Module 3. Sudden death in sport

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Sudden cardiac death (SCD) is defined as a natural death, apparently of cardiac cause, that occurs within one hour of the onset of symptoms, in cases where it was witnessed, and within 24 hours of the last time the victim was seen alive, in cases where it was not. In the event that an autopsy is performed, any natural and unexpected death due to a cardiac or unknown cause will be referred to as SCD. The cessation of normal cardiac activity with hemodynamic failure will be called cardiac arrest (CA) (Zeppenfeld et al., 2022).

Although this section deals with SCD in sport, we must start from the premise that, at present, we have ample evidence that allows us to affirm that both mortality and the risk of suffering from cardiovascular and other diseases (cancer, metabolic, etc.) are significantly lower in those who practice physical exercise regularly (Paffenbarger et al., 1993; Tsao et al., 2023).

However, a CA – whether it ends in SCD or not – can occur unexpectedly in an apparently healthy individual, and of any age, sex and race. When it occurs in an athlete, especially if he or she is young and has some fame, the wide coverage through the media makes the impact enormous both in the field of sport and in the general population, since it occurs in individuals who are part of those who are considered to have the best levels of health in our society. This impact can even be considered excessive, among other reasons, because it is usually not sufficiently clear that most cases of CA/SCD in sport occur in individuals who suffer from some heart disease, whether previously diagnosed or not.

Unit 3.1 Incidence

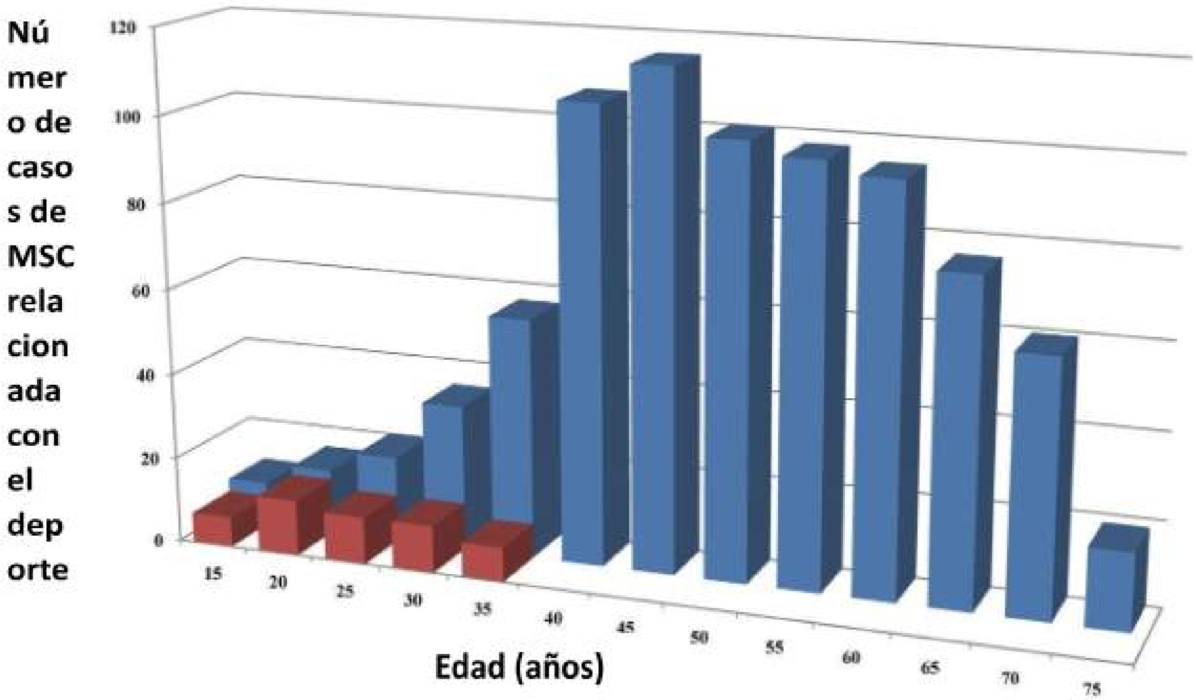
SCD is responsible for half of all deaths from cardiovascular causes, and in 50% of these cases, it appears as the first symptom. The annual incidence varies with age, from 1 in 100,000 in childhood, up to 50 out of 100,000 in adults in the 5th and 6th decades of life, and up to 200 out of 100,000 in the 8th decade. At any age, it is significantly more frequent in men, even after adjusting for risk factors for ischemic heart disease (IHD); ethnic and racial origin are also influences (Zeppenfeld et al., 2022). In Europe, emergency medical services attend about 300,000 cases of out-of-hospital CA per year (Empana et al., 2018).

While it is true that heart disease is the leading medical cause of sports-related sudden death (Harmon et al., 2015; Maron et al., 2009; Morentin et al., 2021), it is also true that only a small percentage of all CA/SCD cases are related to sports practice. That percentage, which according to most studies is 5 to 6 percent (Berdowski et al., 2013; Ha et al., 2021; Ha et al., 2023; Marijon et al., 2015; Risgaard et al., 2014), in some cases it represents 14 % of the total of those under 35 years of age, and up to 39 % in the group under 18 years of age (Jayaraman et al., 2018). These findings are, certainly, above all related to the fact that regular physical exercise reduces mortality from ischemic heart disease (IHD) (Paffenbarger et al., 1993; Tsao et al., 2023). Most cases occur in individuals who practice sports at an amateur or recreational level (Bohm et al., 2023; Marijon et al., 2011), mainly because the number of participants is much higher than that of competitive athletes.

There exists a great variability in the results of studies and registries on the incidence of CA/SCD during sports practice related to differing methodological aspects, such as the definition of “athlete” used, and whether or not it included cases of CA that did not result in SCD, as well as those that occurred in athletes during rest. Other variabilities are reflected in the source(s) of information used (news in the media; claims to insurance companies; records in groups of controlled athletes or autopsies; etc.), the characteristics of the population studied (age, sex, race), and the rigor and standardization of the study protocol in the autopsy records. A further determining aspect in the results is that which is related to the existence of public health measures, both in primary prevention (cardiological examinations prior to sports practice and education of the population on alarm symptoms), and secondary prevention (training in cardiopulmonary resuscitation and availability of public defibrillators to improve survival).

The annual incidence of CA/SCD in sport is clearly influenced by age and, according to the most reliable studies and records, varies from 0.3 to 2.3 per 100,000 in athletes under 35 years of age (Berdowski et al., 2013; Bohm et al., 2023; Corrado et al., 2003; Marijon et al., 2011; Peterson et al., 2021; Risgaard et al., 2014) and up to 2.2 to 6.6 per 100,000 in athletes over 35 years of age (Marijon et al., 2015; Risgaard et al., 2014). The highest annual incidence appears to be in the 5th and 6th decades of life: it can reach figures of up to 13 per 100,000 in runners aged 30 to 64 years (Thompson et al., 1982). From the 6th decade onwards, the annual incidence decreases, with values of 2.1 to 3.3 cases of CA per 100,000 in athletes over 65 years of age (Holmstrom et al., 2022). The influence of age is clearly related to the increase in the prevalence of IHD due to atherosclerotic coronary disease in aging populations (Figure 1).

Figure 1: Incidence of sudden death



Source: Marijon et al., 2011, p 2.

Figure 1. Incidence of sudden death. Incidence of sudden cardiac death related to sport in different age groups in young competitive athletes (in red) and general population (in blue) (Marijon et al., 2011).

Translation of Fig. 1:

Number of cases of SCD related to sport

Age (in years)

Although the number of women who practice sports has increased considerably in recent decades, the annual incidence of CA/SCD remains 5 to 30 times lower in women (Rajan et al., 2022), regardless of age, race and ethnicity. The reasons are not entirely clear, but they surely have to do with the lower prevalence of IHD in premenopausal women, probably derived from the lower risk of plaque rupture as a mechanism of acute coronary syndrome during exercise and the protective effect of estrogens. Also, it is thought that there may be an influence stemming from differences in cardiac adaptations to training and in the regulation of the autonomic nervous system; the lower prevalence of myocardial fibrosis and susceptibility to arrhythmogenic substrates; and, possibly, also from psychological factors related to the greater tendency of men to practice high-intensity physical exercise, and in an addictive form (Bohm et al., 2023; Han et al., 2023; Marijon et al., 2015).

The influence of race on incidence is clearly demonstrated by the record of CA/SCD cases in school and college athletes in the US. US aged 11 to 29 years (Peterson et al., 2021), where the risk of CA/SCD in male college athletes was 2 times higher in African American athletes (5.4 per 100 000 and year) than in Caucasians. In this same study, the annual incidence rate was almost 50 per 100,000 in African-American male college basketball players at the highest level. In the study of adolescent soccer players in the United Kingdom, the incidence of CA/SCD was also 7 times higher in black players (Malhotra et al., 2018). The reasons are unclear, but are probably related to the different prevalence of some of the heart diseases with a higher risk of CA/SCD and of the classic cardiovascular risk factors in certain races and ethnicities.

Most cases of CA/SCD occur during exercise and, more frequently, in certain sports in which repeated high-intensity efforts are performed, such as soccer, basketball and American football (Malhotra et al., 2018; Maron et al., 2007; Peterson et al., 2021). While it is true that this data may be partly owing to the fact that these are more popular sports specialties and, therefore, have a greater number of practitioners, it is also true that intense physical exercise increases the risk of CA/SCD in individuals with underlying electrical or structural heart disease, and favors conditions (dehydration, greater adrenergic stimulation, electrolyte and acid-base imbalance) in which the probability of generating potentially malignant arrhythmias is increased (Albert et al., 2000; Corrado et al., 2003).

These mechanisms are surely those that are causing many of the cases of CA/SCD that also occur more frequently in the final part of popular races, in which many of the runners from that—increasingly—large group of middle-aged amateurs tend to make an additional extra effort in order to improve their personal best results (Bohm et al., 2021).

Beyond the already classic debate on the need and type of screening protocols in athletes, the higher incidence of sports-related CA/SCD in certain population groups (older age, men, black race, higher level athletes and specialties that involve repeated efforts of greater intensity) would open an even more complex debate on the need to carry out a more exhaustive assessment in these higher risk groups.

CONTINUE

Unit 3.2 Etiology

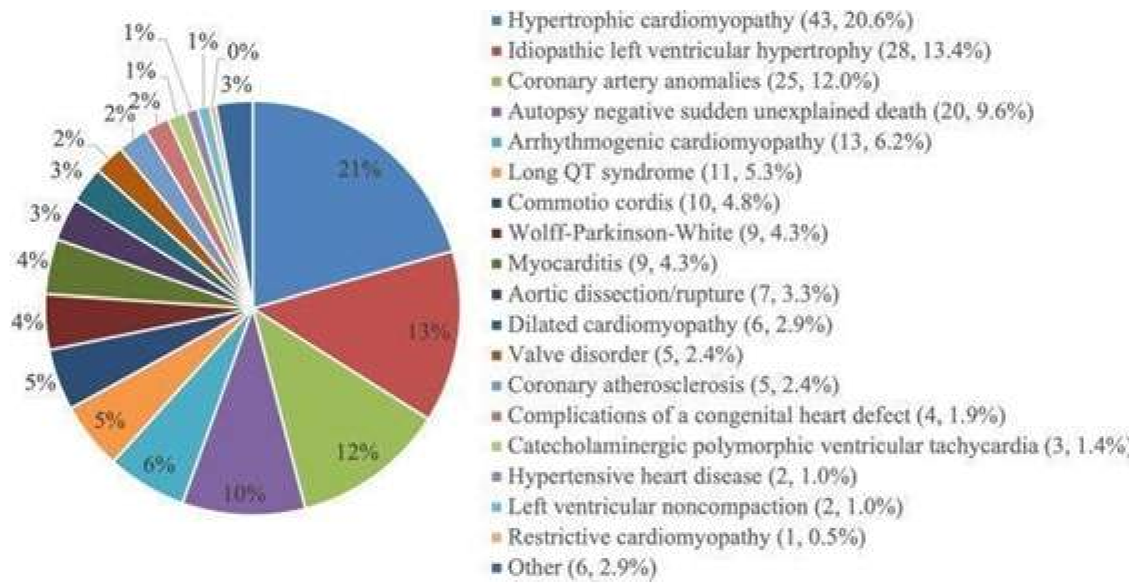
3.2.1 Most common causes of CA/SCD

As mentioned above, age has a clear influence on the etiology and, according to most studies and registries of exercise-related CA/SCD, we know that, while IHD due to atherosclerotic disease causes the majority of cases in people over 35 years of age (Bohm et al., 2021; Eckart et al., 2011; Marijon et al., 2011; Marijon et al., 2015), in the group of athletes under 35 years of age, the causes are more diverse and mostly of hereditary and/or congenital origin (cardiomyopathies, channelopathies, Wolff-Parkinson-White syndrome, congenital coronary artery anomalies [CCAA]). This variability is crucial in the design of prevention strategies, especially with regard to the selection of the most effective tests and their assessment criteria in the cardiological examination of athletes of different age groups.

Cardiomyopathies have always occupied a preferential place in most studies of CA/SCD in athletes under 35 years of age, but, while in some studies—especially those carried out in the USA—hypertrophic cardiomyopathy (HCM) is clearly the most frequent (Maron et al., 2009; Maron et al., 2007; Peterson et al., 2021), in European studies, this place is occupied by arrhythmogenic cardiomyopathy (AM) (Corrado et al., 2003; Finocchiaro et al., 2016; Morentin et al., 2021). Among the reasons possibly justifying these differences is surely the mandatory cardiological assessment in the Italian study (Corrado et al., 2003), which would have made it possible to detect and prevent a serious cardiac event in some of those affected by HCM, by not granting them permission to continue practicing competitive sport; also, the greater rigor of the HCM assessment and diagnosis protocols used in autopsy records (Finocchiaro et al., 2016; Morentin et al., 2021).

Among cardiomyopathies of hereditary origin, special caution will be required with AM, since, even without phenotypic expression, it is clearly demonstrated that intense physical exercise implies a more accelerated progression of the disease and a risk of CA/SCD up to 6 times higher than in other heart diseases (Finocchiaro et al., 2016) (Figures 2 and 3).

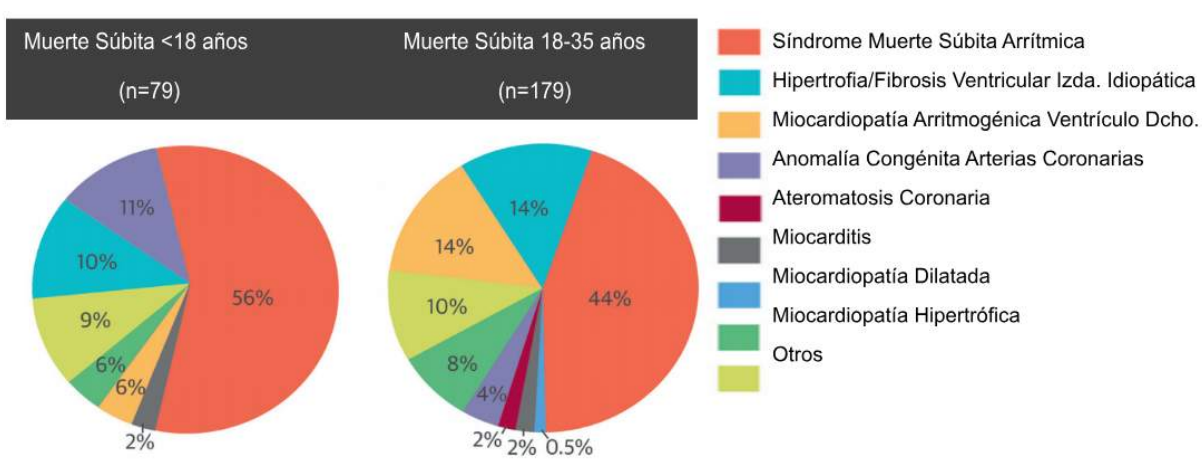
Figure 2: Causes of sudden death



Source: Peterson et al., 2021, p. 4.

Figure 2. Causes of sudden death. Causes of cardiac arrest and sudden cardiac death in 209 cases of cardiac arrest (n=68) and sudden cardiac death (n=141) in athletes aged 11 to 29 years, with a diagnosis attributed by different means (Peterson et al., 2021).

Figure 3: Causes of sudden death in athletes under 35 years of age



Source: Finocchiaro et al., 2016, p. 2111.

Figure 3. Causes of sudden death in athletes under 35 years of age. Causes of sudden cardiac death in young athletes under 35 years of age having undergone detailed autopsy and assessment by a pathologist with expertise in heart disease (Finocchiaro et al., 2016).

Translation of Fig. 3:

Sudden death <18 years of age (n=79)

Sudden death 18-35 years of age (n=179)

Sudden arrhythmic death syndrome

Idiopathic left ventricular hypertrophy

Arrhythmogenic right ventricular cardiomyopathy

Congenital coronary anomalous artery

Coronary atheromatosis

Myocarditis

Dilated cardiomyopathy

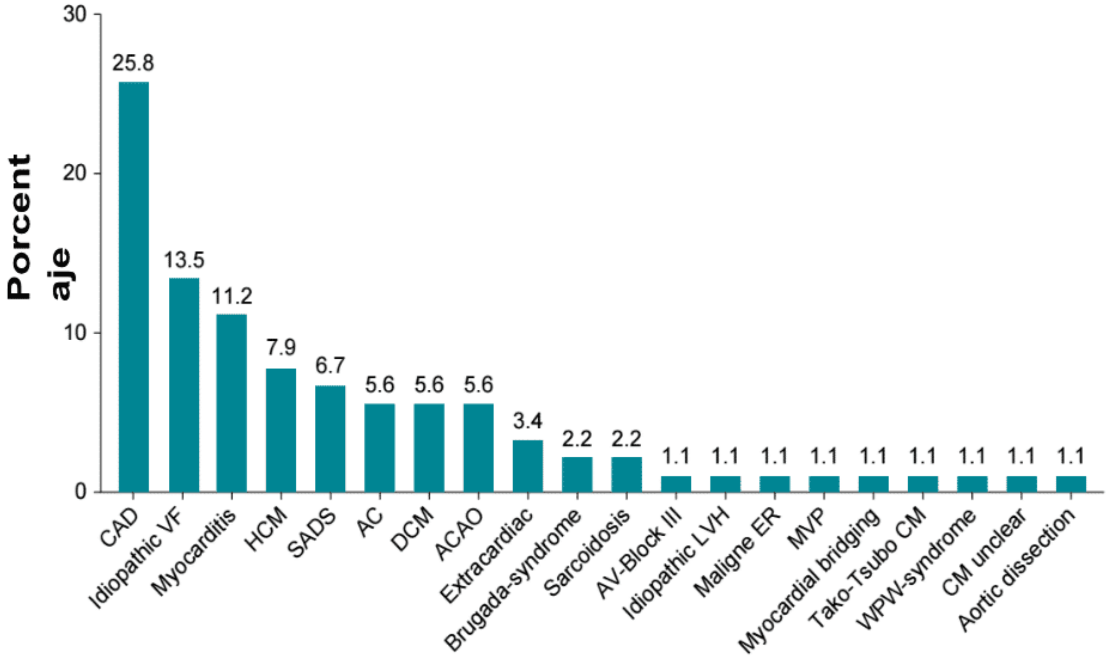
Hypertrophic cardiomyopathy

Others

Among cardiomyopathies, it is also necessary to mention the prominent role of those which are secondary to infectious processes in some CA/SCD studies (Bohm et al., 2023; Bohm et al., 2021; Eckart et al., 2004; Winkel et al., 2014) and which can often lead to doubts in the differential diagnosis with some of those of hereditary origin, especially AM and dilated cardiomyopathy (DCM) .

The high incidence of Covid-19 in athletes described in some of the first published studies created great alarm in the first months of the pandemic (Rajpal et al., 2021). However, the most recent records indicate that cases of Covid-19-associated myocarditis in athletes are rare (Moulson et al., 2021). In any case, these results lead us to strongly recommend that we remember the risk of exercising during an infectious process, especially in the presence of general symptoms; and/or returning to training/competing too soon during the recovery phase (Figure 4).

Figure 4: Causes of cardiac arrest related to sports practice



Source: Bohm et al., 2023.

Translation of Fig. 4:

Percentage

Figure 4. Causes of sports-related cardiac arrest. Causes of sports-related cardiac arrest in 89 cases with a definitive diagnosis of individuals aged 18 to 35 years. AC: arrhythmogenic cardiomyopathy; ACAO/CCAA: congenital coronary artery anomaly; CAD: ischemic heart disease due to coronary atherosclerosis; CM: cardiomyopathy; DCM:

dilated cardiomyopathy; ER: early repolarization; HCM: hypertrophic cardiomyopathy; LVH: left ventricular hypertrophy; MVP: mitral valve prolapse; SADS: sudden arrhythmic death syndrome; VF: ventricular fibrillation; WPW: Wolff-Parkinson-White (Bohm et al., 2023).

In some of the most recent studies and registries of sport-related SCD, **sudden arrhythmic death syndrome (SADS)** appears as one of the most frequent causes, especially in the group under 35 years of age (Eckart et al., 2011; Egger et al., 2022; Finocchiaro et al., 2016; Finocchiaro et al., 2023; Ha et al., 2021; Harmon et al., 2015). SADS is defined as SCD in which the autopsy result is a structurally normal heart and a normal toxicological examination. It is generally due to a cardiopathy of an arrhythmic nature, with long QT syndrome, Brugada syndrome and catecholaminergic polymorphic ventricular tachycardia (CPVT) being the most frequent (Figure 3).

The hereditary nature of most cases of CA/SCD in people under 35 years of age should lead us to consider the need to resort to genetic study (molecular autopsy in the case of SCD) of the victim in the event that there is no clear diagnosis; and also, to study first-degree relatives (Solberg et al., 2016). Recent studies show that up to 50% of families of SCD victims are affected by some type of hereditary heart disease—the most common being channelopathies, but also cardiomyopathies—which may be related to SCD (Behr et al., 2008; Lahrouchi et al., 2017). Unfortunately, there are still few reliable autopsy records of sport-related SCD, mainly because those performed with the intervention of expert cardiac pathologists are very few (Finocchiaro et al., 2016; Finocchiaro et al., 2023; Morentin et al., 2021; Solberg et al., 2016) (Figure 3).

We cannot fail to mention that, in some recent studies, **ischemic cardiomyopathy** also appears among the most frequent causes of CA/SCD related to physical exercise **in those under 35 years of age** (Bohm et al., 2023; Eckart et al., 2011; Ha et al., 2021; Meyer et al., 2012) (Figure 3). These results are probably related to some of the classic cardiovascular risk factors, such as smoking and obesity, as well as to the consumption of some substances used socially/recreationally and in sports, such as cannabis and stimulants. Therefore, there seems to be some evidence that would justify that, in the assessment of athletes, cardiomyopathy is also taken into account as a diagnostic possibility from the age of 25 and, above all, when other possible causes of a hereditary and/or congenital nature have been ruled out. Furthermore, since a significant proportion of exercise-related CA/SCD cases demonstrate the presence of one or more classic cardiovascular risk factors, previous warning symptoms (chest pain, palpitations and dizziness/syncope associated with exercise), and/or a significant family history of heart disease and sudden death in first-degree relatives, it seems logical that public health strategies should contemplate measures aimed at improving the education of the general population about these warning signs and symptoms (Finocchiaro et al., 2016; Jayaraman et al., 2018; Marijon et al., 2015).

CCAAs (Congenital Coronary Artery Anomalies) appear as one of the most frequent causes of SCD/CP, especially in the group of younger athletes under 18 years of age (Corrado et al., 2003; Finocchiaro et al., 2016; Finocchiaro et al., 2023; Maron et al., 2009; Maron et al., 2007; Peterson et al., 2021) (Figures 2 and 3). In this age group, we must be especially alert to symptoms such as chest pain and/or syncope during exercise and, in general, these can usually be easily visualized in echocardiography. Those that imply a higher risk of CA/SCD during exercise are those of anomalous origin of the left coronary artery from the right sinus of Valsalva with an interarterial course (Finocchiaro et al., 2019).

Idiopathic **left ventricular hypertrophy (LVH)** is another diagnosis worth mentioning. Since no diagnostic criteria for HCM were found in the first-degree relatives of 46 cases of SCD with idiopathic LVH, Finocchiaro et al. (2020) concluded that these are 2 distinct entities. However, given the notable prevalence in some of the studies of SCD in athletes (Finocchiaro et al., 2016; Peterson et al., 2021), it is advisable to carry out a closer follow-up in those athletes with LVH that have no other diagnostic criteria for HCM (Figures 2 and 3).

Finally, and also in relation to the significant prevalence in young athletes and the possibility of improving prevention strategies, we cannot fail to mention those cases of CA/SCD triggered by a blow or impact of an object or another athlete in the left anterior precordial region during the vulnerable phase of the cardiac cycle. This mechanism, which we call ***commotio cordis***, acts by triggering ventricular fibrillation (VF) and the consequent CP (Maron et al., 2009; Peterson et al., 2021) (Figure 2).

The risk is higher, especially in younger athletes and in those specialties with a higher probability of suffering this type of impact. Strategies to prevent these cases should be aimed at using adequate protection for this part of the thorax in those athletes with a higher risk, especially the youngest and most exposed (goalkeepers in football or hockey; catchers in baseball; etc.). Also, rules should be established that penalize more severely the impacts in this area of the body in specialties with a higher risk (rugby, American football, Australian football, etc.) and to encourage a greater number of people trained in cardiopulmonary resuscitation (CPR) and the availability of automatic external defibrillators (AED) (Maron and Estes, 2010).

In the sports context, a faster response—deriving from a higher level of alertness and availability of AEDs—has made it such that, in recent years, survival rates of up to 58% have been registered in CA cases secondary to commotio cordis (Maron et al., 2013) .

3.2.2 Prevalence of high-risk heart diseases

Beyond the incidence data of CA/SCD in sport, the data that can surely be of greatest help to us in better understanding the importance of developing primary and secondary prevention strategies is related to the prevalence of diseases with a higher risk of CA/SCD during sports practice.

In young people, several studies agree that 1 in every 250 to 300 athletes who undergo a cardiovascular screening have one of the heart diseases associated with a higher risk of CA/SCD in athletes (cardiomyopathies, channelopathies, Wolff-Parkinson-White syndrome, ACAC, etc.) (Corrado et al., 2006; Fuller et al., 1997; Malhotra et al., 2018; Sarto et al., 2023).

Furthermore, Malhotra et al. (2018) found that another 2%, of the just over 11,000 15 to 17 year old soccer players assessed in their study had some type of valvular heart disease (bicuspid aortic valve, mitral valve prolapse, etc.) or congenital (septal) disease that, although not related to a higher risk of imminent CA/SCD, will require more continuous cardiological monitoring and a prescription of physical exercise appropriate to each heart disease.

To this number of young athletes at higher risk, we must add the even larger group of those who, from the 3rd decade of life, will be affected by the progressive increase in prevalence of IHD due to atherosclerotic disease and who, fortunately, are increasingly taking up physical exercise on a regular basis. Currently, IHD continues to lead the world rankings in terms of both prevalence and number of years lost due to illness, disability or premature death (disability-adjusted life years (DALY)) (Lindstrom et al., 2022).

These data, related to the not inconsiderable prevalence of heart diseases with a higher risk associated with the practice of high-intensity physical/sports activity, will allow us to estimate the huge number of athletes of all ages and around the world who could benefit from the implementation of the most appropriate primary and secondary prevention strategies. These strategies would allow not only to avoid serious cardiac events, but also to accelerate the progressive deterioration of those heart diseases with or without risk of CA/SCD. Physical exercise in the dose (intensity, duration, frequency) and type most appropriate for each patient/athlete should be an essential part of these strategies, especially effective for the prevention of IHD due to atherosclerotic coronary disease (Pelliccia et al., 2021).

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Unit 3.3 Secondary prevention

The tragic and unexpected sudden death of the footballer Marc Vivien Foe, at the Confederations Cup organized by the Fédération Internationale de Football Association (FIFA) in France in 2003, was a turning point for FIFA and other sports organizations to improve their strategies to reduce cases of CA/SCD in football and other sports. On the one hand, the implementation of regulations requiring a pre-competition medical assessment for all participants in competitions regulated by these organizations began to become widespread. This pre-competition assessment was mandatory for the first time at the 2006 World Cup in Germany (Dvorak et al., 2013), and in Italy, it had already been mandatory by state law since 1971 (Pelliccia and Maron, 1995).

Although all aspects related to primary prevention will be discussed in detail in Chapter 1.4 (indicate which chapter you refer to), we must assume that not even the most exhaustive medical assessment protocols carried out by the best and most experienced specialists will be able to detect all those at greatest risk of suffering from a sports-related CA. Therefore, we must try to ensure that, both in training and in competitions—and regardless of whether the victim is an athlete, a spectator or any other person present at the activity—there are the necessary means to recognize the seriousness of the event and act immediately, starting CPR maneuvers, using an AED as soon as possible, and transporting the victim in appropriate conditions to the nearest hospital or medical center for definitive treatment.

3.3.1 SCD in the athlete

Over the past two decades, FIFA, the Union of European Football Associations (UEFA), and most of the organizations and associations that organize sports competitions of different specialities at national and international levels have developed protocols and guides for minimum medical requirements for official competitions and training (Dvorak et al., 2013; UEFA, 2022). These guides, which include protocols for action in medical emergencies such as a CA or head injury, detail the minimum human and material resources required, and in some cases even the contents of the medical emergency kit or backpack (Figure 5).

Figure 5: Minimum and necessary materials

Source: Dvorak et al., 2013, p. 4.

Figure 5. Minimum and necessary materials. The contents of the FIFA medical emergency backpack are shown (Dvorak et al., 2013).

Despite the considerable improvement regarding field-side emergency medical services (EMS) in stadiums, pavilions and sports facilities in general, in the training not only of doctors for the clubs and federations, but also of players, coaches, referees and the general population, along with greater availability of AEDs in competitions and training, recent studies show that there is still great variability in survival rates between different countries and that, in less developed ones, the margin for improvement is still considerable.

In the CA/SCD registry carried out worldwide by FIFA over 4 years, survival in the more than 600 cases recorded in football players was around 50% in Australia and North America, and only 3-4 % in countries in Africa and South America (Egger et al., 2022). In the CA registry conducted in 2,149 secondary/high schools in the USA, along with a medical emergency program that included the use of an AED, 42 (71%) out of a total of 59 cases of CA occurring in students and adults, survived. In 92% of these cases, CPR maneuvers were performed, and in 85% an AED was used. The fact that survival was up to 89% in athletes and adults who suffered the CA during physical activity should serve as a strong argument to convince us of the need to improve the availability of AEDs and train as many people as possible in CPR among those who are most frequently present at training and competitions (Drezner et al., 2013).

Today, we have numerous similar studies showing that survival is higher in cases of CA that is exercise-related (Berdowski et al., 2013; Bohm et al., 2023; Landry et al., 2017; Marijon et al., 2011; Marijon et al., 2015). This is probably, in part, due to the fact that these are more frequently witnessed events in which a rapid and effective response with CPR and AED use is more likely to occur. And, probably, these are also more active individuals and, therefore, have better cardiovascular health.

In recent years, the media has increasingly reported cases in which teammates or coaches of athletes, often school-aged, have been able to revive and save the life of a victim of a CA. We have even witnessed live on television some cases in which the rapid intervention of EMS, team doctors, referees or even the athletes themselves has managed to keep the victim alive (Christian Eriksen, Damar Hamlin, Fabrice Muamba, Miguel García, etc.). Unfortunately, cases have continued to occur, even in the most developed countries, in which the athlete ended up dying due to a late and inadequate response (Zeke Upshaw, Patrick Eckeng, etc.).

The special circumstances section of the guidelines published by the European Resuscitation Council (ERC) in 2015 included, for the first time, a section specifically dedicated to CA during sports activity (Truhlář et al., 2015). This section, which has been maintained in subsequent updates (Lott et al., 2021), was discussed in an article subsequently published for practical purposes in the field of sports medicine, highlighting some of the differential characteristics of CA during sports practice and the essential aspects for its management, related to a plan that includes the recognition of CA, immediate response, resuscitation maneuvers, and transport to a definitive treatment center (Kramer et al., 2016).

3.3.1.1 Recognition

Anyone who witnesses an athlete suddenly and unexpectedly collapse, without contact or previous trauma, should consider a CA as the most likely cause and approach as quickly as possible to assess their condition. Depending on whether it occurs in a competition or in training, the referee, judge, coach or teammates themselves must be alert to interrupt the activity and facilitate immediate access to team doctors and/or EMS. In any case, in recent years, rules have been established in the different sports specialties that allow the entry of medical officers into the competition area without authorization from the referee, whenever an athlete faints without contact. If, upon reaching the athlete's side, it is found that they are not responding, have an abnormal breathing pattern and/or limb movements similar to convulsions, it can be confirmed that it is a CA. Starting resuscitation maneuvers when the victim still presents an agonal breathing pattern, evident in the first moments in up to 40% of cases, appears to improve survival rates (Bobrow et al., 2008). In any case, it should be made clear that neither pseudo-convulsive movements of the secondary limbs nor decreased cerebral blood flow nor an abnormal respiratory pattern should delay the immediate initiation of resuscitation maneuvers.

3.3.1.2 Response

Once the cardiac arrest has been identified, help should be immediately requested by telephone from the local EMS (112, 911), informing them of the severity of the situation and the precise location of the event, to facilitate access to the nearest ambulance. In addition, there are currently free-to-download applications for mobile phones that allow the location of the AEDs and volunteers trained in CPR closest to the site of the cardiac event (Ariadna, PulsePoint, etc.). Some of these applications are also connected to local EMS. We already have evidence showing that this type of strategy reduces the time elapsed from the start of the CA to the first defibrillation (Semeraro et al., 2021). In any case, we must try to ensure that as many as possible of those present at training and competitions receive ongoing training in CPR and AED use, since it has been amply demonstrated that an early and adequate response improves survival.

Through decades of experience in some northern European countries, we know that the best long-term strategy to reach the entire population is achieved through state laws that incorporate CPR training programs in schools. Along these lines, the ERC recommends 2-hour courses from the age of 12 onward, and on an annual basis (Semeraro et al., 2021).

In addition to the essential classroom training programs, numerous mobile phone applications have also been developed in recent years to improve CPR and AED training for the general population. The videos and texts in some of these applications include specific aspects of CA management in sport, especially in important cases, such as contact sports. These aspects may include: taking the necessary precautions in handling the spine when moving the victim, immobilization and transport techniques using a spinal board, and minimizing interruptions in the administration of compressions and ventilations (Kramer et al., 2016; Serratosa et al., 2016).

The ERC guidelines place special emphasis on highlighting that the survival rate can reach values of up to 50 to 70 % if the defibrillator is used in the first 3 to 5 minutes after the CA and that, for every minute that defibrillation is delayed, survival decreases by 10-12 % (Semeraro et al., 2021). These data support strategies such as those promoted by some protocols, such as FIFA's protocol for an AED to be on the field of play in all matches and training sessions, and for it to be used by the EMS within the first 2 minutes from the start of the CA (Dvorak et al., 2013; Kramer et al., 2016).

However, initiating CPR within the first minute and defibrillating within the first 3 to 5 minutes is a real challenge in some of the sports events held outside enclosed venues (mountain or desert races; open water swimming events; etc.). Some long-distance races (10-42 km), which have mobile EMS teams made up of emergency technicians equipped with AEDs who ride bicycles along the race course, have achieved average response times of the first defibrillation within just over 2 minutes, and return of spontaneous circulation in situ in 100% of cases of CA witnessed (Kinoshi et al., 2018) (Figure 6).

Figure 6: Mobile emergency teams

Source: [Untitled image about cyclists]. (sf). https://bit.ly/3nZLqhf

Figure 6. Mobile emergency teams. These are mobile teams, made up of emergency technicians equipped with AEDs, who travel by bicycle along the race route.

3.3.1.3 Resuscitation

Providing quality chest compressions (5-6 cm, 100-120/min, allowing the chest to recover after each compression) remains the initial method of CPR and one of the determining factors for the success of resuscitation maneuvers. Chest compressions may be sufficient for the first few minutes, since the blood in the lungs and arterial system still retains a certain degree of oxygenation. However, once an adequate airway and device (face mask or laryngeal mask) are available, ventilations can be started (inflating for 1 s and at a rate of 2 for every 30 compressions). Compressions should not be stopped: if it is necessary in order to perform ventilations, use the AED, or transfer the victim, interruptions should be for less than 10 seconds.

Once we have the AED, we should continue to administer compressions until the pads are placed on the chest, connected to the AED, and the message, "Analyzing heart rhythm, do not touch the patient," is heard. From that point, the AED instructions should be followed and, if it is a CA, the rhythm is most likely to be VF, and will respond to defibrillation. Although in the sports setting it is more likely that compressions will be administered while the AED arrives and is being prepared, since it will often be a witnessed CA and the priority is to defibrillate as soon as possible, if there is an organized medical team of professionals with experience in advanced life support (ALS), the administration of 3 shocks in a row may be considered before starting CPR maneuvers.

It is also worth bearing in mind that these events usually take place in public places, sometimes in stadiums or arenas with thousands of spectators and a television audience, so all possible means must be taken to ensure that the entire intervention is carried out with as much privacy as possible. The recent case of Christian Eriksen at Euro 2020 can serve as a model for intervention in the case of CA in a public place. As for medication, in principle it is not recommended to administer any unless prescribed by a physician with experience in ALS (Kramer et al., 2016; Truhlář et al., 2015).

3.3.1.4 Transport

Resuscitation maneuvers should be performed in situ, and moving the victim should only be considered, in ideal conditions, once the pulse has recovered; however, even if this is not the case, it will still be considered essential to continue with the maneuvers in a more sheltered and suitable place. In any case, transport should never be carried out at the expense of performing early defibrillation, when this is possible. If and when it is carried out, transport should be paused as many times as necessary so as to refrain from interrupting the administration of compressions, ventilations, and use of the AED for periods of more than 10 seconds. When there is no medical team or AED immediately available, CPR maneuvers should be continued until ALS medical assistance arrives. If the victim regains a pulse, the victim can be transferred to the nearest medical center for assessment and definitive treatment. Transport should be carried out with the necessary equipment and under the supervision of healthcare professionals with experience in ALS, capable of continuing with resuscitation and defibrillation maneuvers in case the rhythm reverts back to VF (Kramer et al., 2016; Lott et al., 2021; Truhlář et al., 2015) (Figure 7).

Figure 7: Transport

Source: [Untitled image about football match]. (sf). https://bit.ly/42FLp0J

Figure 7. Transport. The transport of an athlete who suffered a cardiac arrest during a competition is shown, after he has regained his pulse, been adequately stabilized and monitored, all the while trying to safeguard his privacy.

3.3.2 Medical care at mass sporting events

So far, we have discussed serious cardiac events that occur in athletes, but we must not forget that in sports competitions we must also be prepared to provide medical care of any kind to the rest of the attendees. In this section, we will discuss the organization of EMS intended to care for at least 1,000 people (spectators, participants and organization staff) gathered in a specific place and for a specific period of time on the occasion of a sporting event.

Within this definition of medical care at mass events (De Lorenzo, 1997), the organization of EMS in the context of sport will have to adapt to the different challenges posed by a single match held in a stadium or pavilion, to competitions held simultaneously in several facilities, sometimes in different geographical locations, to different climates, and to those held over several days or weeks (Olympic Games, World Football Championships, World Athletics Championships, etc.), without forgetting those that take place over several kilometers of streets and roads, in mountains, deserts or over open water. In addition, some competitions—such as those in adapted sports—will present specific needs related to the medical care of each category, and even of each individual athlete.

EMS at any mass sporting event must be prepared to deal with any type of emergency, but their main challenges will always include responding to a CA promptly and appropriately, at any point during the event. EMS managers at the event must also take into account the potential impact on local hospitals and outpatient EMS centers.

The incidence of acute coronary syndrome among spectators is lower than in athletes, and varies from 0.17 (Borjesson et al., 2010) to 0.38 per 1,000,000 (Leusveld et al., 2008; Luiz et al., 2014). At the FC Barcelona stadium, a total of 7 cases of acute coronary syndrome were recorded among spectators during the 2000-2001 season (Serra Grima et al., 2005). IHD is undoubtedly the most frequent cause of these events and, although it is not clear, emotional stress could act as a trigger (Barone-Adesi et al., 2010; Kloner et al., 2009; Niederseer et al., 2013; Wilbert-Lampen et al., 2008).

In the study carried out in the 2005-2006 season in the first and second division leagues of several European countries, it was observed that 28% of stadiums did not have an AED and just over a third did not have a medical action plan (MAP) with a CPR training programme for staff (Borjesson et al., 2010). In light of these results, and following the 2011 publication by the Sports Cardiology group of the European Society of Cardiology of a consensus document on cardiac safety in stadiums and sports halls, the situation has improved significantly (Borjesson et al., 2011). Some competitions, such as the German Football League, have had well-organized EMS facilities in their stadiums for years, as demonstrated by the 96% survival rate in the 52 cases of CA recorded in spectators during the 2008-2009 and 2009-2010 seasons (Luiz et al., 2014). In a recent study conducted in the top 4 divisions of the English Football League, all 79 professional teams that responded to the survey had an AED in the stadium during matches and training, and 83% had a medical action plan (MAP) in place, for use in the event of medical emergencies (Malhotra et al., 2019).

3.3.2.1 Medical action plan

EMS organizations require an action plan tailored to the specific characteristics of each event so that they can respond to a CA victim at any location, starting CPR within the first minute, and being able to defibrillate within 3 to 5 minutes of the start of the CA. As most CPR victims will usually be witnessed at mass events, the response will be activated sooner, and it will be more likely to start CPR and use the AED within the first 3-5 minutes. The plan must be in writing and include a description of all necessary medical resources and instructions for their correct operation. The EMS organization's top managers must review and update the MAP at least once annually.

The PAM must consider each and every one of the following aspects:

- Responsibilities and contact information for the event medical director
- Duties and responsibilities of all healthcare personnel
- Medical equipment, including AEDs
- ALS and basic life support (BLS) medical care centers
- ALS and BLS means of transport
- Communication system
- Patient information recording system
- Training programs and periodic activities aimed at improving the quality of care (meetings and drills)
- Coordination with local hospitals and out-of-hospital EMS

As a guide for EMS personnel during the event and for pre- and post-event meetings, it will be helpful to include in the MAP a map showing the location of all clinics or fixed medical care stations and ambulances, both ALS and BLS, as well as mobile medical equipment, defibrillators, and emergency exits and evacuation routes (Figure 8).

Figure 8: Plan of a football stadium

Source: Adapted from Serratosa et al., 2020.

Translation of Fig. 8

Emergency Medical Services

Figure 8. Plan of a football stadium. Image of a plan of a football stadium with a capacity of 80 000 viewers, detailing the location of all medical assistance resources. This includes the advanced life support unit (ALS) and the basic life support unit (BLS).

All EMS members, service centers and mobile units must be ready well in advance of the start of the event and remain available until the last spectator and athlete has left the venue.

Periodically, drills should be organized to ensure that EMS can respond in a timely and appropriate manner to any cardiac emergency that may occur, even at the most difficult-to-access points of the event. Similarly, members of mobile emergency teams (EMS) should practice transporting a stretcher or spinal board with a patient in cardiac arrest up stairs, ramps, elevators, etc.

3.3.2.2 Human resources

The EMS medical director should preferably be a physician with experience in out-of-hospital emergency medicine and, if possible, be familiar with local health services. As the person ultimately responsible for the proper functioning of EMS, he or she should always be available and reachable by some communication device during the event. Other responsibilities include:

- Design, update and implementation of MAP
- Selection of healthcare personnel and supervision of their adequate training
- Organization of drills and training activities
- Coordination of periodic meetings before and after sports events, and after cardiac events
- Communication with local hospital physicians to follow up on patients transported to the hospital
- Act as an interlocutor for the media if necessary

Early and appropriate care for a case of CA at any point during a sporting event will depend on having sufficient EMS personnel with training and experience in out-of-hospital emergencies. The number, level of training and experience of EMS personnel must be adapted to the specific characteristics of the venue or environment in which the event is taking place:

- Stadium or arena capacity; expected attendance of spectators; length of race route; etc.
- Existence of architectural barriers or complicated topography
- Degree of risk of the sport (intensity, contact, etc.) and event (fan rivalry, familiarity with the venue, etc.)
- Weather forecast
- Distance to the nearest hospital

All of these factors will be decisive when estimating the personnel needed to adequately attend to a cardiac emergency in a timely manner at any point during the event. Taking into account the existing recommendations, we can start from a minimum of 1-2 doctors for every 50,000 spectators and 1 nurse for every 10,000 spectators, in both cases certified in ALS, and separate from those of the teams; and 2 emergency technicians (EM) for every 10,000 spectators, certified at least in BLS (Borjesson et al., 2011).

Typically, the initial response to a CA at a mass sporting event will be provided by one of the EMS—composed of 2-4 personnel, some with BLS-trained personnel—strategically positioned in different areas of the event. Depending on the nature of the event, some of these EMS may use bicycles, motorcycles, or emergency-adapted golf carts capable of carrying a stretcher or spine board. Event planning and security personnel should also be knowledgeable and able to activate an immediate EMS response; and, if possible, trained in BLS.

3.3.2.3 Material and other resources

The EMS must have an adequate number of first aid stations or centers and, depending on the size and characteristics of the event, at least one ALS station or clinic. All must be strategically located, with easy access also for disabled people. In the case of the ALS clinic, it must be located on the playing field, the changing room area and the VIP area in stadiums; at the finish line in races; and in any type of event on the rapid evacuation routes by means of an ALS ambulance.

ALS clinics should be staffed by a physician, nurse, and at least one EMT, and primary care centers should be staffed by a nurse and at least one EMT. Both medical care centers and EMS should have all necessary equipment, including defibrillators (manual in ALS), to treat a CA. In stadiums and sports halls, AEDs should also be strategically located, in visible places, checked periodically, and in sufficient numbers to be able to administer a shock within the first 3-5 minutes of the start of a CA at any point during the event (Motyka et al., 2005). ALS centers and EMS should have all necessary materials and medication to treat a CA.

There must be sufficient signage throughout the venue to facilitate the quick location of medical care centers/clinics and AEDs. All venue and/or event maps—both those used for EMS personnel (Figure 8) and those appearing in the event program or website—must include the location of medical care centers, ambulances, EMS, and AEDs for the information of the opposing team, referees, or spectators.

The number of ALS and BLS ambulances, as well as golf carts adapted for emergencies with the capacity to carry a stretcher, must be calculated according to the characteristics of the event (location, architectural barriers, size/extension, etc.). The permanent presence of a minimum of one ALS ambulance, equipped with one doctor, one nurse and at least one EMT is recommended if at least 10,000 spectators are expected to attend (Borjesson et al., 2011).

An internal communication system (portable radio transmitter/receiver, mobile and landline telephones, etc.) must be in place to allow all EMS members and other event personnel involved in the response and management of any medical emergency to contact and communicate with each other. The system must allow for constant communication with the event operations center to facilitate the quickest possible location and evacuation if necessary. The operation of the communication system must be sufficiently tested prior to the event, and the main telephone numbers and other relevant details must be listed on the MAP.

Any medical assistance, especially if it is a cardiac emergency, must be documented and recorded on some form of medical incident record. In the event of evacuation to hospital, the patient must always be accompanied by a complete written report that includes all the data related to the incident and its management (location and time of the event; patient's condition; tests performed; treatment; and means of transport and problems that occurred during it). References

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