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The Effectiveness of Periodic Cardiovascular Screening in Preventing Sudden Cardiac Death in Young Athletes

Authors:

Gólcz Adrian

0009-0009-8831-7398

Email: adriangolcz@gmail.com

Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Szaryński Mikołaj

0009-0001-7344-8020

Email: mikolaj.szarynski@gmail.com

Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Sikorski Adam 0009-0006-8463-3957 adam.sikorski515@gmail.com

Medical University of Gdańsk, M. Skłodowskiej-Curie Street 3a, 80-210 Gdańsk, Poland

Kadłubowska Karolina 0009-0006-5588-1329 karolina.kadlubowskaa@gmail.com
Medical University of Białystok, ul. Jana Kilińskiego 1, 15-089 Białystok, Poland Jakubowska Paulina
0009-0007-6376-3135
Email: paula.bialystok@wp.pl
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Chojnowska Natalia
0009-0004-8714-1726
Email: nataliachojnowska@poczta.fm
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Rytel Jan
0009-0006-0831-9990
Email: janryt@poczta.fm
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Jakubowska Martyna
0009-0008-7234-5178
Email: m.jakubowska2003@gmail.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Bursztyn Michał
0009-0004-7566-6859
Email: bursztyn82@gmail.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089 Białystok, Poland

Bursztyn Tomasz
0009-0003-1862-1155
Email: tomasz.bursztyn03@gmail.com
Faculty of Medicine, University of Rzeszów, al. Tadeusza Rejtana 16C, 35-959 Rzeszów

Gólcz Julia
0009-0009-3424-4082
Email: golczjulia@gmail.com
Faculty of Medicine, Medical University of Białystok, Jana Kilińskiego 1, 15-089
Białystok, Poland

Abstract

Sudden cardiac death (SCD) in young athletes, though infrequent, remains a key concern in sports cardiology due to its unexpected occurrence in apparently healthy individuals. This review summarizes current evidence on the effectiveness of periodic cardiological assessments, including pre-participation screening (PPS), in preventing SCD among young athletes. Epidemiological data indicate an annual SCD incidence of 1–3 cases per 100,000 athletes, higher than in the non-athletic population. The etiology varies with age: in athletes under 35 years, inherited and congenital conditions such as hypertrophic cardiomyopathy, arrhythmogenic right ventricular cardiomyopathy, and channelopathies predominate, whereas in those over 35 years, atherosclerotic coronary artery disease is the main cause. Standard PPS protocols include a thorough medical and family history, physical examination, and resting 12-lead electrocardiogram (ECG), with some programs adding exercise stress testing (EST) or advanced imaging. Evidence from long-term screening programs, particularly in Italy, suggests that ECG-based screening can identify potentially fatal cardiac disorders and may reduce SCD

incidence. Nevertheless, challenges include high false-positive rates, significant costs, and logistical difficulties. The cost-effectiveness of PPS is influenced by disease prevalence, diagnostic accuracy, and healthcare resource availability. Proper interpretation of screening results requires expert knowledge to differentiate physiological athletic adaptations from pathological abnormalities. Although observational findings are encouraging, randomized controlled evidence confirming reduced SCD mortality remains lacking. Therefore, PPS initiatives should be adapted to local healthcare capabilities, epidemiological patterns, and economic conditions. Emerging diagnostic technologies, such as mobile cardiac monitoring and artificial intelligence–based analysis, may further improve the accuracy, efficiency, and accessibility of SCD prevention strategies in athletic populations.

Keywords: sudden cardiac death (SCD); young athletes; pre-participation screening (PPS); sports cardiology; hypertrophic cardiomyopathy (HCM); arrhythmogenic right ventricular cardiomyopathy (ARVC); channelopathies; electrocardiogram (ECG); exercise stress testing (EST); cardiological evaluation; epidemiology; cost-effectiveness; false-positive results; screening protocols; cardiovascular disease prevention; athlete's heart; artificial intelligence; mobile cardiac monitoring

Introduction

Sudden cardiac death (SCD) in young athletes is a tragic event that, despite its relatively low incidence, has attracted considerable attention from both the medical community and the world of sports. Intense physical exertion can act as a "trigger" for arrhythmia or sudden cardiac arrest in individuals with undiagnosed cardiovascular disease. [1]

This paper reviews the current scientific evidence regarding the effectiveness of periodic cardiological evaluations — including pre-participation screening (PPS) — in preventing SCD among young athletes. The review addresses epidemiology, etiological factors, screening methodologies, diagnostic value, costs, limitations, and recommendations for clinical practice. [2]

Epidemiology and Causes of Sudden Cardiac Death in Athletes

Sudden cardiac death (SCD) among athletes represents a critical issue in sports medicine and public health. Although its occurrence is rare, its dramatic nature and impact on young, seemingly healthy individuals make it a subject of major scientific and social concern. [3]

A study published in the *Journal of the American College of Cardiology* reported that while the incidence of SCD among athletes is low, it is higher than in the non-athletic population. Most SCD events occur during or immediately after exercise, with cardiac arrest often representing the first and only manifestation of an underlying cardiac disorder. Cohort studies estimate an annual incidence ranging from 1 to 3 cases per 100,000 young athletes, depending on population, age, sex, and sport type. [1]

An article in *The Lancet* (2024) emphasized that despite long-standing screening initiatives and case registries, the true scale of the problem remains difficult to quantify. There is no globally uniform definition of SCD in sports, and diagnostic criteria vary widely.

Epidemiological data may therefore be underestimated, as some cases remain unreported or misclassified as deaths from non-cardiac causes. [4]

A systematic review published on *ResearchGate* (*Sudden cardiac death in athletes: a systematic review*) revealed that incidence patterns differ by age and sex. Men account for the majority of SCD cases. In athletes under 35 years of age, genetic and structural causes predominate, while in those over 35, atherosclerotic coronary artery disease is the main cause. These disparities likely reflect both biological factors and the predominance of men in highintensity competitive sports. [5]

The *Spanish Journal of Legal Medicine* (Elsevier) further highlights the lack of standardized monitoring systems for SCD, which hampers reliable trend analysis and international comparison. In many countries, SCD case registration is local, and autopsy data are incomplete or unavailable. Variations in methodology — including how “athlete” is defined, the classification of sports disciplines, and diagnostic confirmation procedures — contribute to uncertainty regarding true incidence rates. [3]

Despite these challenges, consistent trends emerge. The highest SCD risk occurs in sports characterized by high-intensity exertion and dynamic cardiovascular load fluctuations — such as football, basketball, track and field, cycling, and swimming. Geographical variations are also

evident: cardiomyopathies are more frequently reported in Europe, while coronary anomalies dominate in the United States. [1]

Etiology

Available evidence indicates that the causes of SCD differ substantially between younger and older athletes.

In athletes under 35 years of age, congenital or inherited disorders — often clinically silent — are most common. These include:

- **Hypertrophic cardiomyopathy (HCM)**
- **Arrhythmogenic right ventricular cardiomyopathy (ARVC)**
    - Coronary artery anomalies
- **Congenital channelopathies**, such as long QT syndrome, Brugada syndrome, or catecholaminergic polymorphic ventricular tachycardia (CPVT). [6]

According to the systematic review, cardiomyopathies account for 30–40% of all SCD cases among young athletes. The underlying mechanism typically involves malignant ventricular arrhythmia (most commonly ventricular fibrillation) triggered by intense exertion and heightened myocardial oxygen demand. [5]

In contrast, in athletes over 35 years old, the predominant cause of SCD is **coronary artery disease** and its complications, including acute myocardial infarction and ventricular fibrillation. Data published in *The Lancet* and *Spanish Journal of Legal Medicine* indicate that atherosclerotic lesions are responsible for up to 80% of cases in this age group. [3,4]

Across both age groups, intense physical activity serves as a common precipitating factor. Many athletes who experience SCD had previously been asymptomatic, with no abnormalities detected in routine medical examinations. Moreover, geographic and demographic variations are well established: European cohorts report higher frequencies of cardiomyopathies and electrical disorders, whereas American data indicate greater prevalence of congenital coronary anomalies. Channelopathies are comparatively more frequent in African and Asian populations. [7]

Components of a Typical Pre-Participation Screening (PPS) Protocol

A standard PPS protocol generally consists of three elements: (1) comprehensive medical and family history, (2) physical examination, and (3) additional tests — most often a resting 12lead ECG, and in some cases, exercise stress testing (EST) or other diagnostic procedures. [6]

In a large Italian program for youth athletes aged 7–18 years, annual screening included history, physical examination, resting ECG, and EST. Over 11 years (65,397 screenings in 22,324 participants), 69 cases of potentially life-threatening cardiac conditions (~0.3%) were identified, at a cost of approximately €73,312 per diagnosis. [8]

The *American Academy of Family Physicians* (AAFP) notes that routine ECG screening is not standard practice in the United States due to insufficient evidence of benefit and the high rate of false-positive results. [9]

Medical History and Physical Examination

History taking and physical examination remain the foundation of PPS. These assessments explore exertional symptoms (chest pain, dyspnea, syncope, palpitations), family history of premature cardiac death, cardiomyopathies, or channelopathies, and signs of connective tissue disorders such as Marfan syndrome. The AAFP reports that while widely implemented, this component alone has not been proven to reduce SCD mortality. [10]

Resting Electrocardiogram (ECG)

Resting 12-lead ECG is increasingly adopted in European PPS programs. It can detect electrical abnormalities associated with structural or channel diseases, such as HCM or Brugada syndrome. However, U.S. guidelines from the *American Heart Association (AHA)* and *American College of Cardiology (ACC)* advise against routine ECG screening for asymptomatic athletes because of low predictive accuracy and high false-positive rates.

Zorzi et al. demonstrated that supplementing ECG with EST significantly increased diagnostic yield, suggesting that ECG alone may be insufficient. [11]

Exercise Stress Testing (EST) and Additional Examinations

Including EST in PPS protocols can reveal previously unrecognized ventricular arrhythmias (VA). In the referenced study, 5% of participants exhibited VA during exercise, and 0.22% were diagnosed with conditions predisposing to SCD. Although this approach increased detection by approximately 75%, it also lowered the positive predictive value (PPV) from 6.9% to 5.5%, indicating more false-positive findings. [11]

Athletes with abnormal results on history, physical exam, ECG, or EST were referred for further diagnostics, such as echocardiography, cardiac MRI, or 24-hour Holter monitoring. [12]

Interpretation and Limitations

A major challenge in PPS interpretation lies in differentiating physiological adaptations ("athlete's heart") from pathological changes. The 2017 *International Criteria for Electrocardiographic Interpretation in Athletes* emphasize the need for expert, contextspecific evaluation. [13]

An effective screening program must achieve high sensitivity and specificity, target a population with sufficient disease prevalence, and ensure appropriate follow-up when abnormalities are detected. [14]

Costs, Cost-Effectiveness, and Implementation Challenges

Economic Aspects

The costs of PPS programs include initial assessments (history, physical exam, ECG), followup testing, and long-term monitoring of identified athletes. Hamad (2022) described history, physical exam, and ECG as the most cost-efficient PPS components.

Belgian modeling data (KCE Report) estimated a cost of ~€60 million for 1 million athletes (€60 per person), with follow-up testing adding €6–35 million depending on test accuracy. In the United States, Schmehil et al. (2017) projected that replicating the Italian ECG-based model would cost $51–69 billion over 20 years, at approximately $10–14 million per life saved. [15]

Cost-Effectiveness and Return on Investment

In Italy's 25-year program, 0.2% of athletes were diagnosed with SCD-related cardiac disease, and SCD incidence dropped from 3.6 to 0.4 per 100,000 person-years (a ~90% reduction). Despite this, Sarto et al. (2023) and Ramesh & Dhutia (2025) emphasize that costeffectiveness

varies by national resources, disease prevalence, and program quality. Universal screening may not be economically viable in low-prevalence populations. [16]

Implementation Barriers

1. **Scale and logistics** – Large athlete populations require trained cardiologists, diagnostic infrastructure, and data systems.
2. **False-positive results** – Rates may reach ~7%, generating unnecessary testing, anxiety, and potential disqualification.
3. **Low disease prevalence** – Limits population-level benefit ("low frequency–low yield").
4. **Repeat testing** – Regular re-screening significantly increases total program cost.
5. **Specialist interpretation** – Distinguishing adaptive from pathological ECG changes requires expertise.
6. **Ethical considerations** – Screening raises questions regarding exclusion from competition and the psychological impact of abnormal findings. [14]

Summary

Implementing PPS programs in young athletes involves substantial financial and operational challenges. While evidence from long-term initiatives (such as the Italian model) suggests potential reductions in SCD incidence, these results depend on high-quality protocols, expert evaluation, and low false-positive rates. In large, low-risk populations, costs may outweigh benefits. Thus, PPS should be tailored to local resources, population characteristics, and risk profiles. [16]

Conclusions

1. Periodic cardiological screening using history, physical examination, and additional testing (ECG, EST) can improve detection of cardiovascular conditions predisposing young athletes to SCD. [16]
2. However, there is insufficient randomized controlled evidence confirming that PPS significantly reduces SCD mortality. [14]

3. Implementation should consider local resources, costs, false-positive rates, and diagnostic quality. [14]
4. Athlete-specific ECG interpretation criteria and standardized follow-up pathways are essential. [13]
5. Emerging technologies, including mobile diagnostics and artificial intelligence, may enhance the efficiency and accessibility of future screening programs, reshaping SCD prevention strategies in athletic populations. [17]

Disclosure

Author's contribution

Conceptualization: Adrian Gólcz, **Methodology:** Adrian Gólcz, Julia Gólcz,

Formal analysis:

Investigation:

Writing-rough preparation: Adrian Gólcz,

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References

[1] Gherardo Finocchiaro, Joseph Westaby, Mary N. Sheppard, Michael Papadakis, Sanjay Sharma, Sudden Cardiac Death in Young Athletes: JACC State-of-the-Art Review, Journal of the American College of Cardiology, Volume 83, Issue 2, 2024, Pages 350-370, ISSN 07351097, https://doi.org/10.1016/j.jacc.2023.10.032.

[2] Petek BJ, Baggish AL. Pre-participation Cardiovascular Screening in Young Competitive Athletes. Curr Emerg Hosp Med Rep. 2020 Sep;8(3):77-89. doi: 10.1007/s40138-020-00214-5.

[3] Albert Agut-Busquet, Ignasi Galtés, Sudden cardiac death and sport. Review and key trends, Spanish Journal of Legal Medicine, Volume 44, Issue 4, 2018, Pages 158-168, ISSN 2445-4249, https://doi.org/10.1016/j.remle.2017.12.003.

[4] Kim JH, Martinez MW, Guseh JS, Krishnan S, Gray B, Harmon KG, Papadakis M, Phelan DM, Stewart K, Levine BD, Baggish AL; American College of Cardiology Sports & Exercise Leadership Council. A contemporary review of sudden cardiac arrest and death in competitive and recreational athletes. Lancet. 2024 Nov 30;404(10468):2209-2222. doi: 10.1016/S01406736(24)02086-5.

[5] Ferreira M, Santos-Silva PR, de Abreu LC, Valenti VE, Crispim V, Imaizumi C, Filho CF, Murad N, Meneghini A, Riera AR, de Carvalho TD, Vanderlei LC, Valenti EE, Cisternas JR, Moura Filho OF, Ferreira C. Sudden cardiac death athletes: a systematic review. Sports Med Arthrosc Rehabil Ther Technol. 2010 Aug 3;2:19. doi: 10.1186/1758-2555-2-19.

[6] Dores, H., Dinis, P., Viegas, J. M., & Freitas, A. (2024). Preparticipation Cardiovascular Screening of Athletes: Current Controversies and Challenges for the Future. *Diagnostics*, *14*(21), 2445. https://doi.org/10.3390/diagnostics14212445

[7] Hamad AKS. Risk of sudden cardiac death and preventive measures in athletes. Int J Cardiovasc Acad. 2022 Nov 29;8(4):89-95. doi: 10.4103/ijca.ijca_17_22.

[8] Schmehil C, Malhotra D, Patel DR. Cardiac screening to prevent sudden death in young athletes. Transl Pediatr. 2017 Jul;6(3):199-206. doi: 10.21037/tp.2017.05.04.

[9] Mirabelli, M. H., Devine, M. J., Singh, J., & Mendoza, M. (2015). The Preparticipation Sports Evaluation. *American family physician*, *92*(5), 371–376.

[10] Wexler, R., & Estes, N. A., 3rd (2015). Should Preparticipation Cardiovascular Screening of Athletes Include ECG? No: There Is Not Enough Evidence to Support Including ECG in the Preparticipation Sports Evaluation. *American family physician, 92*(5), 343–344.

[11] Zorzi, A., Vessella, T., De Lazzari, M., Cipriani, A., Menegon, V., Sarto, G., Spagnol, R., Merlo, L., Pegoraro, C., Marra, M. P., Corrado, D., & Sarto, P. (2020). Screening young athletes for diseases at risk of sudden cardiac death: role of stress testing for ventricular arrhythmias. *European journal of preventive cardiology, 27*(3), 311–320. https://doi.org/10.1177/2047487319890973

[12] Leischik, R., Dworrak, B., Foshag, P., Strauss, M., Spelsberg, N., Littwitz, H., & Horlitz, M. (2015). Pre-Participation and Follow-Up Screening of Athletes for Endurance Sport. *Journal Of Clinical Medicine Research, 7*(6), 385-392.

[13] Drezner, J. A., Sharma, S., Baggish, A., Papadakis, M., Wilson, M. G., Prutkin, J. M., Gerche, A., Ackerman, M. J., Borjesson, M., Salerno, J. C., Asif, I. M., Owens, D. S., Chung, E. H., Emery, M. S., Froelicher, V. F., Heidbuchel, H., Adamuz, C., Asplund, C. A., Cohen, G., Harmon, K. G., … Corrado, D. (2017). International criteria for electrocardiographic interpretation in athletes: Consensus statement. *British journal of sports medicine, 51*(9), 704–731. https://doi.org/10.1136/bjsports-2016-097331

[14] Ramesh, Pranav & Dhutia, Harshil. (2025). Cardiac screening in athletes: benefits and potential challenges. British Journal of Cardiology. doi:10.5837/bjc.2025.048

[15] Hamad, A. K. S. (2022). Risk of sudden cardiac death and preventive measures in athletes. International Journal of the Cardiovascular Academy, 8(4), 89-95. https://doi.org/10.4103/ijca.ijca_17_22

[16] Sarto, P., Zorzi, A., Merlo, L., Vessella, T., Pegoraro, C., Giorgiano, F., Graziano, F., Basso, C., Drezner, J. A., & Corrado, D. (2023). Value of screening for the risk of sudden cardiac death in young competitive athletes. *European heart journal, 44*(12), 1084–1092. https://doi.org/10.1093/eurheartj/ehad017

[17] Smaranda, A. M., Drăgoiu, T. S., Caramoci, A., Afetelor, A. A., Ionescu, A. M., & Bădărău, I. A. (2024). Artificial Intelligence in Sports Medicine: Reshaping Electrocardiogram Analysis for Athlete Safety-A Narrative Review. *Sports (Basel, Switzerland), 12*(6), 144. https://doi.org/10.3390/sports12060144