Immediate Bystander Response to Sudden Cardiac Arrest During Sports is Associated with Improved Survival – A Video Analysis.

Nicole M Panhuyzen-Goedkoop (nicolepanhuyzen@me.com)
Universiteit van Amsterdam https://orcid.org/0000-0002-9321-9321

Hein JJ Wellens
Universiteit Maastricht Cardiovascular Research Institute Maastricht

Andre LM Verbeek
Radboud Universiteit

Jan J Piek
Amsterdam Universitair Medische Centra

Ron JG Peters
Amsterdam Universitair Medische Centra

Original Research Article

Keywords: Sudden cardiac death, sudden cardiac arrest, athlete, sports participant, sport, soccer, chest compressions, AED, cardiopulmonary resuscitation

Posted Date: July 6th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-39762/v1

Version of Record: A version of this preprint was published at Sports Medicine-Open on July 22nd, 2021. See the published version at https://doi.org/10.1186/s40798-021-00346-2.

Abstract

Background

Sudden cardiac arrest (SCA) during sports can be the first symptom of yet undetected cardiovascular conditions. Immediate chest compressions and early defibrillation offer SCA victims the best chance of survival, which requires prompt bystander response.

Aims

To determine the effect of rapid bystander response to SCA during sports by searching for and analyzing videos of these SCA/SCD events from the internet.

Methods

We searched images.google.com, video.google.com and YouTube.com, and included any camera-witnessed non-traumatic SCA in athletes and other sports participants at any sports facility. The rapidity of starting bystander chest compressions and defibrillation was classified as <3, 3-5, or >5 minutes. The year SCA occurred was allocated to 1990-2009, 2010-2014 or 2015 onwards, compatible with the current guidelines.

Results

We identified and included 28 victims of average age 27.9 years (SD=9.8); 27 were males, 22 elite athletes, and 17 participated in soccer. Bystander response <3 minutes (6/28) or 3-5 minutes (1/28) and defibrillation <3 minutes was associated with 100% survival. Not performing chest compressions and defibrillation was associated with death (14/28), and >5 minutes delay of intervention with worse outcome (death 4/28, severe neurologic dysfunction 1/28). Survival was highest between 2010-2014 (71.4%).

Conclusions

Analysis of internet videos showed that immediate bystander response to non-traumatic SCA during sports was associated with improved survival. This suggests that immediate chest compressions and early defibrillation are crucially important in SCA during sport, as they are in other settings. Optimal use of both will most likely result in survival. The observed bystander responses to SCA during sports do not show awareness of current guidelines.

Key Points

Analysis of internet videos showed that immediate bystander response to non-traumatic SCA during sports was associated with improved survival.

Immediate chest compressions and early defibrillation are crucially important in SCA during sports, as they are in other settings. Optimal use of both will most likely result in survival.

Bystander responses to SCA during sports do not show awareness of current guidelines.

Background

Sudden cardiac arrest (SCA) during sports in otherwise healthy athletes is a rare and unexpected event with disastrous consequences, including sudden cardiac death (SCD). Athletes have a role model for the community, and resuscitation of athletes is an example for the society, as a result of which SCA usually receives a lot of media attention. Published media reports typically relate to pre-competition screening and cardiopulmonary resuscitation (CPR).

The annual incidence of SCA/SCD among athletes aged 35 years and younger is 2.2-9.8/100,000, and is consistently lower in females (ratio up to 1:9) and non-athletes (0.31/100,000).[1-3] It is well-known that physical activity can trigger life-threatening ventricular tachycardia and fibrillation (VT/VF) in (silent) underlying cardiovascular conditions, such as cardiomyopathy, ion channellopathy, and coronary artery disease.[4-9] To prevent SCA/SCD the international sports governing bodies International Olympic Committee (IOC) and Fédération Internationale de Football Association (FIFA) recommend pre-competition screening of athletes to detect these high-risk cardiovascular conditions (HRCC).[10-13] However, if SCA does occur in spite of preventive programs, restoring the circulation first is extremely important to improve survival.[4-9,1417] Therefore, the international medical societies and sports associations have provided detailed medical action plans and training programs for handling SCA at sports facilities, including the use of an automatic external defibrillator (AED).[11,14,15,18-23] However, unexpected episodes of SCA during sports continue to happen, with uncertain outcomes.[11,18,19,24,25] The rapidity of bystander response, a critical component of survival, has received less attention.

Methods

Aim

In this study we set out to analyze the rapidity of bystander response to non-traumatic SCA and outcomes during sports by searching for and analyzing videos of these SCA/SCD events from the internet.

Study design

We searched on images.google.com, video.google.com and YouTube.com for available videos using the keywords 'sudden cardiac arrest athlete', 'sudden cardiac death athlete' and 'resuscitation athlete'. We included any camera-witnessed non-traumatic SCA that occurred in athletes and other sports participants during or shortly after sports participation at any sports facility, by any age, gender, type and level of sports, that occurred after 1990. Exclusion criteria were traumatic SCA (bodily collision, accident),

spontaneous recovery from collapse <2 minutes, implantable cardioverter defibrillator (ICD) carrier, and videos inappropriate for assessment.

Next, we searched on google.com using each victim's personal name, 'cause of cardiac arrest' or 'cause of death' as keywords to determine the cause of SCA and survival. This included news reports posted on the internet. We did not review medical records of the victim involved. All data of each victim were anonymized for analysis.

Four observers (NB, PD, LH, MM) collected the obtained videos. The observers were grouped into two pairs to evaluate the included videos. A fifth independent observer (NP) analyzed all obtained and included videos, blinded to the results of the two pairs of observers. Disagreement between the two pairs and the fifth observer was resolved by consensus.

We determined each victim's baseline characteristics, such as age, sex, ethnicity, type of sports, level of sports, year and country of event. To determine recognition of SCA from the videos, we evaluated for each victim the physical activity immediately before onset of SCA, the mode of collapse during SCA onset, the appearance during on-going SCA (body position, movements, facial expression), and the nature and rapidity of bystander responses to SCA.

To determine the main purpose of our study the rapidity of bystander response, we assessed the time from SCA onset to starting chest compressions and from SCA onset to defibrillation using a stopwatch. Time was measured in minutes and seconds. When the exact time period could not be measured, but was beyond 5 minutes, the victim was included in our analysis and their time indicated as >5 minutes. We classified the rapidity of bystander response as <3, 3-5 or >5 minutes. The year in which SCA occurred was categorized towards 1990-2009, 2010-2014, or 2015 onwards, compatible with the periods of several published guidelines.

Definitions

We defined 'athlete' as an individual who participates in an organized team or individual sports competing against others on a regular basis aiming to improve skills, excellence and athletic achievements. This includes high-school and collegiate sports . 'Elite athlete' is an athlete who competes at the highest level of national and international competition. 'Recreational sports participant' is an individual performing leisure-time activity. 'Victim' is any athlete, elite-athlete and recreational sports participant suffering SCA.

Statistical analysis

Descriptive statistics of continuous variables were presented with means and standard deviation (SD) and by median values and interquartile ranges (IQR) for non-normal distributed variables. Categorical variables were presented with the number of patients and percentages. We conducted the statistical analyzes using the SPSS package version 26.0 (SPSS® Inc., Chicago, IL, USA).

Results

In total, we identified and included 28 victims with camera-witnessed non-traumatic SCA during sports in our analysis (Figure 1). Individual summaries of each victim are shown in Table 1.

Table 1: Summary of camera witnessed non-traumatic sudden cardiac arrest in 28 victims during sports

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
		GROUP I : before 2010		
1	Male, 33y., Afr/AfrCar	opening airway, CC: no	-	died, HCM
	basketball, elite (1990)	AED: no	-	
2	Male, 28y., Afr/AfrCar	CC: no	-	died, HCM
	soccer, elite (2003)	AED: no	-	
3	Male, 25y., Caucasian	CC: physician	CC: 2.36	died, HCM
	soccer, elite (2004)	AED: physician	AED: 5.15	
4	Male, 30y., Hispanic	CC: yes	CC: 0.31	died, HCM
	soccer, elite (2004)	AED: no	-	
5	Male, 21y., Caucasian	CC: paramedic/physician	CC: >5	survived, AVC (ICD)
	soccer, elite (2005)	AED: yes	AED: >5	
6	Male, 35y., Caucasian	CC: yes	CC: >5	died, ion channelopathy
	soccer, elite (2007)	AED: yes	AED: >5	
7	Male, 23y., Caucasian	opening airway, CC:no	-	died
	soccer, elite (2008)	AED: no	-	
		GROUP II : 2010-2015		
8	Male, 23y., Afr/AfrCar	CC: paramedic/physician	CC: 1.50	survived, HCM (ICD)
	soccer, elite (2010)	AED: physician	AED: 1.50	
9	Male, 31y., Caucasian	CC: yes	CC: 0.54	survived, ACS
	soccer, elite (2010)	AED: yes	AED: >5	
10	Male, 23y., Afr/AfrCar	CC: no	-	died
	soccer, elite (2010)	AED: no	-	
11	Male, 31y., Hispanic	CC: yes	CC: 1.07	survived
	soccer, elite (2010)	AED: paramedic	AED: 1.50	
12	Male, 24y., Afr/AfrCar	CC: yes	CC: 1.07	survived, HCM (ICD)
	soccer, elite (2012)	AED: yes	AED: >5	
13	Male, 25y., Caucasian	CC: physician	CC: 2.50	died, AVC
	soccer, elite (2012)	AED: no	-	
14	Male, 52y., Caucasian	CC: teammate	CC: 3.55	survived

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
	basketball, competition (2013)	AED: teammate	AED: 1.50#	
			GROUP III : 2015 onward	
15	Male, 27y., Caucasian	opening airway, CC: no	-	died, ion channelopathy
	soccer, elite (2015)	AED: no	-	
16	Male, 19y., Afr/AfrCar	opening airway, CC: no	-	died, HCM
	soccer, elite (2016)	AED: no	-	
17	Female, 17y., Caucasian	CC: parents/other	CC: 0.48	survived, ACA (CABG & ICD)
	volleyball, competition (2016)	AED: parent/other	AED: 2.50	
18	Male, 26y., Afr/AfrCar	CC: paramedic	CC: 2.25	died
	soccer, elite (2016)	AED: no	-	
19	Male, 20y., Afr/AfrCar	CC: paramedic	CC: 12.56	survived with severe neurologic dysfunction, iVT
	soccer, elite (2017)	AED: paramedic	AED: 13.10	
20	Male, 39y., Afr/AfrCar	CC: no	-	died
	volleyball, elite (2017)	AED: no	-	
21	Male, 16y., Caucasian	opening airway, CC: no	-	died
	volleyball, high school (2017)	AED: no	-	
22	Male, 15y., Afr/AfrCar	CC: teammates	CC: 1.50	survived
	basketball, competition (2017)	AED: teammate	AED: 2.50	
23	Male, 49y., Caucasian	CC: sparring partner	CC: 0.20	survived, ACS (PCI & stent)
	karate, competition (2017)	AED: paramedic	AED: 2.20	
24	Male, 23y., other race	opening airway, CC: no	-	died
	cricket, elite (2018)	AED: no	-	
25	Male, 25y., Caucasian	CC: physician	CC: 1.50	died
	soccer, elite (2018)	AED: no	-	
26	Male, 23y., Caucasian	CC: paramedic	CC: >5	died, no struct HD
	cycling, elite (2018)	AED: paramedic	AED: >5	
27	Male, 26y., Afr/AfrCar	CC: no	-	died
	basketball, elite (2018)	AED: no	-	

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
28	Male, 52y., Caucasian icehockey, recreational (2019)	CC: physician AED: physician	CC: 0.20 AED: 0.35	survived, ACS (PCI & stent)

Legends: CC chest compressions; AED automated external defibrillator (shocks); # AED shock before chest compressions were started; Afr/AfrCar African/Afro-Carribean; HCM hypertrophic cardiomyopathy; AVC arrhythmogenic cardiomyopathy; ACS acute coronary syndrome; ACA anomalous coronary artery origin; iVT idiopathic ventricular tachycardia; ICD implantable cardioverter defibrillator; CABG coronary artery bypass grafting; PCI percutaneous coronary intervention. Note: References of the videos/images are not displayed due to privacy regulations.

Of the victims, 27/28 were males (96.4%), 14/28 Caucasians (50.0%), 22/28 elite athletes (78.6%), and 17/28 participated in soccer (60.7%). The average age was 27.9 years (SD = 9.8; range 15-52) years. The country where SCA was in 13/28 victims (46.4%) occurred in Europe.

Before SCA occurred, 27/28 victims were competing (96.4%) (Table 2). During the onset of SCA 13/28 victims gradually collapsed on their back (46.4%), and 14/28 suddenly dropped face down (50%). 7/28 sat down or by moved on hands and knees (25.0%) prior to the collapse. During SCA, 17/28 victims had a fixed-gaze (60.7%), 18/28 held their arms alongside (64.3%), and 6/28 manifested uncontrolled limb movements (21.4%) (Table 2).

Table 2: Characteristics of victims' behavior at non-traumatic sudden cardiac arrest during sports

		n	%
Behavior prior to collapse			
Performance	participating in the game	27	96.4
	substituted	1	3.6
Physical action	walking/dribbling after attack or prior to free kick/throw-in	21	75.0
	running after scoring	2	7.1
	standing prior to free kick	1	3.6
	descending on bike	1	3.6
	sitting after substitution	1	3.6
	immediately after basketball dunk	1	3.6
	tries to stand up after tackle	1	3.6
Behavior during the onset of SCA			
Collapse	suddenly dropping face down	14	50.0
	first on the knees	5	17.8
	first grabbing head/chest, second on the knees	1	3.6
	collapsing on the back side	13	46.4
	first grabbing head/chest, second on the knees	3	10.7
	lateral side	3	10.7
	first grabbing head/chest, second on the knees	1	3.6
Trying to prevent collapse		7	25.0
Behavior during SCA (before chest compressions or defibrillation)			
'Dropping dead' position	front side with face down	11	39.3
	back side	13	46.6
	lateral side	4	14.3
Eyes	fixed gaze	17	60.7
	closed	2	7.1
	not visible	9	32.1
Pupils' position	superior	8	28.6
	right lateral	1	3.6

	centered	4	14.3
	not visible	15	53.6
Arms	alongside	18	64.3
	spread apart	6	21.4
	one arm beneath the body	4	14.3
Legs	spread apart	6	21.4
	one knee bend	1	3.6
	bicycle between legs	1	3.6
Uncontrolled limb movements		6	21.4

Legends: SCA sudden cardiac arrest

11/28 victims survived (39.3%) including five Caucasians and one Caucasian with severe neurologic dysfunction (3.6%). Bystanders performed chest compression in 14/28 victims (50%), and defibrillation in 12/28 (42.8%). Ten victims received no chest compressions or defibrillation (35.7%). In 6/28 victims, bystanders concentrated on trying to open the airway without giving chest compressions (21.4%). Medical and paramedical personnel performed chest compressions in 9/28 victims (32.1%) and defibrillation in 7/28 (25%). Referees did not perform chest compressions in any of the videos analyzed.

The rapidity of bystander response to start chest compressions was <3 minutes in 6/28 victims (21.4%) and 3-5 minute in 1/28 (3.6%; median 1.50 minutes) (Table 3). All seven rapid aided victims received defibrillation <3 minutes, which was associated with survival in all. The median time to defibrillation was 4.55 minutes. 14/28 victims (50.0%) received neither chest compressions nor defibrillation. All of these victims died. Delaying both chest compressions and defibrillation by >5 minutes was associated with worse outcome: death 4/28 (14.3%) and neurologic dysfunction 1/28 (3.6%). We could not calculate the IQR, because the rapidity was indicated as >5 minutes for chest compressions in three victims and for defibrillation in five victims.

Table 3: The rapidity of bystander chest compression and defibrillation for non-traumatic SCA during sports in relation to survival

Numbers of victims/numbers of survivors		Chest compressions				Totals
		≤3 minutes	3-5 minutes	>5 minutes	none	
Defibrillation	≤3 minutes	6/6	1/1	0	0	7/7
	3-5 minutes	0	0	0	0	0
	>5 minutes	3/2	0	4/2*	0	7/4
	none	4/0	0	0	10/0	14/0
Totals		13/8	1/1	4/2	10/0	28/11

Legends: *one athlete survived with severe neurologic dysfunction; bold 100% survival

Survival was highest between 2010-2014 (5/7 victims). All five received defibrillation, three of them <3 minutes. Survival between 1990-2009 was 1/7, and in the period 2015 onwards 5/14.

The cause of SCA was reported in 17/28 victims. One was reported as 'no structural heart disease', and 16 with cardiac conditions: hypertrophic cardiomyopathy (7), arrhythmogenic cardiomyopathy (2), ion channelopathy (2), idiopathic VT (1), anomalous coronary artery origin (1), coronary artery occlusion (3).

Discussion

Our analysis of the internet videos of 28 victims showed that immediate bystander response to non-traumatic SCA during sports was associated with improved survival. This suggests that immediate chest compressions and defibrillation within three minutes are crucially important in SCA at sports facilities, and will most likely result in survival. Almost all SCA victims caught on video were elite athletes, with an organized medical team and emergency equipment including AED for immediate chest compressions and defibrillation on-site. Although the numbers are small, we observed that survival improved after the introduction of the CPR guidelines in 2010, but declined after the updated guidelines of 2015 were published. This indicates that bystanders are not aware of current CPR guidelines.

The first important question is why to date athletes still die at the sports facility? SCA may occur in every individual and is the leading cause of death in sport.[11] Survival from SCA is determined by early recognition, immediate bystander chest compressions and early defibrillation without any hesitation. In this study, it appears that bystanders do not always recognize SCA. Viskin et al. reported in a similar camera-witnessed study of 23 traumatic or non-traumatic SCA and 6 sudden collapses in athletes during sport that bystanders failed to recognize SCA and tried to open the airway without performing chest

compressions in 72.4%.[26] In our study this was 21.4%. Contrary to Viskin et al., we included non-traumatic SCA only to exclude external factors causing SCA, such as blunt chest trauma that may induce asystole or VT/VF depending on the timing of the cardiac cycle in which the impact occurred.[27] In a previous study, we used the same method as we did in this study for video analysis in six elite athletes suffering non-traumatic SCA during sports .[17] We observed that an unexpected sudden loss of the upright position, loss of normal breathing, and a fixed gaze were manifest in all six victims during the initiation of syncope.[17] In this study of 28 victims, the fixed gaze was observed in 60.7%. Recognizing the lethal situation of SCA is an important topic in CPR and AED training for medical and paramedical personnel, team staff and referees.[11,19] Although referees are included in CPR training programs, we did not observe that referees who are nearby to a victim (especially in soccer) performed chest compressions. Nevertheless, if an athlete suddenly collapses during sports for no apparent reason and is unresponsive and not breathing normally, bystanders should perform CPR immediately without any hesitation or delay in starting chest compressions.[21] One bystander should start chest compressions, whilst others fetch an AED and apply it and sending for the emergency medical services (EMS) (911 US, 112 EU). Bystanders should follow the instructions given by the AED concerning chest compressions, analysis of the cardiac rhythm and defibrillation.[15]

AEDs can be life-saving as is demonstrated by a Swedish (n=474) and a Dutch study (n=320).[28,29] Both studies observed that survival from out-of-hospital cardiac arrest if AED was used were 70% and 52%, respectively.[28,29] However, if bystanders performing CPR were interrupted by EMS paramedics or the application of the next AED shock was delayed, survival was reduced.[29] Drezner et al. demonstrated in a two-year prospective study in 2,149 American high schools equipped with an AED, that on-site defibrillation within 3.5 minutes was associated with a survival of 89% (42/59 athletes).[6] Of the included 59 SCA events, 54 were witnessed, AED was applied in 50 victims, and 39 of them received defibrillation.[6] Bohm et al. reported from a prospective German registry of SCA during sports (n=144) a survival rate of 26.4%.[9] The authors found that immediate bystander CPR was performed in 82%, and 40.7% had a shockable rhythm.[9] The survival rate in the German study among predominantly male middle-aged sports participants was lower than in the Swedish and Dutch studies among the general population.[9,28,29]

The remaining question is why there was such a defibrillation delay of beyond five minutes? It is widely accepted that defibrillation within 3-5 minutes increases survival (50-70%).[15] Compatible with the related CPR guidelines, the survival in our study was highest between 2010-2014 (71.4%), but has not further increased or sustained from 2015 onwards (35.7%). In that recent period bystander response was delayed or not performed at all, demonstrating that the current guidelines have not been translated into improved rapid initiation of chest compressions and defibrillation at sports facilities. Although our study popultion is small, this should raise concerns with guideline committees and CPR trainers for EMS paramedics, physicians and other personnel witnessing athletic activities in being trained for basic life support (BLS) and AED.[14-16,18] In a French registry of exercise-related SCA (n=820), the authors observed delay of AED arrival (beyond six minutes) to indoor- and outdoor-sports facilities, and infrequent use of an AED (<1%).[7] They reported higher survival in indoor-sports facilities (23%) than in outdoor-

sports facilities (8%).[7] In addition it was noted that not performing or delaying AED shocks explained low survival.

in a similar study reviewing 26/35 videos of traumatic and non-traumatic SCA and arrhythmia-collapse in athletes, Steinkog et al. reported an association between very rapid bystander response and high survival (100%).[30] Also, a favorable association between defibrillation within one minute and survival (n=12, 92%) was observed.[30] In our study with different inclusion criteria, we found an important association between immediate chest compressions and defibrillation within three minutes and 100% survival in 7 victims (25%).

Athletic activities are often witnessed by many spectators, and therefore if SCA occurs there are more bystanders present to respond to SCA. However, it is difficult to explain that sometimes bystanders hesitate or delay immediate chest compressions and defibrillation and that other bystander do not take their responsibility to start chest compressions. AEDs are recommended to be available on-site during athletic events and laymen are allowed to use them.[14,18,19,21] In the FIFA 11 steps to prevent SCD in soccer, FIFA recommend to put a medical emergency bag with an AED in position besides the field-of-play and checked it before each professional soccer match.[11] In addition, in case of SCA the AED should be retrieved, applied and used as soon as possible.[11] Unfortunately, even to date a rapid emergency action sometimes fails.

Another avoidable (or unavoidable) delay is an emotional blockade of the bystander to initiate chest compressions and defibrillation. Wik et al. analyzed the quality of CPR in 176 out-of-hospital advanced cardiac life supports procedures in the general population.[31] The authors found that bystanders, highly-trained paramedics and a anesthetist, failed to perform chest compressions in 48% of cases, probably because of an emotional blockade to perform CPR.[31] In our study, many bystanders were on the professional athletic team and therefore had a more personal relationship with the victim. It could be possible that some bystanders had an emotional blockade to initiate chest compressions and defibrillation. Furthermore, it seemed that medical professionals performing CPR at sports facilities did not follow the BLS/AED algorithm, which also implies substantial room for improvement.[15,16,32]

In our study, most athletes participated in commonly filmed elite sports, such as soccer. However, it does not reflect the risk of SCA in soccer compared to other sports. We found no camera-witnessed SCA in other popular sports, such as marathon running. During mass events with thousands of participants, the chance of capturing SCA on video is extremely small. Nevertheless, it is unacceptable that athletes still die during sports and that despite BLS/AED training and the availability of AED on-site, bystander response to SCA is delayed or absent. Our data strongly suggest that more SCA victims survive if bystander response is rapid and any delay in starting chest compressions and defibrillation is avoided.

Strengths and limitations

The included videos were posted by television stations, athletic organizations and individuals recording SCA and CPR. Therefore, the information is selected and heterogeneous. Nevertheless, it is relevant and

valuable. The main advantage of the camera-witnessed analysis was to objectively review victims' behavior before, at the onset and during SCA, and most importantly the rapidity of bystander response to SCA. We did not try to assess the quality of bystander CPR. The technical aspects of CPR, such as the depth and rate of chest compressions, defibrillation, and ventilation were beyond the scope of our study.

In some victims the exact time to chest compressions and defibrillation could not be measured and was set at >5 minutes. Survival improved if chest compressions was performed within five minutes. Therefore, we included these >5 minutes results in our analysis.

Our collection of victims was limited to those uploaded on the Internet, thereby introducing selection bias.

We excluded traumatic SCA including bodily collision from our study. However, it could be possible that we may have missed commotio cordis as a cause of SCA.

Our cohort is not a representative sample of SCA occurring during sports . Most included victims were elite athletes competing in popular sports like soccer, especially in Europe. Other sports participants were underrepresented in our study. Notwithstanding these limitations and small numbers, our study suggests that more work is needed to improve the recognition and response to SCA during sport.

Future directions

To improve early recognition of SCA immediately followed by chest compressions and defibrillation without any hesitation we propose that everyone involved in sports events is encouraged to attend BLS/AED training, thereby increasing SCA awareness and BLS/AED familiarity. This applies to teammates, coaching staff, referees and jury members, and especially supporting medical and paramedical professionals. Referees and jury are part of the competition and are nearest to a potential victim. Finally, as suggested in the literature, CPR training programs should also address the mental status of bystanders, including medical and paramedical professionals, to ensure adequate emergency action during the stressful circumstances of SCA. This can be done by inclusive training of the whole team - or of all match officials - to try to eliminate 'human factors' and promote working as a team to support each other in responding promptly and appropriately to a victim in SCA.

Conclusions

Analysis of internet videos showed that immediate bystander response to non-traumatic SCA during sports was associated with improved survival. This suggests that immediate chest compressions and early defibrillation are crucially important in SCA during sport, as they are in other settings. Optimal use of both will most likely result in survival. Bystander responses to SCA during sports do not always show awareness of current guidelines.

Declarations

Ethics approval and consent to participate

We performed an Internet search, an open access medium, but we did not include a review of medical records, nor tested or treated the included individuals. Therefore, medical ethical approval was not mandated. In addition, all victim's data were anonymized, as mentioned in Methods, and all references related to the victim ,potentially identifying them, were not mentioned in this paper. The latter is added to the legends of Table 1. Therefore, we did not violate privacy regulations.

Consent for publication

No consent for publication required

Availability of data and material

In Methods we mentioned that 'All victim's data were anonymized for analysis' to protect the victim's privacy, we mentioned in the Legend of Table 1 'Note: References of the videos/images are not displayed due to privacy regulations'. As we do not want to violate the privacy regulations, we decided not to mention the references of the Internet sides displaying the videos. The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

Funding

No external funding was obtained.

Acknowledgement

We would like to express our gratitude to the students Nils L Bakker, Pieter S van Dorst, Lars P Huizinga, and Maarten C Marinussen, who participated in this research as part of their medical research internship and assisted in collecting the data and the analysis of the videos.

References

1 Corrado D, Basso C, Rizoli G, et al. Does sports activity enhance the risk of sudden death in adolescent athletes and young adults? J Am Coll Cardiol 2003;42:1959-63

2 Marijon E, Tafflet M, Celermajer DS, et al. Sports-related sudden death in the general population. Circulation 2011;124:672-81

3 Thoresdahl BG, Rao Al, Harmon KG, et al. Incidence of sudden cardiac arrest in high school student athletes on school campus. Heart Rhythm 2014;11:1190-94

4 Corrado D, Basso C, Pavei A, et al. Trends in sudden cardiovascular death in young competitive athletes after implementation of a pre-participation screening program. J Am Medical Assoc 2006;296:1593-601

5 Harmon KG, Asif IM, Maleszewski JJ, et al. Incidence, Etiology, and Comparative Frequency of Sudden Cardiac Death in NCAA Athletes: A Decade in Review. Circulation 2015;132:10-19

6 Drezner JA, Toresdahl BG, Rao AL, et al. Outcomes from sudden cardiac arrest in US high schools: a 2-year prospective study from the National Registry for AED Use in Sports. Br J Sports Med 2013;47:1179-83

7 Marijon E, Bougouin W, Karam N, et al. Survival from sports-related sudden cardiac arrest: In sports facilities versus outside of sports facilities. Am Heart J 2015;170:339-45.e1

8 Solberg EE, Borjesson M, Sharma S, et al. Sudden cardiac arrest in sports - need for uniform registration: a position paper from the Sports Cardiology Section of the European Association for Cardiovascular Prevention and Rehabilitation. Eur J Prev Cardiol 2016;23:657-67

9 Bohm P, Scharhag J, Meyer T. Data from a nationwide registry on sports-related sudden cardiac death in Germany. Eur J Prev Cardiol 2016;23:649-56

10 Corrado D, Pelliccia A, Bjornstad HH, et al. Cardiac pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol. Consensus Statement of the Study Group of Sport Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology and the Working Group of Myocardial and Pericardial Diseases of the European Society of Cardiology. Eur Heart J 2005;26:516-24

11 Dvorak J, Kramer EB, Schmied CM, et al. The FIFA medical emergency bag and FIFA 11 steps to prevent sudden cardiac death: setting a global standard and promoting consistent football field emergency care. Br J Sports Med 2013;47:1199-202

12 Maron BJ, Levine BD, Washington RL, et al. Eligibility and Disqualification Recommendations for Competitive Athletes With Cardiac Abnormalities: Task Force 2: Pre-participation Screening for Cardiac Disease in Competitive Athletes. Circulation 2015;132:e267-72

13 Drezner JA, O'Connor FG, Harmon KG, et al. AMSSM Position statement on cardiac preparticipation screening in athletes: current evidence, knowledge gaps, recommendations and future directions. Br J Sports Med 2016; 51:153-67

14 Nolan JP, Soar J, Zideman DA, et al. European Resuscitation Council Guidelines for Resuscitation 2010 Section 1.Executive summary. Resuscitation 2010;81:1219-76

15 Perkins GD, Handley AJ, Koster RW. European resuscitation council guidelines for resuscitation 2015. Section 2. Adult basic life support and automated external defibrillation. Resuscitation

2015;95:81-99

16 Berg RA, Hemphill R, Abella BS, et al. 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2010;122:S685-705

17 Panhuyzen-Goedkoop NM, Wellens HJ, Piek JJ. Early recognition of sudden cardiac arrest in athletes during sports activity. Neth Heart J 2018;26:21-25

18 15Link MS, Myerburg RJ, Estes NA III. Eligibility and disqualification recommendations for competitive athletes with cardiovascular abnormalities: Task Force 12: emergency action plans, resuscitation, cardiopulmonary resuscitation, and automated external defibrillators: a scientific statement from the American Heart Association and American College of Cardiology. J Am Coll Cardiol 2015;66:2434-38

19 Borjesson M, Serratosa L, Carre F, et al. Consensus document regarding cardiovascular safety at sports arenas: position stand from the European Association of Cardiovascular Prevention and Rehabilitation (EACPR), section of Sports Cardiology. Eur Heart J 2011;32:2119-24

20 Siebert DM, Drezner JA. Sudden cardiac arrest on the field of play: Turning tragedy into a survivable event. Neth Heart J 2018;26:115-19

21 Hainline B, Drezner JA, Baggish A, et al. Interassociation consensus statement on cardiovascular care of college student-athletes. J Athl Train 2016;51:344-57

22 Public Access Defibrillation Guidelines. Federal Register 2001;66:28495-511.

The Federal Register Online via GPO Access [wais.access.gpo.gov]

23 Kramer E, Bohta M. Emergency cardiac care in the athletic setting: from school sports to the Olympic arena. In: Wilson MG, Drezner JA, Sharma S, editors. IOC manual of sports cardiology, first edition, International Olympic Committee. John Wiley & Sons, Ltd.;2017. p.

24 en.wikipedia.org/wiki/Sudden_cardiac_death_of_athletes. Wikipedia, August 2019

25 en.wikipedia.org/wiki/List_of_association_footballers_who_died_while_playing. Wikipedia, July 2019

26 Viskin D, Rosso R, Havakuk O, et al. Attempts to prevent “tongue swallowing” may well be the main obstacle for successful bystander resuscitation of athletes with cardiac arrest. Heart Rhythm 2017;14:1729-34

27 Link MS. Mechanically induced sudden death in chest wall impact (commotio cordis). Progress in Biophysics & Molecular Biology 2003;82:175-86

28 Ringh M, Jonsson M, Nordberg P, et al. Survival after public access defibrillation in Stockholm, Sweden - A striking success. Resuscitation 2015;91:1-7

29 Berdowski J, de Beus MF, Blom M, et al. Exercise-related out-of-hospital cardiac arrest in the general population: incidence and prognosis. Eur Heart J 2013;34:3616-23

30 Steinskog DM, Solberg EE. Sudden cardiac arrest in sports: a video analysis. Br J Sports Med 2019;53:1293-98

31 Wik L, Kramer-Johansen J, Myklebust H, et al. Quality of cardiopulmonary resuscitation during out-of-hospital cardiac arrest. J Am Med Assoc 2005;293:299-304

32 Zijlstra JA, Radstok A, Pijls R, et al. Overleven na een reanimatie buiten het ziekenhuis: vergelijking van de resultaten van 6 verschillende Nederlandse regio's. In: Reanimatie in Nederland, 2016. Den Haag: Hartstichting, 2016

Tables

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
GROUP I : before 2010				
1	Male, 33y., Afr/AfrCar	opening airway, CC: no	-	died, HCM
	basketball, elite (1990)	AED: no	-	
2	Male, 28y., Afr/AfrCar	CC: no	-	died, HCM
	soccer, elite (2003)	AED: no	-	
3	Male, 25y., Caucasian	CC: physician	CC: 2.36	died, HCM
	soccer, elite (2004)	AED: physician	AED: 5.15	
4	Male, 30y., Hispanic	CC: yes	CC: 0.31	died, HCM
	soccer, elite (2004)	AED: no	-	
5	Male, 21y., Caucasian	CC: paramedic/physician	CC: >5	survived, AVC (ICD)
	soccer, elite (2005)	AED: yes	AED: >5	
6	Male, 35y., Caucasian	CC: yes	CC: >5	died, ion channelopathy
	soccer, elite (2007)	AED: yes	AED: >5	
7	Male, 23y., Caucasian	opening airway, CC:no	-	died
	soccer, elite (2008)	AED: no	-	
GROUP II : 2010-2015				
8	Male, 23y., Afr/AfrCar	CC: paramedic/physician	CC: 1.50	survived, HCM (ICD)
	soccer, elite (2010)	AED: physician	AED: 1.50	
9	Male, 31y., Caucasian	CC: yes	CC: 0.54	survived, ACS

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
	soccer, elite (2010)	AED: yes	AED: >5	
10	Male, 23y., Afr/AfrCar	CC: no	-	died
	soccer, elite (2010)	AED: no	-	
11	Male, 31y., Hispanic	CC: yes	CC: 1.07	survived
	soccer, elite (2010)	AED: paramedic	AED: 1.50	
12	Male, 24y., Afr/AfrCar	CC: yes	CC: 1.07	survived, HCM (ICD)
	soccer, elite (2012)	AED: yes	AED: >5	
13	Male, 25y., Caucasian	CC: physician	CC: 2.50	died, AVC
	soccer, elite (2012)	AED: no	-	
14	Male, 52y., Caucasian	CC: teammate	CC: 3.55	survived
	basketball, competition (2013)	AED: teammate	AED: 1.50#	
GROUP III : 2015 onward				
15	Male, 27y., Caucasian	opening airway, CC: no	-	died, ion channelopathy
	soccer, elite (2015)	AED: no	-	
16	Male, 19y., Afr/AfrCar	opening airway, CC: no	-	died, HCM
	soccer, elite (2016)	AED: no	-	
17	Female, 17y., Caucasian	CC: parents/other	CC: 0.48	survived, ACA (CABG & ICD)
	volleyball, competition (2016)	AED: parent/other	AED: 2.50	

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
18	Male, 26y., Afr/AfrCar	CC: paramedic	CC: 2.25	died
	soccer, elite (2016)	AED: no	-	
19	Male, 20y., Afr/AfrCar	CC: paramedic	CC: 12.56	survived with severe neurologic dysfunction, iVT
	soccer, elite (2017)	AED: paramedic	AED: 13.10	
20	Male, 39y., Afr/AfrCar	CC: no	-	died
	volleyball, elite (2017)	AED: no	-	
21	Male, 16y., Caucasian	opening airway, CC: no	-	died
	volleyball, high school (2017)	AED: no	-	
22	Male, 15y., Afr/AfrCar	CC: teammates	CC: 1.50	survived
	basketball, competition (2017)	AED: teammate	AED: 2.50	
23	Male, 49y., Caucasian	CC: sparring partner	CC: 0.20	survived, ACS (PCI & stent)
	karate, competition (2017)	AED: paramedic	AED: 2.20	
24	Male, 23y., other race	opening airway, CC: no	-	died
	cricket, elite (2018)	AED: no	-	
25	Male, 25y., Caucasian	CC: physician	CC: 1.50	died
	soccer, elite (2018)	AED: no	-	
26	Male, 23y., Caucasian	CC: paramedic	CC: >5	died, no struct HD

Victim No.	Baseline characteristic (year of event)	Bystander response	Time to start chest compressions and defibrillation (min)	Survival, cause of SCA (intervention)
	cycling, elite (2018)	AED: paramedic	AED: >5	
27	Male, 26y., Afr/AfrCar	CC: no	-	died
	basketball, elite (2018)	AED: no	-	
28	Male, 52y., Caucasian	CC: physician	CC: 0.20	survived, ACS (PCI & stent)
	icehockey, recreational (2019)	AED: physician	AED: 0.35	

Figures

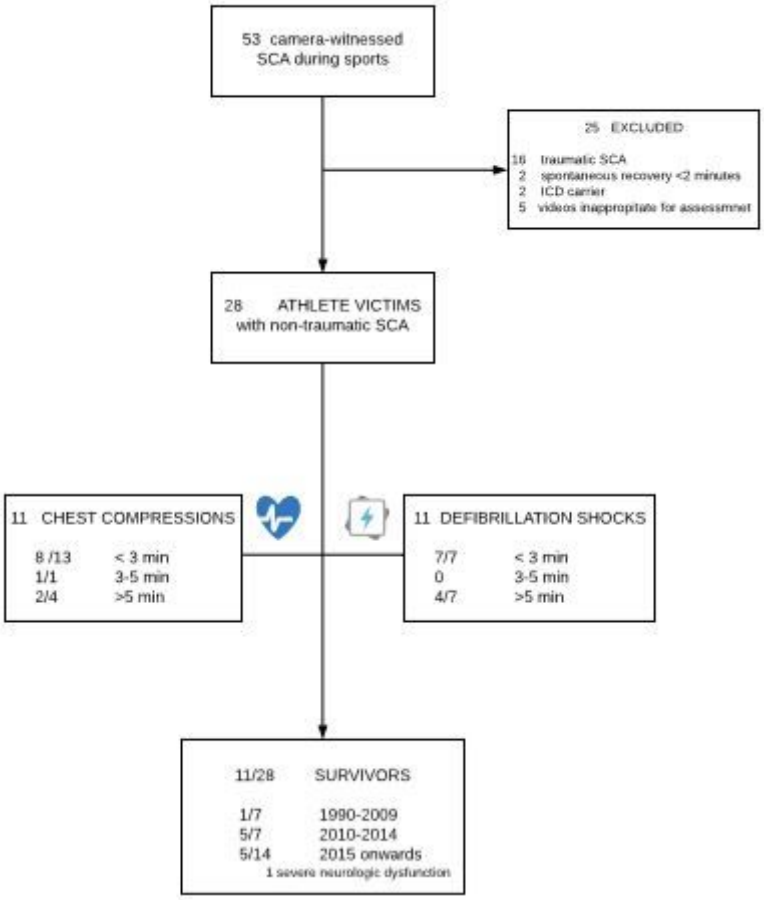

Figure 1

Bystander response to camera-witnessed non-traumatic sudden cardiac arrest in athletes during sports
Legends: SCA sudden cardiac arrest; ICD implantable cardio defibrillator