

The most common cause of sudden cardiac death in athletes

Najčešći uzročnici iznenadne srčane smrti kod sportista

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Sažetak

Pozitivan uticaj vežbanja na zdravlje kardiovaskularnog sistema dobro je poznat. Sportisti, koji su stalno fizički aktivni, smatraju se najzdravijim pripadnicima našeg društva, pa njihova iznenadna smrt tokom treninga ili takmičenja privlači pažnju celokupne javnosti. Retki, tragični događaji iznenadne srčane smrti (ISS) razlog su za postavljanje pitanja da li pored višestrukih pozitivnih postoje i negativni uticaji fizičkog vežbanja. Prvi slučaj ISS zabeležen je davne 490. godine p.n.e., kada je grčki vojnik Fidipid umro pošto je preneo vest o velikoj pobedi Grka nad Persijancima. Opasnost od ISS prepoznat je sredinom dvadesetog veka, a na našim prostorima je o ovoj temi počelo da se raspravlja nakon svetskog prvenstva u košarci, održanog u Ljubljani 1970. godine i iznenadne smrti reprezentativca Trajka Rajkovića. Jedan od važnijih ciljeva moderne sportske medicine je da se rizik od ISS kod sportista smanji na "neizbežnu retkost". Pod ISS može da se svrsta svaka neočekivana smrt uzrokovana iznenadnim zastojem rada srca. Pedo (*Pedoe*) je sve uzroke ISS u sportu podelio u tri kategorije:

- 1) potres srca (*commotio cordis*), koji nastaje tupim udarom u grudni koš sportiste, s posleđičnim fatalnim poremećajem srčanog ritma;
- 2) ISS kod sportista mlađih od 35 godina zbog strukturne, urođene ili zapaljenjske bolesti srca u koje spadaju hipertrofična kardiomiopatija (najznačajniji uzročnik iznenadne srčane smrti), kongenitalne anomalije koronarnih arterija, aritmogena kardiomiopatija desne komore, miokarditis i druge; i
- 3) ISS kod sportista starijih od 35 godina koja najčešće nastaje zbog bolesti koronarnih arterija (dominantan rizik kod maratonaca i polumaratonaca).

Ključne reči: iznenadna srčana smrt, fizička aktivnost, sportisti, hipertrofična kardiomiopatija

Abstract

The positive impact of exercise on cardiovascular health is well known. Athletes, who are constantly physically active, are considered to be the healthiest members of our society. That is why their sudden death, during the training or competition, attracts the attention of the general public. Rarely, tragic events of sudden cardiac death (SCD) are the reason for questioning if by many positive there are also negative impact of physical exercise. The first case of SCD is recorded as far back as the year 490 BC, when the Greek soldier Pheidippides died after he conveyed news of the great victory of the Greeks over the Persians. Risk of SCD is recognized in the middle of the twentieth century. In our region, discussion about this issue began after the World Basketball Championship, which was held in Ljubljana in 1970, because of the sudden death of the national team member Trajko Rajkovic. One of the important goals of modern sports medicine is to reduce the risk of SCD in athletes to "inevitable rarity". Definition of SCD is considered to be any unexpected death due to sudden cardiac arrest. Pedo (*Pedoe*) has divided all causes of SCD in the sport into three categories:

- 1) *Commotio cordis* (agitation of the heart), which results from blunt impact to the athletes chest with consequent fatal disorder of heart rhythm;
- 2) SCD of athletes under the age of 35 because of structural, congenital and inflammatory heart disease, which includes hypertrophic cardiomyopathy as the most important cause of sudden cardiac death, congenital anomalies of the coronary arteries, arrhythmogenic right ventricular cardiomyopathy, myocarditis and other;
- 3) SCD of athletes older than 35 years which is most common due coronary artery disease – atherosclerosis (the dominant risk in the marathon and half-marathon).

Key words: sudden cardiac death, physical activity, athletes, hypertrophic cardiomyopathy

Introduction

The positive impact of exercise on cardiovascular health is well known. Athletes, who are constantly physically active, are considered to be the healthiest members of our society. That is why their sudden death, during the training or competition, attracts the attention of the general public. Rarely, tragic events of sudden cardiac death (SCD) are the reason for questioning if by many positive there are also negative impact of physical exercise. The first case of SCD is recorded as far back as the year 490 BC, when the Greek soldier Philippides died after he conveyed news of the great victory of the Greeks over the Persians. Risk of SCD is recognized in the middle of the twentieth century. In our region, discussion about this issue began after the World Basketball Championship, which was held in Ljubljana in 1970, because of the sudden death of the national team member Trajko Rajkovic. Definition of SCD is considered to be any unexpected death due to sudden cardiac arrest (1). SCD is characterized by abrupt loss of consciousness within one hour of the occurrence of acute symptoms, with previous heart disease may exist but does not have to be necessarily the direct cause of death (1).

Epidemiology of SCD

Epidemiology and prevention of sudden cardiac death (SCD) of athletes is still a subject of a constant debate. Rarely, tragic events of sudden cardiac death (SCD) are the reason for questioning if by many positive there are also negative impact of physical exercise. So one of the important goals of modern sports medicine is to reduce the risk of SCD in athletes to "inevitable rarity". For individuals over 35 years, the undisputable reason of SCD is early onset of coronary arteries disease (CAD) (2,3,15). The incidence of SCD of younger (< 35 years old) athletes varies in different populations and is estimated at 0.5–4:100,000/year (2,4). Those large differences may be explained by diverse geographic prevalence of diseases leading to SCD of athletes but also by the methodology of registries. Cardiac societies have recently expressed concern about the quality of available data and addressed the need for large (international) registries (5). All available registries show that SCD is much more possible with male athletes (80–95% of all cases) (6). The other known risk factors of SCD are age and Afro-Caribbean origin (4,6). The most probable explanation of racial differences is the higher prevalence of hypertrophic cardiomyopathy (HCM) of Afro-Caribbean people (6). Age is strongly related with the development of CAD. When it comes to women athletes, SCD occurs nine times less compared to men. The literature cited following reasons: a small num-

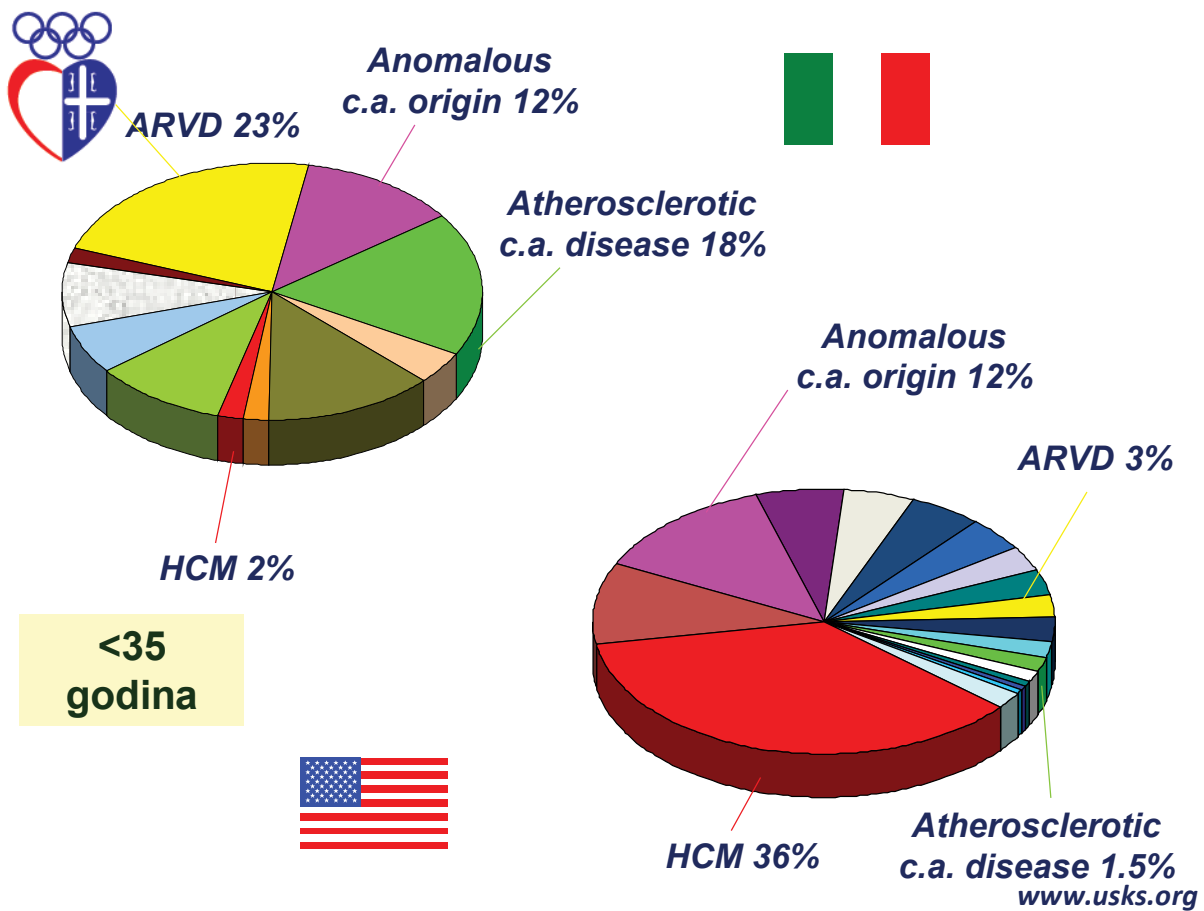
ber of women active in sports, a better adaptation of the cardiovascular system, the protective role of female sex hormones, less stressful demands in the competition as well as less frequent diagnosis of hypertrophic cardiomyopathy among women in the overall population (7).

Etiology of SCD

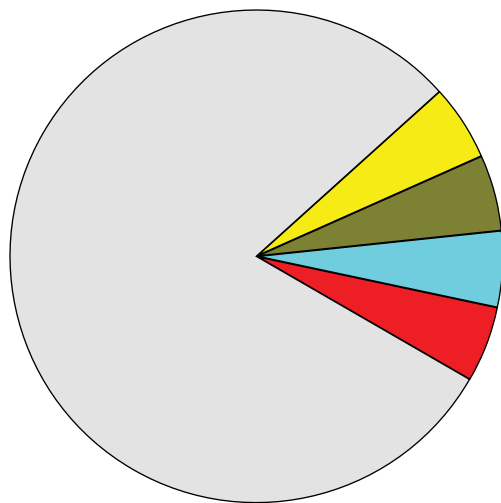
There are many causes of sudden cardiac death. Pedo (Pedoe) (8) shared all causes of SCD in the sport into three categories:

- 1) commotio cordis (agitation of the heart), which results from blunt impact to the athletes chest with consequent fatal disorder of heart rhythm;
- 2) SCD of athletes under the age of 35 because of structural, congenital and inflammatory heart disease, which includes hypertrophic cardiomyopathy as the most important cause of sudden cardiac death, congenital anomalies of the coronary arteries, arrhythmogenic right ventricular cardiomyopathy, myocarditis and other; and
- 3) SCD of athletes older than 35 years which is most common due coronary artery disease (atherosclerosis), (the dominant risk in the marathon and half-marathon).

It is interesting that there is great heterogeneity in geographical terms of the most common causes of SCD. Due to the high percentage of American athletes with African origins, the HCM was and still is cited as the single most important cause of SCD, according to the largest registries from the United States (9). On the contrary, in the registry from Germany published in 2015, HCM was identified as a reason in only 5% of athletes. The most common cause of death of athletes under the age of 35 was myocarditis (10). In Italy, that was arrhythmogenic right ventricular cardiomyopathy (23). Irrespective of the actual primary cause, the direct reason for cardiac arrest of athletes (both under and over 35 years) is ventricular arrhythmia. Therefore, widespread knowledge about basic life support and accessibility of automated external defibrillators is crucial, especially in athletic mass events. The French registry from 2011 showed that those two factors were most important in predicting the survival of SCD during exercise in the general population (11).



Picture 1. The most common cause of sudden cardiac death in athletes under the age of 35 in Italy and USA



- Coronary artery disease
- Left ventricular hypertrophy
- Mitral valve prolapse
- Unknown
- Acquired valve diseases

Picture 2. The most common cause of sudden cardiac death in athletes older than 35 years

Hypertrophic cardiomyopathy (HCM)

Hypertrophic cardiomyopathy represents a broad group of structural heart disease. It is the most common cause of sudden cardiac death in young athletes in America (4, 6). Inherited in an autosomal dominant, characterized by a high degree of penetrance genes, it is characterized by a distinct genetic heterogeneity, with more than 400 different mutations in any of the 11 different genes encoding protein synthesis sarcomeres (12). The most common mutations are in the genes in the chromosome number 14, which codes for the beta-myosin heavy chain (30%), followed by mutations in chromosomes number 1 for the cardiac troponin T (15-20%) and 11 for myosin binding protein C (10-15%), together with 15 for tropomyosin alpha (2-5%) (12, 13). The consequence of defective synthesis of these proteins is hypo-functional sarcomere with reduced power and speed of contraction, which leads to compensatory hypertrophy and proliferation of fibroblasts (13). Asymmetric hypertrophy of the heart, with a marked thickening of the left ventricular wall (15-50 mm; normally up to 13 mm) and hypertrophy of the inter-ventricular septum is characteristic of this disease (14). At the same time, there is no compensatory dilation of the ventricular cavity and a filling chamber is reduced in diastole. Dynam-

ic obstruction of the left ventricular HCM gives no clinical symptoms. Symptoms that suggest heart disease were described in only 20% of deaths of athletes with HCM, who were diagnosed with SCD. In most studies, the most common causes of SCD cited persistent ventricular tachycardia and ventricular fibrillation. Impaired cell structure, myocardial ischemia with the formation of scar tissue and interstitial proliferation of fibrous tissue are arrhythmogenic substrate for electrical instability of the myocardium (13). During clinical examination a person may be suspected HCM. Irregular pulse can be felt on the carotid artery and precordial auscultation can detect a strong aortic systolic murmur over the estuary, whose intensity increases during exercise (13). The best clinical diagnosis of HCM is a two-dimensional echocardiography. Diagnosis can be complemented by Holter ECG, which revealed abnormal findings in 75-95% of cases. Typical Holter ECG findings are: wide Q-wave, which indicates hypertrophy of the septum, negative T-wave, a sign of myocardial ischemia and increased QRS complex voltage (16).

Congenital anomalies of the coronary arteries (CACA)

Congenital anomalies of the coronary arteries (CACA), according to frequency, is the second most common cause of SCD of young athletes, after hypertrophic cardiomyopathy (17). The most common abnormality is the one of the left main coronary artery that comes out of the right sinus of Valsalva under brisk angle (17-19%) and passes between the confluence of the aorta and pulmonary artery (17). Other anomalies described in the literature are: abnormalities of the left coronary artery originating from a pulmonary artery, hypo plastic coronary arteries, congenital agenesis of the right coronary artery and the right coronary artery anomalies that start from the left sinus of Valsalva (17). During the physical activity myocardial hypo perfusion happens, due to the inability of the coronary arteries to adapt and provide adequate oxygenation of the myocardium. The symptoms of myocardial ischemia occur in one third of the athletes, and are more common with people with the right coronary artery anomalies. Ischemic changes, which indicate CACA (elevation and ST-segment depression, a wide Q-wave and T-wave inversion) are rarely detected by ECG, even with the athletes with symptoms (16-17).

Arrhythmogenic right ventricular cardiomyopathy (ARVC)

Arrhythmogenic right ventricular cardiomyopathy (ARVC) is a rare heart muscle disease, characterized by a

progressive myocardial dystrophy with fibro-fatty replacement (18). It is a genetically determined cardiomyopathy caused by heterozygous, or compound heterozygous mutations in genes, mostly encoding proteins of the desmosome complex (about 50 % of probands). Fatty infiltration leads to pseudo hypertrophy of myocardial wall, while he is thinned and weakened in the areas of fibrosis (18, 19). ARVC is clinically manifested tachyarrhythmia in chambers and hemodynamic disorders due to dysfunction of ventricular. The first symptoms usually manifest between 15 and 35 years and can range from a feeling of irregular and rapid heart rate, through weakness, fatigue and syncope (18, 19). Changes in ECG with most people showing left bundle branch block, negative T-wave and enlarged QRS complex on account of the extended S-wave in leads V1-V3. Typical but yet rare is the finding of the Y-wave at the end of the QRS complex (19).

Myocarditis

Acute myocarditis is a rare but potentially dangerous disease, usually caused by viruses (in more than half of the cases by Coxsackie B virus, adenovirus and herpes viruses) (20). Inflammation of the myocardium, lymphocyte infiltration and focal necrosis of tissue, which are determined on histopathological preparations, is a risk factor for electrical instability of the heart and the occurrence of arrhythmias (20). Usually, myocarditis is not accompanied by any symptoms, so SCD is the only manifestation of the disease. However, some patients may have evidence of viral infection, tachycardia, audible third heart sound, or gallop, an enlarged neck vein, peripheral edema and hepatomegaly, while on the chest X-ray observed cardiac enlargement (20). The most common abnormality in ECG seen in myocarditis is sinus tachycardia with non-specific ST segment and T wave changes (diffuse T wave inversion) (20). Physical activity during the acute phase of the disease leads to an increase in viral replication, pronounced myocardial necrosis and increased risk of SCD. That is why these athletes are prohibited to have any physical activity at least six months.

Comotio cordis

Comotio cordis is the sole cause of the SCD, which is not necessarily the result of congenital or acute heart disease (22). It occurs as a result of non-penetrative shock blunt projectile in the chest, or the collision of two bodies of athletes, without the injury of the ribs and heart (22). Low energy impact (with the exception of hockey puck) leads to the formation of ventricular arrhythmias if they occur during repolarization chamber in a sensitive period

of the cardiac cycle (21). In addition to the corresponding period of depolarization infarction, the occurrence of ventricular fibrillation are important and localization of stroke, force and speed of impact, as well as changes at the molecular level Na⁺ / K⁺ ATP-dependent channel (21). Although it rarely happens to the athletes, the danger of it is great, because death is almost instantaneous, and the mortality rate is higher than 90% (22).

Conclusion

Even though the subject of SCD has been present in medical literature for many years, there are many questions remaining, still unanswered. Even it's rare, SCD of young athletes is a tragic event that draws public attention and can be misinterpreted. They are worrying that the majority of athletes who died of SCD had no previous history of heart disease or early symptoms of disease before death. Therefore, the goal of sports medicine physicians in the future is better screening of all persons who engage in physical activity, in order to discover on time all the causes that can lead to sudden cardiac death, and to prevent it.

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