

SUDDEN DEATH IN ATHLETES

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Abstract: In recent years, an increasing number of children and adolescents have been participating in sports activities; however, sudden deaths occurring during competitions or training sessions have raised concerns among families and society. Approximately 95% of sudden deaths are caused by cardiac-related factors. The most common causes include hypertrophic cardiomyopathy, arrhythmogenic right ventricular dysplasia, and congenital coronary artery anomalies. In addition to diagnosed or undiagnosed heart diseases, the effects of performance-enhancing substances should also be considered. In order to prevent sudden deaths, standard screening programs should be implemented for all athletes. A thorough medical history, family history, and physical examination, along with electrocardiographic evaluation, will enable the exclusion of many cardiac conditions.

Keywords: sudden death, sports-related deaths, athlete's heart.

Introduction

In recent years, the number of children and adolescents actively participating in sports has been steadily increasing. Sports and physical activity are widely accepted as beneficial for promoting physical and mental development, preventing obesity, and improving social adaptation skills. However, although rare, sudden death during sports and physical activity can be a matter of serious concern. Even though the incidence of sudden death is not very high, sudden death events occurring in young athletes considered to be the healthiest segment of society cause profound grief in families and communities, and raise concerns among parents whose children are involved in sports. The occurrence of similar events in well-known athletes also draws the attention of the media, keeping this issue in public awareness [1].

In recent years, various cases of athletes who died during training or competitions have been reported and covered by the press; some of these individuals are listed in Table I. One of the earliest known cases of sudden death associated with physical activity dates back to 490 BC, when Pheidippides ran from the battlefield of Marathon to Athens to deliver the news of victory and died immediately after announcing it. Today, this case is considered a historical example supporting the need for screening programs for athletes.

Sudden death is defined as death occurring within 1–6 hours after the onset of symptoms. Sports-related sudden death refers to death that occurs during training or competition, or immediately afterward. The overall incidence of sudden death in athletes has been reported as 2.3 per 100,000 individuals. Approximately 95% of sudden deaths in athletes are due to cardiovascular causes. When compared to non-athletes, the risk of sudden death is 2.5 times higher in athletes, suggesting that intensive physical activity may act as a trigger in individuals with underlying conditions [2].

Table I. Some athletes reported in the media who died during training or competition

Name	Age	Sport / Nationality	Year
Renato Curi	24	Peruvian football player	1977
Omar Sahnoun	24	French football player	1980
Samuel Okwaraji	24	Nigerian football player	1989

John Ikoroma	17	Nigerian football player	1995
Amir Angwe	29	Nigerian football player	1995
Sergei Grinkov	28	Russian figure skater	1995
Catalin Haldan	24	Romanian football player	2000
Stefan Tolceski	28	Macedonian football player	2002
Özgür Özdemir	22	Turkish basketball player	2002
Hüseyin Dönsoy	23	Turkish bodybuilder	2002
Vivien Foe	28	Cameroonian football player	2003
Miklós Fehér	24	Hungarian football player	2004
Serginho	30	Brazilian football player	2004
Gökmen Yıldız	?	Turkish football player	2006
Emre Aydın	15	Turkish athlete (Selimiyespor)	2006

Sudden death is most commonly observed in athletes involved in basketball, football, and American football. The risk of sudden death in male athletes is reported to be nine times higher than in females. The causes of sudden death may be due to cardiac diseases that have been diagnosed previously or undiagnosed underlying heart conditions. These undetected cardiac conditions are often referred to as “silent heart diseases” in the general population. Changes in cardiac physiology during exercise may trigger fatal cardiac events in individuals with such undiagnosed conditions. Additionally, performance-enhancing substances commonly used among professional athletes may contribute to the risk of sudden death [3].

Among cardiac diseases, the most common cause of sudden death reported in studies conducted in the United States is hypertrophic cardiomyopathy. In Italy, where mandatory long-term screening programs for athletes are implemented, the most frequently reported cause of sudden death is Arrhythmogenic Right Ventricular Dysplasia/Cardiomyopathy, likely due to genetic prevalence in that region.

Coronary artery disease is the most common cause of sudden death in individuals over 35 years old. In contrast, in children and adolescents, congenital coronary artery anomalies and early coronary artery disease rank as the second most frequent causes of sudden death. The cardiac conditions that may lead to sudden death are summarized in Table II.

Table II. Cardiac conditions associated with sudden death in athletes

Category	Specific Conditions
Cardiomyopathies	- Hypertrophic cardiomyopathy - Dilated cardiomyopathy - Arrhythmogenic right ventricular dysplasia/cardiomyopathy
Inflammatory Heart Diseases	- Myocarditis
Coronary Artery Diseases	- Atherosclerotic coronary artery disease - Congenital coronary artery anomalies - History of Kawasaki disease
Congenital Heart Diseases	- Aortic stenosis - Aortic coarctation - Pulmonary vascular obstructive disease - Mitral valve prolapse
Connective Tissue	- Marfan syndrome - Ehlers-Danlos syndrome

Disorders		
Electrical Disorders	Heart	- Long QT syndrome (congenital/acquired) - Short QT syndrome - Brugada syndrome - Catecholaminergic polymorphic ventricular tachycardia
	Conduction System Abnormalities	- Wolff-Parkinson-White syndrome - Atrioventricular blocks (Mobitz II)

Additional Notes

Individuals diagnosed with cardiac diseases have their eligibility for specific sports determined based on the severity of their condition, as outlined by the 26th and 36th Bethesda Conferences. In individuals with undiagnosed cardiac diseases, emotional stress, myocardial ischemia, sympatho-vagal imbalance, and hemodynamic instability during exercise may trigger fatal arrhythmias, leading to sudden death [4].

Hypertrophic cardiomyopathy (HCM)

Hypertrophic cardiomyopathy (HCM) is the most common cause of sudden cardiac death in young athletes, accounting for approximately one-third of all cases. Its estimated prevalence in the general population is 1 in 500. The disease is a genetic condition inherited in an autosomal dominant pattern, with more than 150 mutations reported in genes encoding sarcomeric proteins. It is characterized by marked hypertrophy of the heart walls and histological disarray of myocardial fibers. Some cases may be asymptomatic and remain undiagnosed [5].

Diagnosis is made by echocardiographic identification of thickened ventricular walls in the absence of another condition that could lead to left ventricular hypertrophy (such as left ventricular outflow tract obstruction), while the ventricular cavity remains normal or even reduced. Septal thickening is usually more prominent, and some patients may also present with left ventricular outflow tract narrowing. Anterior motion of the mitral valve during systole may be observed. Systolic function is preserved, while diastolic dysfunction may be present. Death occurs during exercise due to ischemia in the hypertrophic myocardium and the development of arrhythmias.

Recognition of hypertrophic cardiomyopathy requires taking a detailed family history and questioning the athlete about symptoms such as chest pain, dyspnea, dizziness, or syncope during exercise. On physical examination, a harsh systolic ejection murmur may be heard. The intensity of the murmur increases in conditions that reduce systemic venous return, such as the Valsalva maneuver. Additionally, a fourth heart sound may be present, and the first upstroke of the carotid pulse may be rapid. Electrocardiography (ECG) is abnormal in 95% of patients. Findings may include left atrial enlargement, left ventricular hypertrophy, abnormal Q waves, ST segment and T wave abnormalities, premature ventricular contractions, ventricular tachycardia, and atrial fibrillation [6].

Differentiating physiological left ventricular hypertrophy resulting from athletic training from hypertrophic cardiomyopathy can be challenging in some cases. Individuals engaged in long-term dynamic (aerobic) sports tend to exhibit “eccentric” hypertrophy, whereas those involved in static sports demonstrate “concentric” hypertrophy. These exercise-induced changes are commonly known as “athlete’s heart”. In concentric hypertrophy, only wall thickness increases, while in eccentric hypertrophy, increased wall thickness is accompanied by dilation of the left ventricular cavity. A septal wall thickness of less than 13 mm suggests physiological hypertrophy, whereas a thickness greater than 16 mm is indicative of hypertrophic cardiomyopathy. However, in borderline cases, diagnosis may be difficult. A detailed family history and genetic testing may be helpful; however, even if these are negative, hypertrophic cardiomyopathy cannot be excluded. Hypertrophy that develops as a result of long-term exercise

regresses when sports activity is discontinued, whereas hypertrophic cardiomyopathy does not regress and follows a progressive course. There is currently insufficient evidence to determine whether secondary hypertrophy due to exceeding physiological limits can cause sudden death.

Arrhythmogenic right ventricular dysplasia/cardiomyopathy (ARVD/C)

Studies conducted in the Veneto region of Italy have reported ARVD/C as the most common cause of sudden death among athletes. It is a genetically inherited disease with an autosomal dominant pattern. The condition is characterized by thinning of the right ventricular myocardium, fatty degeneration, and fibrosis. Ventricular arrhythmias originating from the right ventricle are common and can lead to sudden cardiac death. The disease typically manifests during adolescence or early adulthood and follows a progressive course. Syndromic forms such as Naxos syndrome and Carvajal syndrome have also been identified.

A family history of the disease, episodes of syncope, and electrocardiographic findings such as wide QRS complexes in right precordial leads, right bundle branch block, the presence of epsilon waves following the QRS complex, T-wave inversion, and ventricular premature beats or ventricular tachycardia with left bundle branch block morphology are clinical indicators suggestive of ARVD/C. Echocardiography may demonstrate right ventricular dilation and impaired contractility. The diagnosis can be confirmed using magnetic resonance imaging (MRI) [7].

Dilated cardiomyopathy and myocarditis

Dilated cardiomyopathy (DCM) and myocarditis are thought to account for approximately 6–12% of sudden deaths in athletes. Myocarditis may follow a silent course, making diagnosis difficult. Sudden death can occur during both the acute phase and the recovery phase due to arrhythmias or cardiovascular collapse. Several viruses can cause myocarditis, with Coxsackie B virus being the most common etiological agent.

Clinical manifestations include fatigue, exertional dyspnea, and reduced exercise tolerance. Radiographic imaging may reveal cardiomegaly, while electrocardiography may show low QRS voltage, T-wave inversion or flattening, ST-segment elevation, and arrhythmias. Diagnosis can be made by demonstrating impaired left ventricular systolic function on echocardiography. Athletes diagnosed with myocarditis should be restricted from training for at least six months, and only after comprehensive cardiac evaluation confirming normal ventricular function at rest and during exercise, and the absence of arrhythmias, may they be allowed to resume athletic activity [8].

Coronary artery disease

In adults, atherosclerotic coronary artery disease is the leading cause of sudden cardiac death. In children and adolescents, congenital coronary artery anomalies are the primary cause. Coronary artery involvement may also occur due to previous Kawasaki disease, familial hyperlipidemia, or coagulopathies leading to premature atherosclerotic coronary artery disease. The prevalence of coronary artery anomalies is reported as 1% in individuals undergoing angiography and 0.3% in autopsy studies.

The most frequently implicated anomaly involves the anomalous origin of the left coronary artery from the right sinus of Valsalva. In such cases, the left coronary artery courses intramurally between the aorta and the pulmonary artery, and the increase in stroke volume during exercise can cause compression of the coronary artery, resulting in myocardial ischemia and infarction. Myocardial scar tissue formed due to prior ischemia can also predispose to exercise-related arrhythmias.

Some patients may present with symptoms such as chest pain, syncope, or palpitations during exertion. Physical examination, radiographic imaging, and EKG findings may be normal at rest.

Although echocardiography can identify abnormal coronary artery origins, definitive diagnosis is made using conventional angiography or MR angiography [9].

Congenital heart diseases

Most congenital heart diseases are diagnosed in early childhood, which is why they account for a smaller proportion of sudden deaths in athletes. Among these, aortic stenosis and aortic coarctation, which cause left ventricular outflow tract obstruction and lead to hypertrophy, are the most clinically significant. Aortic stenosis can be identified through the presence of a characteristic ejection systolic murmur heard at the aortic area during physical examination. Elevated systemic blood pressure and the absence of palpable femoral pulses are suggestive of aortic coarctation.

Pulmonary vascular obstructive disease may develop as a late complication in congenital heart diseases with left-to-right shunt and can cause sudden death during exercise. Another congenital cardiac abnormality associated with sudden death is mitral valve prolapse (MVP). However, MVP is a common anomaly in the general population, and sudden death directly related to MVP is extremely rare. Therefore, exercise restriction is not recommended in uncomplicated MVP cases.

Marfan syndrome

Approximately 5–7% of sudden deaths in young athletes are attributed to aortic rupture, and nearly half of these occur in individuals with Marfan syndrome. Marfan syndrome is an autosomal dominant genetic disorder with a reported prevalence of 1 in 10,000, associated with mutations in the fibrillin-1 gene leading to defects in elastic fibers. Pathological features such as cystic medial necrosis of the aortic wall, dilation of the aortic root, dissection, and rupture are characteristic.

Diagnosis is based on physical examination findings and family history. Clinical features include skeletal abnormalities, lens subluxation, arachnodactyly, joint hyperextensibility, scoliosis, chest deformity, and an arm span exceeding body height. Death is usually due to cardiac involvement. Cardiac manifestations include mitral valve prolapse, tricuspid valve prolapse, and aortic dilation. Genetic diagnostic methods may also be utilized [10].

Ehlers-danlos syndrome

This is another genetically inherited connective tissue disorder with cardiac involvement similar to Marfan syndrome.

Long QT syndromes

Long QT syndromes are caused by mutations in genes encoding ion channels responsible for generating action potentials in cardiac myocytes. These abnormalities prolong repolarization and predispose individuals to ventricular arrhythmias. The prevalence in the general population is approximately 1 in 10,000. To date, eight types of congenital long QT syndromes have been identified. Both autosomal dominant and autosomal recessive forms exist, and some are associated with congenital sensorineural hearing loss.

The most common forms, LQT1 and LQT2, arise due to abnormalities in potassium channels, while LQT3 is associated with sodium channel defects. During adrenergic stimulation or exercise, individuals with long QT syndrome may develop a specific type of polymorphic ventricular tachycardia known as *torsades de pointes*, which can lead to sudden death. On the electrocardiogram (ECG), the corrected QT interval (QTc) is typically greater than 450 milliseconds in males and 460 milliseconds in females. Family history, ECG findings, and clinical symptoms are crucial in establishing the diagnosis, and genetic testing may also be utilized. Individuals diagnosed with long QT syndrome should not be permitted to participate in competitive sports. Acquired long QT syndrome may also develop due to the use of certain medications or electrolyte imbalances.

Conclusion

Sudden cardiac death in athletes, although relatively rare, represents one of the most dramatic and preventable causes of mortality in young and seemingly healthy individuals. The majority of these deaths are linked to undiagnosed structural or electrical cardiac disorders, such as hypertrophic cardiomyopathy, arrhythmogenic right ventricular dysplasia, congenital coronary artery anomalies, myocarditis, and channelopathies including long QT syndrome. Intense physical exertion acts as a physiological trigger that can precipitate fatal arrhythmias in individuals with underlying cardiac abnormalities.

The findings of this review highlight that early recognition through standardized pre-participation screening programs is the most effective strategy for preventing sudden death in athletes. A thorough medical and family history, detailed physical examination, and electrocardiographic evaluations supported, when necessary, by echocardiography, cardiac MRI, and genetic testing can successfully identify many high-risk individuals before fatal events occur. Particular attention should be given to athletes with hereditary cardiac disorders, as early diagnosis and appropriate intervention can be lifesaving.

In conclusion, implementing routine cardiac screening protocols, increasing awareness among athletes, coaches, and healthcare professionals, and ensuring that sports cardiology and sports psychology services are integrated into athletic programs are essential components in reducing the incidence of sudden death in athletes. Prevention should be prioritized over intervention, as every avoidable death represents not only a medical failure but also a profound social and emotional loss.

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