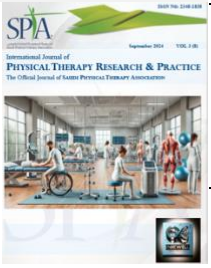

INTERNATIONAL JOURNAL OF
PHYSICAL THERAPY RESEARCH & PRACTICE

AN OFFICIAL JOURNAL OF SAUDI PHYSICAL THERAPY ASSOCIATION

Review Article

Sports-Related Sudden Cardiac Death (SSCD): Insights into Epidemiology, Risk Factors, and Preventive Strategies

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Article info

Received : Aug 22, 2024
Accepted : Sep 11, 2024
Published : Sep 30, 2024

To Cite: AlRayes, M. M., & Husain, M. A. Sports-Related Sudden Cardiac Death (SSCD): Insights into Epidemiology, Risk Factors, and Preventive Strategies. International Journal of Physical Therapy Research &Amp; Practice, 3(8), 340–352. https://doi.org/10.62464/ijoprp.v3i8.45

Abstract

Sports-Related Sudden cardiac death (SSCD) is a tragic and emotionally impacting event generating considerable attention in the community and media. It is a leading cause of mortality in the athletic population. Although rare, it causes a shock as those athletes are health models for the sports spectators. The current focused review aims to highlight the latest evidence regarding this important topic and provide a baseline introduction to future related research. The literature review was done through scientific search engines (Scopus, google scholar, Science Direct, Research gate, and PubMed). The inclusion criteria covered the full access English language Sources published between 2002 till 2022. The current review describes the main issues related to the SSCD such as the definition, epidemiology, etiology, risk factors, warning signs and symptoms, role of screening, prevention and management, COVID-19 and SSCD, and future directions. This review highlights key insights into Sports-Related Sudden Cardiac Death (SSCD) and provides a foundation for future research to improve understanding and prevention.

Keywords: Sports-Related Sudden cardiac death (SSCD), exercise, screening, risk factor, prevention.

Introduction

Recent studies defined physical exercise and sports-related sudden death as "An unexpected death occurring during or immediately after physical exercise (1–3 h) due to any cause, excluding violence, and may be of cardiac etiology (i.e., hypertrophic cardiomyopathy, anomalous coronary artery disease, arrhythmias, valvular diseases, myocarditis, and coronary atherosclerotic disease) and non-cardiac (i.e., use of illicit drugs, pulmonary embolism, brain diseases such as stroke and hyponatremic encephalopathy, hyperthermia, and rhabdomyolysis)" (Palmieri et al., 2018). Adding to that, SSCD is defined according to the American College of Cardiology as ''non-traumatic and unexpected sudden death that may occur from a cardiac arrest, within 6 hours of a previously normal state of health'' (Maron et al., 2005).

Another similar terminology is the Sudden Cardiac Arrest (SCA) which is defined as "The interruption of cardiac mechanical activity in a person expecting the restoration of cardiopulmonary and cerebral function and can be considered the greatest emergency and a major public health problem" (Lippi et al., 2018). According to the European Society of Cardiology guidelines, SCA is defined as unexpected collapse due to cardiac cause regardless of survival outcomes (Pelliccia et al., 2020).

The actual incidence rate of SSCD in athletes is unknown, and the true incidence is controversial. Calculating it requires a precise numerator (the number of deaths/year) and an exact denominator (number of participants/year) in the studied population (Emery & Kovacs, 2018; Harmon et al., 2014). The passive retrospective collection methods such as media reports, insurance claims, and electronic databases are limited, and they underestimate the incidence of SSCD (Dhutia & MacLachlan, 2018). According to Pelliccia et al. (2020), epidemiological studies that use the media reports as the primary source in detecting SSCD cases identify only (5 to 56%) of actual cases.

The estimated incidence is 1 in 500 to 1 in 80,000 athletes/year but can also vary from 1 in 3000 to 1 in 1,000,000 (Harmon et al., 2014). Other references showed that the current estimates of SSCD in competitive athletes range between 1 in 5,000 to almost 1 in a million athletes/year (Pelliccia et al., 2020).

The wide range of incidence rates may be due to the sample recruitment techniques and methodological design of the research. For example, some studies included mortality events only, while others included mortality and survival cases (Emery & Kovacs, 2018). There are many differences in the sample itself, which may play a role in the recorded incidence rates, such as ethnic and genetic factors, pathological substrates, ages, performance levels, and intensity.

Internationally, SSCD in competitive athletes has been reported differently in many studies (Emery & Kovacs, 2018). However, it is more difficult to investigate the incidence rate of SSCD in non-athletes (recreational and veteran athletes) as many cases are unlikely to be witnessed (D'Silva & Papadakis, 2015). In the United States, the recorded estimated incidence rate of SSCD in the population aged less than 19 years is 3,000 and 5,000 events/year (Link & Estes, 2012).

According to the report of the Bahrain Olympic Committee (BOC), which investigated the causes of SSCD in walkways and gyms in Bahrain in the period between 2009 and 2019, the total number of SSCD cases was 24 out of the total population of 1,503,091 (accounts to <0.001% of the population). Most patients were in the male population (83%), Bahraini nationality (79%), and age group between 50 to 59 years (29%). However, there was no clear relationship between the number of cases and weather or location (Hamad, 2020). They concluded that there was no relationship between the fatalities in the walkways or gyms and playing sports. Other details of the 24 cases are summarized in Table 1.

Table 1: The Details of SSCD Cases in Bahrain as Presented by the Bahrain Olympic Committee (BOC)

Aspect	Details	n (%)
Gender	Male	20 (83%)
	Female	4 (17%)
Nationality	Bahraini	19 (79%)
	Non-Bahraini	5 (21%)
Age	50-59 years	7 (29%)
Location	Sports grounds	6 (25%)
	Walkways	4 (17%)
	Miscellaneous	10 (42%)
Month	December	4 (17%)
Season	Winter	9 (37.5%)
Temperature	Relatively moderate	16 (66.7%)

Even though it is worth mentioning that the number of cases has been changing until recently when a few other cases have been reported in the media. The researcher did a retrospective follow-up study to document the SSCD cases in 2021 and found that at least five instances of SSCD have been reported in social media.

As a general classification, the causes of SSCD can be classified into two significant aspects: cardiac-related causes and non-cardiac-related causes. From the cardiac-related perspective, many cardiac pathologies could lead to SSCD, including structural, electrical, and acquired cardiac abnormalities (Chandra et al., 2013).

According to the United States National Registry in 2016, hypertrophic cardiomyopathy (HCM) was a leading cause of SSCD in young competitive athletes (36%), followed by congenital coronary anomalies (17%), possible HCM (8%), myocarditis (6%) atherosclerotic coronary artery disease (4.5%), and other less prevalent causes (Maron et al., 2016).

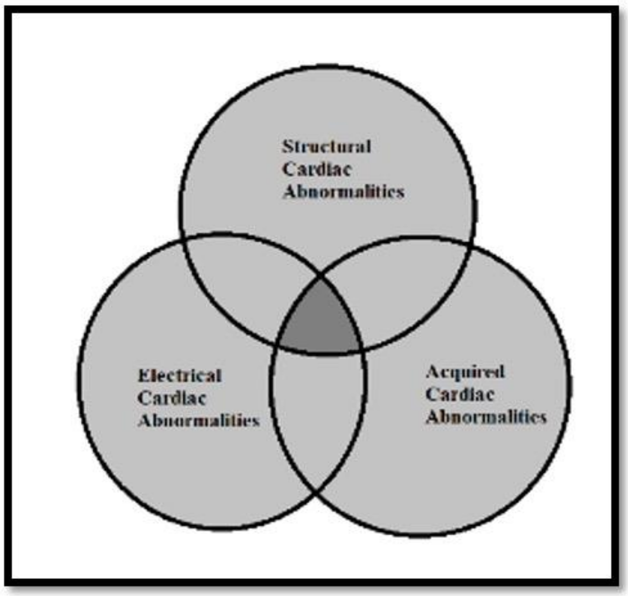

Figure 1: A pie chart summarizing the pathophysiology of SSCD in the US (Emery & Kovacs, 2018)

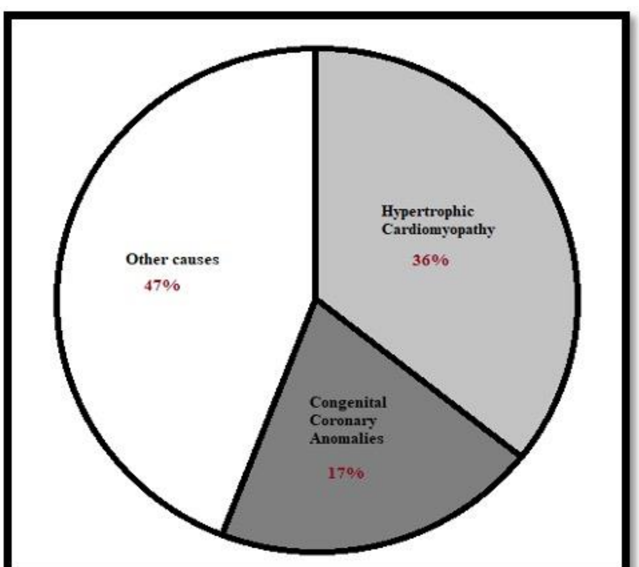

Figure 2: Common causes of SSCD in young athletes (Chandra et al., 2013)

However, the data on the grounds of SSCD in older athletes is much different. It is identified that atherosclerotic coronary artery disease (CAD) is the predominant cause (80% of cases) of SSCD in athletes aged more than 35 years (D'Silva & Papadakis, 2015).

The related literature findings regarding the etiolopathophysiology and causes of SSCD are summarized in Figure 1, and the causes of SSCD with their incidence rates in the US are provided in Figure 2.

Just recently, Egger et al. (2022) published a worldwide observational study about the SSCD in football (soccer) based on the FIFA Sudden Death Registry (FIFA-SDR). They investigated the underlying causes of SSCD in players from 2014 to 2018. Results showed 617 players from 67 countries (34 ± 16 years, men: 96%). In addition to that, they showed that the leading cause of SSCD varies according to the age group and according to region. Details of the study by Egger et al. (2022) mentioned are described below:

SSCD variations based on age:

- In >35 years: the leading cause of SSCD was coronary Disorders (76%).
- In ≤ 35 years: the leading cause of SSCD was Sudden Unexplained Death (SUD, 22%).

SSCD variations based on region (In ≤ 35 years):

- In South America: Cardiomyopathy (42%).
- In North America: Coronary artery anomaly (33%).
- In Europe: SUD (26%).

Risk factors of SSCD

Despite the tiny amount of data related to the risk factors to develop SSCD, it has been recognized that some athletic populations are substantially more susceptible to developing SSCD than others, as reported in different studies. For example, the SSCD risk increases by gender, race, activity level, sport type, and genetics. For instance, male athletes have a 3 to 5 or 3 to 9 times higher risk of SSCD than female athletes, and that is poorly understood (Corrado et al., 2003; Papadakis et al., 2009; Pelliccia et al., 2020). Other data showed that male athletes are 6.5-fold higher than female athletes in developing SSCD (1:121; 691 vs. 1:787,392 athlete-years; P ≤ 0.001) (Maron et al., 2016).

Moreover, literature findings confirmed that ethnic classification predisposes to SSCD events. The National Collegiate Athletic Association (NCAA) in the US reported that African American athletes are 5-fold higher in developing SSCD compared to Caucasian or white athletes (1:12,778 vs. 1:60; 746 athlete-years; P < 0.001). Hypertrophic cardiomyopathy was 42% more common in African Americans compared to whites (31%; P ≤ 0.001) (Harmon et al., 2011; Maron et al., 2016).

In addition to that, studies showed a relatively higher risk of SSCD in athletes than in non-athletes (Corrado et al., 2003; Toresdahl et al., 2014). Training and sport activity pose an increased risk of SSCD by 2.4 to 4.5 times compared to recreational and non-athletic population (95% CI, P < 0.0001) (Corrado et al., 2006; Marijon et al., 2011; Toresdahl, 2014). The risk of sport-related cardiovascular complications is much higher in persons who are just starting sports participation or starting it again after an interval of inactivity. It is documented that those risks increase by 15% to 50% during the first few hours of high-intensity activity, especially in re-starters (Löllgen et al., 2010). Maron et al. (2016) confirmed the previous findings. They reported that 74% of registered events in the US were during practice or competition, and the remaining 26% were during sedentary or mild activity. Generally, 56 to 80% of SCA cases in young athletes are reported to occur during exercising (Pelliccia et al., 2020).

In terms of the rate per sport, SSCD has been reported to be the highest in basketball players (35% males and 24% females), followed by football (30% males and 0% females), soccer (8% males and 13% females), track (7% males and 17% females), and baseball (6% males and 0% females) respectively (Harmon et al., 2015; Maron et al., 2016). These data could be linked to Marfan syndrome as the intense exercise increases the pressure on aorta and therefore the risks of aorta abnormalities (Colombo et al., 2019).

Finally, it is estimated that 60% to 75% of SSCD causes are potentially heritable (Tan et al., 2005). It is a significant risk factor for SSCD, and it represents a prevention opportunity through directed screening (White et al., 2015). Family history paired with examinations of relatives may lead to identifying and diagnosing individuals with high SSCD risk (Wellens et al., 2014). Therefore, collecting family history is a vital first step in detecting and managing high-risk individuals (White et al., 2015).

Warning signs and symptoms

Although 80% of SCAs are asymptomatic (Fudge et al., 2014), attention must be focused on the warning signs and symptoms that may lead to SCA development. In most cases, exertional symptoms related to exercise and sports practice do not ultimately reflect severe or malignant cardiac pathology, and the athlete is successfully returned to the competitive level following necessary evaluation. However, those symptoms may be the first sign or manifestation of a life-threatening cardiac disease, especially when provoked by exercise stress. Therefore, differentiating severe malignant cardiac pathology from usual benign symptoms is the principal key responsibility of the sports medical team (Wilson et al., 2017). According to the learning center of the National Federation of State High School Association (NFHS) and Simon's Heart Organization, there are six main warning signs:

1. Syncope, fainting, or seizures during exercise: Syncope is defined as "a transient loss of consciousness accompanied by loss of postural tone with spontaneous recovery" (Wilson et al., 2017). Fainting during physical activity or exercise is the top warning sign of SCA. In some cases, the collapsed person may begin to shake and is mistakenly diagnosed with seizures, while it may be a sign of SCA. Therefore, SCA must be assumed in any non-injury collapse until proven otherwise. According to the International Olympic Committee (IOC) sports cardiology manual, most syncope cases in athletes are post-exertional syncope caused by a neural-mediated cerebral hypo-perfusion. Syncope that does not occur following exercise but during the exertion must be taken seriously and considered as a manifestation of underlying cardiovascular disease until proven otherwise.
2. Unexplained shortness of breath: During high-intensity exercise, athletes will be temporarily out of breath. However, it could be an SCA-related sign if they catch their breath or always seem winded. In the absence of other symptoms, shortness of breath may be critical. It

could be a cardinal manifestation of cardiovascular diseases or even other conditions (e.g., pulmonary vascular disorders, non-vascular conditions such as anemia) (Wilson et al., 2017).

3. A racing heart (or palpitations): During exercise, the heart rate elevation is a regular physiological adaptation; the heart should slow down in time. It is irregular to feel the heart is racing or "beating out of the chest." According to Wilson et al. (2017), many palpitations may originate from benign causes. However, they may also represent an underlying structural cardiac disease, especially when it triggers the accompanying symptoms (such as syncope) or when it arises in a healthy athlete (with a family history of SCD).
4. Dizziness: According to Cardiology Consultants of Philadelphia (CCP), dizziness and light headiness are common symptoms of many conditions, including cardiac conditions. Example: aortic dissection, arrhythmia, atrial fibrillation, cardiac arrest, cardiogenic shock, cardiomyopathy, heart attack, heart mummer, heart palpitations, etc.
5. Chest pains: Although it is relatively uncommon to have cardiac-caused chest pain in athletes below the age of 35 (< 6%), life-threatening diseases such as hypertrophic cardiomyopathy (HCM) and coronary artery anomalies must not be missed. Moreover, older athletes complaining of exertional chest pain or discomfort must be assumed to have the atherosclerotic coronary disease until proven otherwise (Wilson et al., 2017). The athlete who complains about chest pain should be scrutinized to distinguish the benign from serious symptoms.
6. Extreme fatigue (and performance decline): The irregular tiredness post-exercise when comparing one athlete to their teammates may require some attention. It is tricky and challenging to diagnose the exact underlying causes of performance decline and exertional fatigue; it may range from a completely benign symptom (e.g., relative detraining) to a life-threatening disease (e.g., cardiovascular disease) (Wilson et al., 2017).

Pre-Participation Examinations (PPE) and the role of physiotherapy

The importance of pre-participation examination (PPE) is well documented in the literature. According to Sanders et al. (2018), PPE has primary and secondary objectives. It is initially done to detect the life-threatening or disabling conditions and other conditions that may predispose the athletes to injury or illness. In addition, PPE could be done to determine general health, serve as an entry point to adolescents' health care system, and initiate health-related topics discussion. Medical history must be considered a keystone of any PPE process as it detects as many as 90% of potential health issues. It should address common risks of sudden death and the other elements (Sanders et al., 2018).

The PPE responsibility can be designated to any healthcare decision-maker, such as the team physician, physiotherapist, and other healthcare practitioners (Barbara et al., 2018). From the perspective of the physiotherapy profession, the sports physiotherapist (SPT) is a valuable member and uniquely prepared to be a primary facilitator of the PPE process in connecting with the other health care team. Sport physiotherapy is "a specialized practice that focuses on prevention, evaluation, treatment, rehabilitation and performance enhancement of physically active individuals," as defined by the Sports Physical Therapy Section of the American Physical Therapy Association (APTA). Many states in the USA allow physiotherapists to evaluate without any need for the referral of physicians or other health care providers (Barbara et al., 2018).

Ensuring an athlete's safety is a priority of any health care team, and any well-designed and implemented PPEs will be welcomed by everyone. Physiotherapists are encouraged to develop, implement, and evaluate evidence-based PPEs to help in risk factor identification (Maffey & Emery, 2006).

Role of screening in the prevention of SSCD

The major international medical societies support pre-participation cardiovascular examinations and screening. However, the best method to screen young athletes is still controversial, and the available data to guide this process in master athletes is limited (Pelliccia et al., 2020). Cardiovascular screening of athletes is a challenging and debatable topic (Schmehil et al., 2017). Currently, there is no national consensus on who should be screened, how they should be filtered, and how they should be financed (Mont et al., 2017). As a result, it is strongly recommended that medical professionals define the exact role of screening to design appropriate diagnostic and preventive strategies (Jørstad, 2018).

On one hand, a meta-analysis published in 2016 strongly cautioned against the implementation of national-wide screening programs. They argue that these screening programs have poor detection rates and many false-positive findings, leading to adverse financial and psychological consequences (Brabadt et al., 2016). On the other hand, screening and early identification of high-risk individuals may significantly reduce SSCD rates. For instance, pre-participation screening in Italy showed a dramatic decline (89%) in the SSCD in young competitive athletes compared with the period preceding the screening program (Steinvil et al., 2011). The main goal of including cardiovascular screening in pre-participation programs is to maximize athletes' safety. It includes early detection of underlying cardiac disorders associated with SSCD and reduction of risks through both activity modification and medical management (Asif et al., 2013).

Despite the debate regarding the optimal approach in SSCD screening protocols (Chaitman, 2007; Myerburg & Vetter, 2007), most current strategies recommend including the screening of personal and family history, cardiac physical examinations, and a 12-lead electrocardiogram (ECG) in the pre-participation test (Wheeler, 2010). According to Harmon et al. (2015), history taking reported a sensitivity and specificity of 20% and 94% in detecting severe cardiac abnormalities, while physical examination reported a sensitivity of 9% and a specificity of 97%.

Current recommendations and guidelines

There are many screening protocols and guidelines mentioned in the literature. However, the following part will cover some of them. The questionnaire developed for the research is based on the European Society of Cardiology protocol, the American Heart Association guidelines, the 4th edition of the Pre-Participation Physical Evaluation Monograph, the American College of sports medicine (ACSM) guidelines, and finally, the Physical Activity Readiness Questionnaire (PAR-Q). The Canadian Society for Exercise physiology developed the latter one.

1. European Society of Cardiology (ESC): According to Schmehil et al. (2017), ESC provided the first SSCD prevention and screening protocol for young athletes in 2005. It included personal, and family history, physical examinations, and 12-lead ECG; the athlete is eligible for competition if these findings are negative. However, further investigations will be needed if those examinations show positive results (e.g., echo, stress test, 24-h Holter, etc.). The criteria above were modified in 2010 to improve the specificity of screening by classifying the ECG findings into two groups: "Common and training related ECG findings" and "Uncommon and training Unrelated ECG findings." By doing so, they improved the specificity of ESC 2005 criteria, where the false positives decreased from 16.3% to 9.6% (Weiner et al., 2011). Further modifications were made to improve the ESC criteria when Stanford University provided more specific ECG values in 2011. The Seattle criteria were developed to describe additional ECG abnormal reference values in 2013. A study was done by Pickham et al. (2014) on 1417 athletes found that using the Seattle criteria maintains the sensitivity but significantly decreased the false positives to 6% compared to 8% for Stanford criteria and 26% for ECS criteria. These findings are supported by other researchers such as Bessem et al. (2015) and Brosnan et al. (2014).
2. American Heart Association guidelines (AHA): In 2014, the American Heart Association (AHA) released a new cardiovascular screening checklist to detect genetic and congenital heart diseases (Maron, 2014). It was initially composed of 12 elements, then updated to 14 elements covering personal and family history and physical examinations. A positive finding of one or more items out of the 14 will be fair enough to trigger the need for comprehensive investigations such as ECG, Echocardiography, or stress tests.
   The effectiveness of applying AHA guidelines to detect and predict SSCD is still questionable. Rao et al. (2010) found that the AHA approach was ineffective in detecting and preventing SSCD. Dunn et al. (2015) concluded that a 12-element screening checklist led to

more false positives. Furthermore, whether the AHA 14 element checklist has better specificity and sensitivity in cardiac screening is undetermined, like the 12-element checklist. Another big challenge raised regarding AHA recommendations is the nature of symptoms. It was found that 80% of athletes are asymptomatic, and even the remaining 20% had non-specific symptoms, which make it difficult to depend on history taking alone (Fudge et al., 2014).

3. The 4th edition of Pre-Participation Physical Evaluation Monograph (PPE-4): The PPE-4 is a joint project developed in 2010 through expert consensus (six different medical organizations) and is endorsed by the AHA. The PPE-4 monograph and AHA 14-point PPE are considered the bases of any pre-participation and screening program in the US (Emery & Kovacs, 2018).
Recently, literature has emerged that offers contradictory findings on the use of ECG in routine pre-participation screening. The intense debate within the scientific community may be a result of differences in many factors such as environment, countries, culture, populations, genetics, dietary habits, and other factors that may affect the epidemiology of cardiac diseases (Schmehil et al., 2017).
On the one hand, ECG is a non-invasive and cost-effective technique, and it can detect up to 94% of most significant heart diseases (Higgins & Cadigan, 2016). It is highly sensitive in diagnosing hypertrophic cardiomyopathies (Seto & Pendleton, 2009). A study was done by Vetter et al. (2011) concluded that ECG is 3-fold more likely to detect the leading factors of SSCD when compared to history taking and physical examination, with a reported 93% specificity and 7.8% false-positive rates. On the other hand, many organizations such as American Medical Association (AMA) and AHA do not recommend using ECG in routine screening. It has been argued that ECG may cause unnecessary sports restrictions, which lead to emotional stress for the athletes and their families. Adding to that, the routine use of ECGs in the screening process considered being expensive as the yearly estimated costs in the United States are around $2.5 to $3.5 billion (Asplund & O'Connor, 2016; Halkin et al., 2012). To sum up, using ECG in routine screening protocols for low incidence SSCD events is still a big debatable issue due to the financial burden on the health systems.

4. American College of Sports Medicine (ACSM): According to the standards and guidelines of ACSM, the vital step to optimizing safe exercise participation is identifying individuals with increased levels of cardiac and other fatal events. The primary step to identifying risky individuals is to routinely administer the pre-participation health screening. The latest ACSM pre-participation health screening recommendations and guidelines assess three significant areas. The first one is the current level of physical activity of the individuals, the second is the presence of signs or symptoms in addition to the known medical diseases (e.g., cardiovascular diseases, metabolic diseases, and renal disease), and finally, the desired exercise intensity (Riebe et al., 2015). ACSM developed self-guided and other professionally guided methods to be used in the pre-participation screening process, such as the ACSM algorithm, ACSM Risk Stratification questionnaire, and others (Pescatello et al., 2014).

5. The Canadian Society for Exercise physiology guidelines: The Canadian Society developed a well-known and highly common pre-participation tool for exercise physiology: the physical activity readiness questionnaire for everyone (PAR-Q+). It is a general screening tool aimed at identifying whether there is a need to seek medical consultation from a qualified health care professional or exercise professional or not before being more physically active. It was updated many times, and the last edition was published recently in 2021. It includes general health questions and other specific follow-up questions about medical history (e.g., cancer, cardiovascular problems, metabolic conditions, mental health problems, and others) (Warburton et al., 2021).

In the Arabian Gulf region, a study was done by Alattar et al. (2014) in the United Arab Emirates on 230 competitive male athletes. It aimed to evaluate the effectiveness of Lausanne and ESC recommendations to detect hidden cardiac disorders to prevent SSCD. The first stage of screening used the 12 lead electrocardiograms in addition to the personal and family history based on Lausanne standard questionnaire. The second stage of screening referred the participants who had positive findings and suspected inherited cardiac disease to an expert cardiologist to do further testing (Echocardiogram, 24-h Holter Echo, electrophysiological tests, stress tests, and MRI). They found that 174 (76%) had negative results, while 54 (23%) had positive results. Participants with positive findings underwent further tests, which revealed that 47 (20.4%) had false-positive results, 7 (3%) had true positive results, and 4 (2%) were restricted from the sport. Restricted cases were as follows: one athlete (0.4%) had atrial fibrillation, one athlete (0.4%) had palpitation and T-wave inventions, one athlete (0.4%) diagnosed with myocardial ischemia, and one athlete (0.4%) diagnosed with prolonged QT syndrome. The study concluded that the screening based on Lausanne's recommendations showed favorable results to use the ECG. The study needs improvements to include more extensive trials and samples as the false-positive rate was 20.4%. However, the researchers denied the definite role of screening in reducing the mortality risk as the study was following the observational design.

Adding to the previous contradictions in the literature, far too little attention has been paid to this topic in the local area. To the best of the researcher's knowledge, there were no studies done in Bahrain to standardize or evaluate the effectiveness of such screening protocols. Moreover, no recommended or published screening protocol depends on using a detailed questionnaire as a primary method to detect individuals with a higher risk of developing SSCD. Previously described AHA guidelines using a 14-items checklist performed poorly when compared to ECG, as it was shown in a recent study done by AHA in 2019, they found that AHA 14-point was substantially lower than ECG in the sensitivity, specificity, and positive predictive value (Williams et al., 2019). Moreover, the PPE-4 has not been scientifically validated in a prospective study; a physician should review the initial responses to determine if further evaluation is needed. These findings constitute a significant knowledge gap that needs to be filled with relevant research (Emery & Kovacs, 2018).

Prevention and Management of SSCD

The mortality rates for athletes and non-athletes who have a Sudden Cardiac Arrest (SCA) outside the hospitals remain high, ranging from 70% to 95% (Angelini, 2013). However, prevention strategies and emergency plans must be considered to reduce the mortality rates.

In addition to what the researcher mentioned before in the role of screening and cardiovascular examinations as critical tools in preventing SSCD, there are many other strategies related to the role of health care providers. Increasing the awareness of SSCD among general practitioners and primary care providers is essential; early detection and recognition of symptoms and clinical features related to cardiac conditions and early referral to cardiologists are crucial steps in primary prevention (Semsarian et al., 2015). Adding to that, enhancing the awareness of Cardiopulmonary Resuscitation (CPR) and Automated External Defibrillator (AED) can reduce the SSCD (Blom et al., 2014).

Lifestyle modifications are essential in populations with possible cardiovascular diseases as an important preventive strategy. They may include the use of prophylactic medication treatments (Anti-arrhythmic and Beta-blacker drugs) and implantable cardioverter-defibrillator therapy (ICDs) (Semsarian et al., 2015). The ICDs have been proven to effectively prevent SSCD in athletes with hypertrophic cardiomyopathy (HCM), with 4% as primary prevention and 11% as secondary prevention (Maron, 2010). The restriction from competitive sports for athletes with cardiovascular disorders should be a shared decision-making process between the athletes and their families, the physicians, and the governing bodies (Corrado et al., 2008). It is important to plan for emergency events through establishing standardized Emergency Action Plans (EAPs). According to Drezener et al. (2007) and Link et al. (2015), effective EAPs necessitate various steps: adequate training, availability of functioning AEDs, effective communication with emergency services, and regular EAP review and rehearsal.

According to Dvorak et al. (2013), the International Federation of Football Association (FIFA) has recognized the importance needed to establish standardized emergency medical care on the football field. They developed a medical emergency bag in addition to a series of eleven preventative steps for professionals and amateurs.

Locally, the Bahrain Olympic Committee recommended organizing mandatory courses and programs on first aid to the public, conducting mandatory physical and cardiac investigations annually, organizing community awareness campaigns, and establishing policies, regulations, and strategies in public areas to reduce the chances of SSCD (Hamad, 2020).

Basic Life Support (BLS) and Survival Rates

According to Vancini et al. (2019), understanding and implementing treatment and preventative strategies for SSCD is crucial. It includes the following steps: preparation of people, especially the health professionals in BLS skills, pre-participation evaluation and assessment, early recognition of SCA, early BLS completion, and rapid AEDs access.

The reported survival rates are different from one study to another. Drezner and Rogers (2006) reported that despite a witnessed collapse, timely resuscitation, and prompt defibrillation, only 11% of cardiomyopathy athletes survived from SCA. Another study showed a similar survival rate of 16% in athletic-related SCA (Marijon et al., 2011). A more recent study showed that the survival rate is around 3.4% to 22%, but with persistent neurological problems and poor quality of life (Benjamin et al., 2019).

On the other hand, studies showed a silver lining to applying the BLS and EAPs in getting higher survival rates. Emery and Kovacs (2018) concluded that athletes experiencing SCA could be resuscitated efficiently with prompt CPR and rapid AED application. A quick application of AEDs is associated with a greater likelihood of survival (Weisfeldt et al., 2010). According to FIFA guidelines, it is recommended to apply CPR and AED as soon as possible. The first defibrillation shock must be delivered within the first three minutes of the player's collapse (Dvorak et al., 2013). The prompt CPR and AED use within five minutes of SCA resulted in more than 60% survival rates (Drezner, 2009). More recently, Egger et al. (2022) reported that the survival rate when performing CPR by a layperson is 35%, and it reaches 50% when conducted by a CPR-trained person. The rate increases with adding the AED by a CPR-trained person (the survival rate increase to 85%). Even though the previous results emphasized the importance of BLS knowledge and AEDs availability in sports events, studies showed a worrying situation as the AEDs in sports facilities are still inadequate (Gonzalez et al., 2009; Karam et al., 2017).

COVID-19 and Risks of SSCD

Since the appearance of COVID-19 at the end of 2019, the global landscape has been changed and shifted toward an unrecognizable paradigm. Moreover, concerns were expressed by the community, athletes, and media regarding the relationship between COVID-19 and SSCD and the side effects of COVID-19 vaccines on the heart. The main concern is exercising post-COVID-19 infection could it lead to elevated risks and incidence of SSCD or development of cardiomyopathies over time or not?

A review of the FIFA registry of SSCD during football showed no increase in SSCD cases since the start of the pandemic and vaccination programs compared to the pre-pandemic period records. However, the research showed particularly concerning results regarding cardiovascular complications of COVID-19. Myocarditis, the acute inflammation of the heart, is expected during viral infections and is implicated in many SSCD cases in athletes (up to 22% of the cases). Studies that attempted to evaluate post-COVID-19 myocarditis showed conflicting recommendations and information (Khan et al., 2021).

According to AlQahtani (Sports Cardiology Congress, Bahrain, 2021), the cardiac involvement among 184,179 positive COVID-19 cases in Bahrain between January to November 2021 was low. Only 0.09% developed myocarditis, 0.07% developed cardiomyopathy, and 10% developed cardiogenic shock/cardiac arrhythmias/ sudden cardiac arrest.

To wrap it up, COVID-19, vaccinations, and SSCD are hot topics with many concerns. Much more research is needed to reach a satisfactory conclusion regarding this area.

Future directions

From the diagnosis point of view, working on the genetic mechanisms of inherited cardiac disorders is necessary as it will improve the screening and risk stratification process. Adding to that, risk stratification of patients following the myocardial infarction is of value as those patients are at considerable risk for SSCD (Isbister & Semsarian, 2019). From the therapeutic perspective, continuous improvement of subcutaneous and wearable ICD therapies is a valuable tool (Isbister & Semsarian, 2019). In addition to that, using gene therapy to manage inherited arrhythmia is on the horizon with promising results (Josefson et al., 2017).

Yet, some areas need to be filled in with further research. For example, to develop a diagnostic tool that precisely differentiates between an athlete's heart and underlying cardiomyopathy, determining the genetic and environmental factors that may trigger or increase the risks of SSCD, and establishing the related community programs that effectively enhance awareness and reduce the chances of SSCD (Semsarian et al., 2015).

Conclusions

The previous literature review was based on solid research evidence that considering the most important issues related to the Sports-Related Sudden Cardiac Death (SSCD). It provides the baseline evidence for future research projects to enhance the understanding and risk reduction of SSCD.

Acknowledgments

The Authors extend their appreciation to all students that participated in the study.

Disclosure

The authors report no conflicts of interest in this work.

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