limitations of contemporary cardiovascular screening approaches in competitive athletes, with attention to current controversies.

2. Exercise as a Trigger and Rationale for Cardiovascular Screening

Understanding the relationship between exertional stress and underlying cardiac abnormalities provides the foundation for cardiovascular screening in athletes. This framework informs the development of structured evaluation strategies aimed at identifying significant cardiac disease prior to competitive participation.

2.1 Exercise as a Trigger

Exercise induces substantial increases in heart rate, blood pressure, myocardial oxygen demand, and sympathetic activity. In individuals with structural or electrical heart disease, these physiologic stresses may increase electrical instability and trigger malignant ventricular arrhythmias. In this context, exercise functions primarily as a trigger that unmasks previously silent cardiovascular pathology rather than as the underlying cause of disease [4].

Epidemiologic data from National Collegiate Athletic Association athletes collected between July 1, 2002, and June 30, 2022 indicate that sudden cardiac death (SCD), although uncommon, remains a leading medical cause of death in competitive sport. Approximately half of documented events occurred during exertion, underscoring the interaction between intense physiologic stress and vulnerable cardiac substrate [5].

Although hypertrophic cardiomyopathy (HCM) has historically been considered a predominant cause of athlete SCD, analyses from this 20-year cohort demonstrate a broader and more heterogeneous spectrum of etiologies [5]. Structural causes include arrhythmogenic cardiomyopathy, congenital coronary artery anomalies, myocarditis, dilated cardiomyopathy, and idiopathic left ventricular hypertrophy [5]. Primary electrical disorders such as long QT syndrome, catecholaminergic polymorphic ventricular tachycardia, Brugada syndrome, and other channelopathies may precipitate lethal arrhythmias in the absence of overt structural abnormalities [4]. A substantial proportion of cases were classified as autopsy-negative sudden unexplained death, indicating that fatal arrhythmias may occur without identifiable structural findings [5].

Contemporary guideline discussions within inherited cardiovascular disease populations increasingly emphasize individualized risk stratification and shared decision-making rather than universal restriction from sport [6,7]. These perspectives reflect recognition that arrhythmic risk varies according to phenotype and clinical characteristics.

Collectively, these data characterize exercise as a potent physiologic stressor capable of triggering life-threatening arrhythmias in susceptible individuals. Although the absolute incidence of SCD is low, the catastrophic nature of these events provides the clinical rationale for structured cardiovascular screening. Many of the structural and electrical conditions implicated in athlete SCD are potentially detectable through systematic pre-participation cardiovascular evaluation, forming the foundation of contemporary screening strategies.

2.2 Components of Cardiovascular Screening

Pre-participation cardiovascular screening in competitive athletes is based on structured history-taking, focused physical examination, and electrocardiographic evaluation [1].

The 14-element American Heart Association (AHA) cardiovascular screening checklist provides a standardized framework to identify symptoms and historical features suggestive of congenital or genetic heart disease, including exertional chest pain, unexplained syncope, abnormal blood pressure, and premature sudden cardiac death in first-degree relatives [10]. A detailed family history is a critical component of this evaluation; however, screening systems vary in their age thresholds and criteria for defining a positive family history of cardiovascular disease or sudden cardiac death [11].

Physical examination includes blood pressure assessment and cardiac auscultation to detect murmurs or other abnormal findings [10]. Although accessible and low cost, history and examination may not identify asymptomatic structural or electrical disease.

Electrocardiographic (ECG) screening enhances detection of primary electrical abnormalities and patterns suggestive of structural heart disease. Advances in ECG interpretation, including structured criteria and Z-score-based analysis, aim to improve differentiation between physiological athletic adaptation and pathological findings in young athletes [8]. These approaches seek to identify occult cardiomyopathies and channelopathies prior to high-intensity exertion.

Integrated screening protocols combining history, ECG, and focused cardiovascular imaging during the pre-participation physical examination have also been described, illustrating structured models for comprehensive cardiovascular evaluation in athletic populations [9]. Together, these components form the foundational structure of cardiovascular screening in athletes.

2.3 Additional Imaging Modalities in Cardiovascular Screening

Beyond structured history, physical examination, and electrocardiography, advanced cardiac imaging may be incorporated into cardiovascular evaluation in selected athletes [3].

Echocardiography allows assessment of cardiac structure and function, including ventricular wall thickness, chamber dimensions, systolic and diastolic performance, and structural abnormalities such as cardiomyopathies or congenital anomalies [14]. Within the pre-participation setting, it is typically reserved for cases in which structural assessment is clinically indicated.

Cardiac magnetic resonance (CMR) provides detailed structural and tissue characterization and may assist in distinguishing physiological athletic remodeling from pathological conditions such as arrhythmogenic cardiomyopathy or myocarditis [13]. When initial screening findings are equivocal, CMR can offer additional clarification.

Perspectives emphasizing integration of cardiac imaging with clinical cardiology and machine-assisted analysis illustrate the evolving role of advanced imaging within broader cardiovascular evaluation and risk stratification [12]. Together, these modalities function as adjunctive extensions of cardiovascular assessment rather than primary screening tools.

3. Discussion

The following discussion evaluates the clinical impact of structured cardiovascular screening in athletes, including both its strengths and recognized limitations.

3.1 Strengths and Positive Impact of Screening

Cardiovascular screening in athletes facilitates early identification of occult structural and electrical heart disease prior to high-intensity participation. Population-based data from NCAA athletes collected between 2002 and 2022 indicate that many sudden cardiac deaths occurred in individuals without a previously recognized diagnosis, underscoring the potential value of structured pre-participation evaluation within defined athletic populations [6,16].

Beyond detection, screening frameworks establish a standardized system for cardiovascular risk stratification and eligibility assessment within organized sport. The 2024 Heart Rhythm Society (HRS) expert consensus statement outlines structured pathways for evaluation, treatment, and decisions regarding return to play in athletes with suspected or confirmed arrhythmias, emphasizing individualized clinical assessment and shared decision making [15]. This evolution reflects a shift from automatic disqualification toward more individualized management guided by clinical characteristics.

Structured evaluation also enables early referral, targeted surveillance, and appropriate intervention in athletes identified with cardiomyopathies or primary electrical disorders [15,16]. By connecting early detection with appropriate follow-up care, screening supports risk reduction and continuity of cardiovascular care in athletes.

3.2 Limitations and Criticisms

Important limitations and areas of controversy persist in pre-participation cardiovascular evaluation in athletes. A central debate concerns the relative role of electrocardiography compared with history and physical examination. Critics contend that routine adoption of ECG-based screening in place of established AHA/ACC history-focused approaches may not be fully supported by available evidence and may result in overdiagnosis or unnecessary restriction from sport [17]. In addition, variability in ECG interpretation, particularly in distinguishing physiological athletic adaptation from pathological findings, contributes to inconsistency in screening outcomes [2].

Risk stratification in inherited cardiomyopathies further illustrates the complexity of translating screening findings into participation decisions. In arrhythmogenic cardiomyopathy, exercise may influence arrhythmic risk and disease progression; however, risk varies and cannot be predicted with certainty [18]. This variability limits the ability of screening to determine safety definitively.

Screening sensitivity is also imperfect. A systematic review comparing history, physical examination, and ECG demonstrated variability in detection of potentially lethal cardiac disorders [22]. Studies of asymptomatic athletes similarly indicate that occult disease may remain undetected despite structured evaluation [19,20].

Broader concerns include cost-effectiveness, variability in international recommendations, and uncertainty regarding optimal screening models [21,23]. These challenges highlight the difficulty of balancing athlete safety with feasibility and preservation of competitive participation.

Cardiovascular screening reduces, but does not eliminate, the risk of sudden cardiac events. Its effectiveness ultimately depends on consistent implementation, experienced interpretation, and individualized clinical judgment [22].

4. Conclusions and Path Forward

Competitive athletes are exposed to sustained physiological stress that may reveal previously unrecognized structural or electrical cardiac disease. Pre-participation cardiovascular screening offers a structured approach to identifying individuals at increased risk of exercise-related arrhythmic events prior to high-intensity participation.

Current evidence supports the use of systematic history-taking, physical examination, electrocardiographic evaluation, and, when indicated, targeted imaging to facilitate early detection and inform eligibility decisions. However, variability in diagnostic performance, interpretive challenges, and ongoing methodological debate indicate that screening functions as a risk-mitigation strategy rather than a definitive safeguard. Effective screening ultimately depends not only on the tools employed but also on structured implementation, appropriate expertise, and access to consistent follow-up pathways.

Future efforts should focus on continued refinement of screening criteria, standardization of interpretive training, and rigorous evaluation of implementation models across diverse athletic

populations. Enhancing consistency in application while preserving individualized clinical judgment will be central to optimizing athlete safety without unnecessarily restricting participation.

Disclosure

Author's contribution

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Funding - No specific funding was received for this work.

All authors have read and agreed to the published version of the manuscript.

Financing statement

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Not applicable.

Acknowledgements

Not applicable.

Conflict of Interest

The authors deny any conflict of interest.

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