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PREVENTION OF SUDDEN CARDIAC DEATH IN ATHLETES WITH ARRHYTHMIAS – CURRENT GUIDELINES AND CONTROVERSIES

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ABSTRACT

Purpose: This paper aims to conduct a thorough examination of contemporary studies pertaining to the prophylaxis of unexpected cardiac mortality in athletes presenting with arrhythmic conditions.
Methodology: A thorough and extensive literature review was undertaken utilizing various scientific databases, such as PubMed, Scopus, and Google Scholar. The criteria for selection emphasized clinical trials, systematic reviews, and meta-analyses that examined sudden cardiac death in athletic populations. The studies were assessed for their methodological robustness, relevance, and practical implications, with particular focus on the risk determinants and essential recommendations.
Findings: Early detection and risk stratification are key to preventing SCD in athletes. Individualized preventive strategies, including lifestyle changes, medical therapy, and ICDs, should be led by a multidisciplinary team. Genetic testing can aid in identifying inherited conditions but is mostly limited to specialist centers. Ongoing disparities in access highlight the need for coordinated international action.
Conclusions: Preventing SCD in athletes requires personalized, team-based care and improved access to diagnostics. Wider implementation of genetic testing and harmonized global guidelines are essential to address current gaps and ensure effective prevention.

KEYWORDS

Sudden Cardiac Death (SCD), Athletes, Arrhythmia, Prevention

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1. Introduction

Definition and significance of SCD in athletes

Sudden cardiac death (SCD) in athletes refers to the unexpected death due to heart-related causes that occurs during or shortly after exercise(Zorzi et al., 2023). It is often caused by underlying heart conditions such as cardiomyopathies, congenital anomalies, coronary artery disease, and inherited arrhythmia syndromes(Zorzi et al., 2023). These conditions may not have been previously diagnosed and can lead to fatal cardiac events, particularly during physical activity(Zorzi et al., 2023). SCD is a leading cause of death in young athletes, accounting for a significant proportion of cardiovascular mortality(Malik et al., 2023). It is particularly prevalent in sports like basketball, football, and soccer (Malik et al., 2023). SCD is the most frequent cause of mortality in athletes during exercise, with an estimated incidence of approximately 0.46-3.7 events per 100,000 person-years(Mahendran et al., 2023).

The role of arrhythmias in athletic SCD

Arrhythmias, particularly premature ventricular beats (PVBs), can be a sign of underlying heart disease that increases the risk of sudden cardiac death in athletes(Zorzi et al., 2023). While PVBs are common and often benign, they may indicate conditions such as cardiomyopathies, congenital heart diseases, coronary artery diseases, heart valve diseases, and ion channel diseases, all of which can lead to SCD(Zorzi et al., 2023).

Ventricular fibrillation is the most frequent arrhythmia associated with commotio cordis, but other arrhythmias such as polymorphic ventricular tachycardia, heart block, and atrial fibrillation have also been reported(Okorare et al., b.d.).

Importance of early detection and prevention

Careful clinical assessment is required to rule out potentially dangerous conditions, as PVBs are common in athletes during pre-participation screening(Zorzi et al., 2023). Identifying inherited heart rhythm conditions such as channelopathies and cardiomyopathies early can help manage and mitigate the risk of exercise-related SCD(Katyal et al., 2023). Early detection can help identify individuals at risk and implement preventive measures, such as lifestyle changes, medical interventions, and the use of implantable cardioverter defibrillators (ICD), which have been noted to be protective against SCD(Okorare et al., b.d.). Prevention strategies, including the use of chest protectors and safety balls in sports, can reduce the risk of fatal arrhythmias caused by blunt chest trauma, such as commotio cordis(Okorare et al., b.d.).

2. Methodology

The research utilized a comprehensive review of existing literature, sourcing studies from databases including PubMed, Scopus, and Google Scholar. This review is based on a structured search and critical analysis of current literature regarding the prevention of sudden cardiac death in athletes with arrhythmias. The primary objective was to identify and synthesize evidence from clinical studies, expert consensus documents, and international guidelines relevant to the screening, diagnosis, management, and return-to-play decisions in this population.

3. Arrhythmias and Underlying Cardiac Conditions

Common arrhythmias linked to SCD (e.g. VT, AF, WPW)

Several arrhythmias are associated with an increased risk of sudden cardiac death in athletes(D'Ambrosio et al., 2024). Ventricular tachycardia and ventricular fibrillation (VF) are the most directly linked to fatal outcomes, with VF often occurring in cases of commotio cordis(D'Ambrosio et al., 2024; Patel et al., 2022). Atrial fibrillation (AF), while typically less dangerous, is more common in endurance athletes and may contribute to long-term cardiac risk(D'Ambrosio et al., 2024). Wolff-Parkinson-White syndrome is another important arrhythmic condition associated with SCD, particularly if rapid conduction occurs during atrial fibrillation(D'Ambrosio et al., 2024).

Structural and inherited conditions

Hypertrophic cardiomyopathy is one of the most common causes, though its diagnosis can be challenging due to physiological cardiac remodeling in athletes(D'Ambrosio et al., 2024). Arrhythmogenic right ventricular cardiomyopathy, an inherited disorder characterized by fibrofatty myocardial replacement, predisposes individuals to ventricular arrhythmias(D'Ambrosio et al., 2024). Long QT syndrome, particularly type 1 caused by *KCNQ1* mutations, increases the risk of malignant arrhythmias during exercise(D'Ambrosio et al., 2024). Dilated cardiomyopathy, especially when related to prior myocarditis or *LMNA* mutations, is another important contributor to SCD in young athletes(D'Ambrosio et al., 2024).

Physiological vs pathological adaptations in athlete's heart

Athlete's heart involves a range of physiological adaptations to sustained training, including increased left ventricular wall thickness, mass, and enhanced cardiac output(D'Ambrosio et al., 2024). These changes are typically benign and reflect the cardiovascular system's response to volume and pressure overload(D'Ambrosio et al., 2024). However, pathological adaptations can also occur, such as exercise-induced arrhythmogenic cardiomyopathy, non-ischemic left ventricular scar, and myocardial fibrosis, all of which increase the risk of ventricular arrhythmias and sudden cardiac death(D'Ambrosio et al., 2024). Electrocardiogram (ECG) changes may reflect either physiological remodeling, such as increased R/S-wave voltages, ST-segment elevation, or incomplete right bundle branch block, or underlying pathology, including hypertrophic and arrhythmogenic cardiomyopathies, valvular diseases, or tachyarrhythmias(Sawczuk et al., 2023).

4. Risk Stratification and Screening

Clinical assessment: history, physical exam, ECG

Athletes presenting with cardiac symptoms, a family history of inherited cardiac conditions or sudden cardiac death, and those with electrocardiogram or structural abnormalities suggestive of heart disease should be referred to specialized centres for in-depth evaluation(Castelletti et al., 2022). Clinical assessment involves a multiparametric approach that integrates imaging, clinical data, family history, and genetic analysis(Dello Russo et al., 2023). Key diagnostic tools include resting ECG, ambulatory ECG monitoring, exercise testing, and echocardiography(Dello Russo et al., 2023). Particular attention is given to the morphology of ventricular arrhythmias, as it may indicate an underlying cardiomyopathy, even in the absence of frequent ectopy, while common premature ventricular beat patterns generally do not require further testing unless accompanied by other risk factors(Dello Russo et al., 2023). Cardiovascular preparticipation screening in young athletes typically includes a structured personal and family history questionnaire, physical exam, 12-lead resting ECG, and exercise testing(Sarto et al., 2023). A positive family history of conditions like cardiomyopathy, Marfan's syndrome, long QT syndrome, or SCD in first- or second-degree relatives, as well as personal symptoms such as exertional chest pain, syncope, or palpitations, warrants more detailed investigation according to international ECG interpretation standards(Sarto et al., 2023).

Additional tools: echocardiography, cardiac MRI, genetic testing

Echocardiography, cardiac MRI, and genetic testing are key components in the evaluation of athletes with suspected inherited cardiac conditions, aiding in the differentiation between physiological adaptations and pathological findings(Castelletti et al., 2022). Echocardiography serves as the first-line imaging modality, while cardiac MRI offers advanced assessment, particularly for detecting myocardial fibrosis and subtle structural abnormalities(Dello Russo et al., 2023). Genetic testing, now increasingly accessible, plays a critical role in diagnosing conditions with unclear phenotypes, guiding management, and enabling familial cascade screening(Castelletti et al., 2022). Its utility is especially evident in confirming diagnoses such as long QT syndrome and excluding conditions like catecholaminergic ventricular tachycardia in select cases(Castelletti et al., 2022; Mahendran et al., 2023). Genetic counselling remains essential to address the psychological, ethical, and social aspects of testing(Castelletti et al., 2022; Sarto et al., 2023).

Overview of current screening practices and challenges

Current screening practices in sports cardiology aim to identify athletes at risk of malignant arrhythmias, heart failure, or sudden cardiac death, with particular focus on genetically determined cardiac conditions(Castelletti et al., 2022). Differentiating between physiological remodeling due to intense exercise and inherited cardiac conditions remains a major challenge, often requiring a comprehensive, multiparametric approach including ECG, stress testing, imaging, and in select cases, genetic testing (Dello Russo et al., 2023; Sarto et al., 2023). While genetic testing is becoming more accessible, its application outside specialized cardio-genetic centers remains limited and often unclear(Castelletti et al., 2022). National practices vary - Italy, for instance, mandates annual preparticipation screening from an early age and has shown effectiveness in detecting conditions linked to SCD, while the U.S. military has only recently begun implementing mandatory ECG screening for recruits, prompted by high rates of SCD in service members(Franzos et al., 2025; Sarto et al., 2023). In regions like Québec, challenges include limited automated external defibrillator (AED) access in rural areas and inconsistent implementation of preventive recommendations, underscoring the need for both systemic improvements and innovative strategies such as drone-based AED delivery(Richard et al., 2024).

5. Guidelines and Return-to-Play Criteria

Key recommendations from ESC, AHA, and IOC

Current guidelines emphasize a cautious and multidisciplinary approach to managing athletes with or at risk of cardiovascular disease(Dello Russo et al., 2023). The 2020 European Society of Cardiology (ESC) guidelines on sports cardiology stress the importance of a team-based evaluation when considering advanced diagnostic tools like electroanatomic mapping(Dello Russo et al., 2023). The American Heart Association (AHA) and American College of Cardiology recommend a minimum three-month restriction from competitive sports following significant cardiac events, although this advice is based on limited evidence(Kojima et al., 2022). The ESC guidelines on adult congenital heart disease recognize the utility of exercise ECG in risk stratification for athletes with suspected or confirmed coronary artery disease(Sareban et al., 2022). The International Olympic Committee (IOC) provides condition-specific guidelines(Wilson, b.d.). Typically for arrhythmias and ICDs, athletes should avoid contact sports (e.g., rugby, boxing) and high-risk activities (e.g., swimming, cycling)(Wilson, b.d.). ICD implantation should not create a false sense of security - ongoing risks, potential interventions, and medical support must be carefully considered(Wilson, b.d.).

Sport eligibility after arrhythmia diagnosis or treatment

Athletes with ventricular arrhythmias but without evidence of structural heart disease on noninvasive evaluation are generally deemed eligible for competitive sports, as long as no other concerning features are present(Dello Russo et al., 2023). In higher-risk cases, such as during the vulnerable post-myocardial infarction phase or while awaiting implantable defibrillator placement, a wearable cardioverter defibrillator is recommended to reduce the risk of sudden cardiac death(Schmidt et al., 2022). Athletes who have undergone successful surgical repair of a coronary artery anomaly may resume full sports participation after three months, provided that maximal exercise testing shows no evidence of inducible ischemia or complex arrhythmias(Sareban et al., 2022).

Differences between European and American approaches

European guidelines, particularly the Italian ones, tend to be more restrictive in defining eligibility and disqualification criteria for athletes with cardiovascular abnormalities, prioritizing safety and early (preclinical) diagnosis to limit exercise-induced disease progression and arrhythmogenic risk(Dello Russo et al., 2023). In contrast, the American Heart Association and American College of Cardiology adopt a more permissive stance, allowing athletes with certain forms of long QT syndrome to return to sports after a three-month restriction period following a cardiac event, despite limited supporting evidence(Kojima et al., 2022).

6. Management and Emergency Preparedness

Medical and interventional treatment

Preparticipation screening remains essential for identifying individuals at high risk of cardiac events, enabling timely evaluation or intervention before they engage in athletic activities, thereby enhancing participant safety(Seely et al., 2023). For conditions like Brugada Syndrome, diagnostic testing can confirm the diagnosis and lead to the implantation of an intracardiac defibrillator when appropriate(Seely et al., 2023). Advanced Cardiac Life Support protocols highlight the critical role of immediate recognition and response, particularly early cardiopulmonary resuscitation (CPR) and airway management, in improving outcomes during SCD events(Seely et al., 2023). Epicardial ablation of the arrhythmogenic substrate in the right ventricular outflow tract has been suggested and performed for Brugada Syndrome, but its precise role is still to be determined(Scarà et al., 2025). Catheter ablation for patients with PVBs should be reserved for symptomatic cases or asymptomatic individuals with a high PVB burden and evidence of PVB-induced tachycardiomyopathy, as it has not been shown to improve survival and its symptomatic benefits must be weighed against risks associated with the procedure(Zorzi et al., 2023). In high-risk Long QT patients, ICDs are recommended to prevent sudden cardiac death(Mahendran et al., 2023).

On-field emergency protocols: AEDs, CPR access

Sports organizations are strongly urged by the Interassociation Task Force, AHA, American College of Cardiology, and FIFA to implement an Emergency Action Plan to ensure effective management of sudden cardiac arrest events(Malik et al., 2023). A comprehensive Emergency Action Plan should include personnel training in emergency response, immediate access to an AED, emergency medical services activation, and transport protocols to advanced care facilities(Malik et al., 2023). Clear signage for AEDs at venues increases awareness and access during SCD incidents(Malik et al., 2023). Regular rehearsals and precompetition reviews of the Emergency Action Plan further enhance preparedness and response efficiency(Malik et al., 2023).

Monitoring and follow-up strategies

Efficient communication among all involved parties is essential for the success of an Emergency Action Plan, which should be regularly reviewed and updated with input from medical personnel, athletes, and coaches(Malik et al., 2023). Studies have shown that implementing an Emergency Action Plan improves knowledge and emergency response to sudden cardiac arrest in young athletes(Malik et al., 2023). A case report further illustrates the importance of timely intervention, as a young patient who experienced commotio cordis made a full recovery without neurological or cognitive deficits after proper emergency care and follow-up rehabilitation(„Commotio Cordis (Cardiac Concussion) in a Child. A Case Report", 2022).

7. Controversies and Ethical Issues

Universal ECG screening: pros and cons

The exercise ECG test is commonly employed as an initial screening tool for athletes, as it offers a rapid, cost-effective and readily available assessment method with less operator dependency compared to echocardiography(Zujko & Małek, 2022). The primary concern with ECG screening in athletes is the high false-positive rate, often leading to further testing, potentially causing unnecessary costs, unwarranted sports restrictions, and increased anxiety(Seely et al., 2023). ECG interpretation in athletes can be challenging, as many changes commonly seen may reflect normal, physiological adaptations associated with the "athlete's heart", making it particularly difficult to differentiate these from pathological conditions on ECG findings alone(D'Ambrosio et al., 2024; Landry et al., 2021; Schmidt et al., 2022; Seely et al., 2023). The ECG is known to be insensitive in detecting arrhythmogenic cardiomyopathy in young asymptomatic patients(Landry et al., 2021). Resting ECG often shows no distinctive abnormalities in young individuals with conditions like myocarditis or coronary artery anomalies(Sareban et al., 2022; Schmidt et al., 2022). Furthermore, the ECG exercise test has limited sensitivity for detecting coronary artery disease, and the presence of intraventricular conduction disturbances makes interpretation of ST-segment changes challenging(Zujko & Małek, 2022).

Risk vs autonomy in competitive athletes

Competitive athletes face significant risks related to sudden cardiac arrest, which necessitates careful consideration of their autonomy in decision-making regarding participation in sports(Malik et al., 2023). Studies have shown that male athletes are nearly four times more likely to experience SCD compared to female athletes, and Black athletes are nearly three times more likely compared to their white counterparts(Malik et al., 2023). This highlights the need for targeted preparticipation screening and education campaigns to help prevent SCD in at-risk populations(Malik et al., 2023). The ethical dilemma arises when athletes diagnosed with cardiovascular conditions at risk of SCD are mandated as ineligible for competitive sports(Sarto et al., 2023). In Italy, the non-eligibility decision of the sports medicine physician following the diagnosis of a condition at risk of SCD is legally binding(Sarto et al., 2023). This approach contrasts with a more liberal policy implying shared decision-making for return to play between athletes and physicians, which remains to be proven more effective(Sarto et al., 2023). Genetic testing in athletes presents specific ethical and legal aspects that need to be considered(Castelletti et al., 2022). The decision about whether to pursue genetic testing should be made following pre-test genetic counseling, ensuring that decisions are made by the athlete without undue duress(Castelletti et al., 2022). Post-test counseling is critical given the potential psychosocial, financial, and mental health implications, particularly if the athlete is excluded from play(Castelletti et al., 2022).

Disparities in screening access and guideline implementation

Although preparticipation screening has become more sensitive and specific, factors such as cost, psychological impact, and feasibility of broad implementation must also be taken into account(Malik et al., 2023). These interrelated issues contribute to the differing recommendations issued by organizations like the AHA, ESC, and IOC, leaving the optimal strategy for detecting these conditions unresolved(Malik et al., 2023). Furthermore, insurance implications for the athlete and their club are determined by the regulations of the athlete's country of residence(Castelletti et al., 2022). Despite the effectiveness of preparticipation screening programs, such as the Italian PPS program, which has shown a low incidence of adverse events and emphasizes the need for annual screenings, disparities in access to these screenings remain(Sarto et al., 2023). Countries with less experienced clinicians or limited cardiology resources may not be able to replicate the same sensitivity or cost per diagnosis, highlighting the need for improved access to screening and guideline implementation(Sarto et al., 2023).

8. Conclusions

Summary of evidence and key takeaways

Preventing sudden cardiac death in athletes with arrhythmic conditions remains a complex and evolving challenge that demands harmonized international guidelines and ongoing research. Key priorities include early detection and risk stratification through comprehensive screening and advanced diagnostics, as well as the implementation of individualized preventive measures such as lifestyle modification, pharmacologic therapy, and implantable cardioverter-defibrillators. Optimal care requires a multidisciplinary team approach, with cardiologists, sports physicians, and genetic counselors working together to manage affected athletes. While genetic testing shows promise in identifying inherited cardiac conditions, its utility is still limited outside specialized centers. Disparities in healthcare infrastructure and access to cardiovascular expertise contribute to uneven implementation of screening and prevention programs worldwide. To address these gaps, coordinated efforts from major organizations such as the European Society of Cardiology and the American Heart Association are needed to develop and disseminate harmonized guidelines.

Continued research is essential to refine risk stratification strategies, evaluate long-term outcomes, and ensure that preventive efforts are both effective and equitable.

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