

Survival After Exercise-Related Sudden Cardiac Arrest in Young Athletes: Can We Do Better?

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Background: Sudden cardiac arrest (SCA) is the leading cause of death in young athletes during sports.

Hypothesis: Survival after SCA in young athletes is variable.

Study Design: Prospective, active surveillance study.

Level of Evidence: Level 3.

Methods: From July 1, 2014, to June 30, 2016, exercise-related SCA in competitive young athletes was identified through a systematic search of traditional and social media sources, direct reporting to the National Center for Catastrophic Sports Injury Research, searching of the National Collegiate Athletic Association Resolutions List, regular communication with national and state high school athletic associations, and review of cases in the Parent Heart Watch database.

Results: A total of 132 cases were identified during the 2-year study period (mean patient age, 16 years; age range, 11-27 years; 84% male; 51% white non-Hispanic/Latino, 30% black/African American, and 11% white Hispanic/Latino). High school athletes accounted for 78 (59%) cases, with 28 (21%) in middle school and 15 (11%) in college athletes. Overall survival was 48% (95% CI, 40%-57%; 64 survivors, 68 deaths). Survival was similar in male versus female athletes but higher in white non-Hispanic/Latino (40/67; 60%) versus black/African American (13/39; 33%) athletes (difference, 27%; 95% CI, 7%-45%; $P = 0.008$) and white non-Hispanic/Latino versus all minority (18/59; 31%) athletes (difference, 29%; 95% CI, 13%-46%; $P = 0.001$). Basketball accounted for 30% of cases, followed by football (25%), track/cross-country (12%), and soccer (11%). The majority (93%) of cases were witnessed. If a certified athletic trainer was on-site and involved in the resuscitation, 83% of athletes survived. If an on-site automated external defibrillator was used in the resuscitation, 89% of athletes survived.

Conclusion: Exercise-related SCA in young, competitive athletes is typically witnessed, providing an opportunity for rapid resuscitation. Additional research is needed to identify factors that affect survival in different athlete populations.

Clinical Relevance: Public access defibrillator programs should be universal in schools and youth sporting venues and have the potential to increase survival after SCA in young athletes.

Keywords: out-of-hospital cardiac arrest; sports; cardiopulmonary resuscitation; defibrillation

The sudden death of a young athlete during sports participation is a tragic event with devastating impact on the local community. Sudden cardiac arrest (SCA) is the leading cause of exercise-related death in young competitive athletes, accounting for 75% of all fatalities during sports and exercise.^{15,20} A variety of structural, electrical, and acquired cardiac disorders may predispose a young athlete to SCA.^{15,20} Most young athletes who harbor a potentially lethal cardiac

disorder have no warning signs or symptoms, making effective preparticipation cardiovascular screening challenging and agreement on the optimal screening protocol an area of continued debate and controversy.^{8,13,21,22}

Recommendations for medical emergency response planning for SCA in the school and athletic settings have existed for more than a decade and carry widespread support within the medical community. In 2004, the American Heart Association published

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guidelines for medical emergency response planning in schools, and in 2007, an interassociation task force provided consensus recommendations for emergency preparedness and the management of SCA in high school and college athletic programs.^{7,18} Public access defibrillation programs have improved outcomes from out-of-hospital cardiac arrest, and current best practice recommendations for secondary schools propose access to an automated external defibrillator (AED) within 3 minutes of collapse to first shock for all organized athletic activities.⁵ In a 2-year prospective study of 2149 high schools in the United States, survival in student-athletes after exercise-related SCA was 89% if the event was witnessed and prompt cardiopulmonary resuscitation (CPR) and early defibrillation were provided.¹⁰

Unfortunately, many state and local requirements for medical emergency response planning in schools are inadequate and have not adopted school-based AED programs.²⁸ The purpose of this study was to prospectively monitor cases of exercise-related SCA in young athletes in the United States to define survival rates and identify potential areas to improve survival outcomes.

METHODS

This study was conducted in collaboration with the National Center for Catastrophic Sports Injury Research (NCCSIR) and the UW Medicine Center for Sports Cardiology. The study was approved by the institutional review board at the University of North Carolina at Chapel Hill.

Cases of SCA in young athletes with or without survival were prospectively identified from July 1, 2014, to June 30, 2016, through an active surveillance program led by the NCCSIR. This is an ongoing surveillance program from which 2 years of data were used in this study. Case identification methods included a systematic search of traditional and social media sources; reporting directly to the NCCSIR or UW Medicine Center for Sports Cardiology; searching of student-athlete deaths on the National Collegiate Athletic Association (NCAA) Resolutions List; direct communication with the National Federation of State High School Associations (NFHS), state high school athletic associations, and National Athletic Trainers' Association (NATA); and regular review of cases collected in the Parent Heart Watch database.

Inclusion and Exclusion Criteria

Competitive athletes at the middle school, high school (including premiere-/club-level athletes), collegiate, semiprofessional, and professional levels who experienced exercise-related SCA were included. A competitive athlete was defined as an individual involved in regular training in an organized individual or team sport with an emphasis on competition and performance. Former athletes ($n = 10$) who met one of the previously described categories were included if the cardiac event occurred within 1 year of documented competitive sports participation and they were exercising at the time of arrest.

SCA was defined as an unexpected collapse due to a cardiac cause in which CPR and/or defibrillation was provided regardless of survival outcome. Sudden cardiac death (SCD) was defined as a sudden unexpected death due to a cardiac cause or a sudden death in a structurally normal heart determined by autopsy with no other explanation for death and a history consistent with cardiac-related death. Only SCA/SCD cases that occurred during exercise in a competitive athlete were included.

Attempts were made to collect additional information via phone interviews with family members, school representatives, athletic trainers or coaches involved in the resuscitation, or coroners and medical examiners in the event of autopsy. Outreach to family members and school representatives included 4 to 6 contact attempts by postal mail, email, and/or phone over an 8-week period. Autopsy and medical records were also gathered from public resources or through next-of-kin consent. All records were examined by a multidisciplinary panel, including experts in cardiovascular pathology, sports medicine, and sports cardiology, to determine the underlying cause based on published criteria.¹⁵⁻¹⁷ The specific etiologies associated with SCA/SCD in this cohort are reported elsewhere.²⁵ Cases occurring during exercise in which autopsy or medical records could not be obtained were included as cardiac in nature if the event details supported an abrupt collapse requiring cardiac resuscitation. Cases of SCA/SCD in a recreational athlete or nonathlete ($n = 66$), with undetermined cardiac etiology or a noncardiac diagnosis ($n = 58$), in athletes younger than 11 years (younger than middle school) ($n = 9$), or in a competitive athlete during rest ($n = 29$), sleep ($n = 10$), within 1 hour of exercise ($n = 6$), or unknown activity ($n = 5$) were excluded. All sources of information were used to classify race. If medical examiner or medical records were not available, media reports and athlete photos were used to determine race.

Data Analysis and Statistics

Data variables collected included individual demographics, sport information and level of competition, and when possible, resuscitation details such as witnessed arrest, provision of bystander CPR, presence of a certified athletic trainer, availability and use of a public access AED, or use of a defibrillator by responding emergency medical services (EMS) personnel. Descriptive statistics were used to describe the data. The primary outcome was survival to hospital discharge. Differences in survival based on sport, level of competition, sex, and race were analyzed using a chi-square test. In comparisons where the sample size was less than 10, a Fisher exact test was used. All tests were 2-sided, and a P value <0.05 was considered statistically significant. Analysis was conducted using RStudio software (v 1.0.136; RStudio Team).

RESULTS

A total of 132 cases of exercise-related SCA were identified in young, competitive athletes over the 2-year study period (Table 1).

Table 1. Demographic information for exercise-related sudden cardiac arrest and death in competitive athletes^a

	Sudden Cardiac Arrest With Survival (n = 64)	Sudden Cardiac Death (n = 68)	Total (N = 132)
Sex			
Male	54 (84)	57 (84)	111 (84)
Female	10 (16)	11 (16)	21 (16)
Age, y, mean (range)	16 (12-27)	16 (11-26)	16 (11-27)
Race			
White non-Hispanic/Latino	40 (63)	27 (40)	67 (51)
Black/African American	13 (20)	26 (38)	39 (30)
Asian	2 (3)	2 (3)	4 (3)
White Hispanic/Latino	3 (5)	12 (18)	15 (11)
Native American	0 (0)	1 (1)	1 (1)
Unknown	6 (9)	0 (0)	6 (5)
Athletic level			
Middle school	12 (19)	16 (24)	28 (21)
High school	42 (66)	36 (53)	78 (59)
College	9 (14)	6 (9)	15 (11)
Semiprofessional/professional	0 (0)	1 (1)	1 (1)
Recent/former athlete (within 1 year)	1 (2)	9 (13)	10 (8)
Activity level at time of arrest			
During organized practice or training	34 (53)	32 (47)	66 (50)
During game or competition	22 (34)	15 (22)	37 (28)
During strength and conditioning	2 (3)	2 (3)	4 (3)
Other	5 (8)	19 (28)	24 (18)
Pick-up game (not team sanctioned)	0	6	6
Exercise/conditioning (not team sanctioned)	3	4	7
Physical education class	1	5	6
Other recreational activity	1	4	5
Unknown	1 (2)	0 (0)	1 (1)

^aData obtained between July 1, 2014, and June 30, 2016. Data provided as n (%) unless indicated otherwise.

The mean patient age was 16 years (range, 11-27 years), with 111 (84%) cases occurring in males. Sixty-seven (51%) athletes were white non-Hispanic/Latino, 39 (30%) were black/African American, and 15 (11%) were white Hispanic/Latino. High

school athletes accounted for 78 (59%) cases, with 28 (21%) occurring in middle school athletes and 15 (11%) in college athletes. Sixty-six (50%) cases occurred during practice or training, 37 (28%) during a game or competition, and 4 (3%)

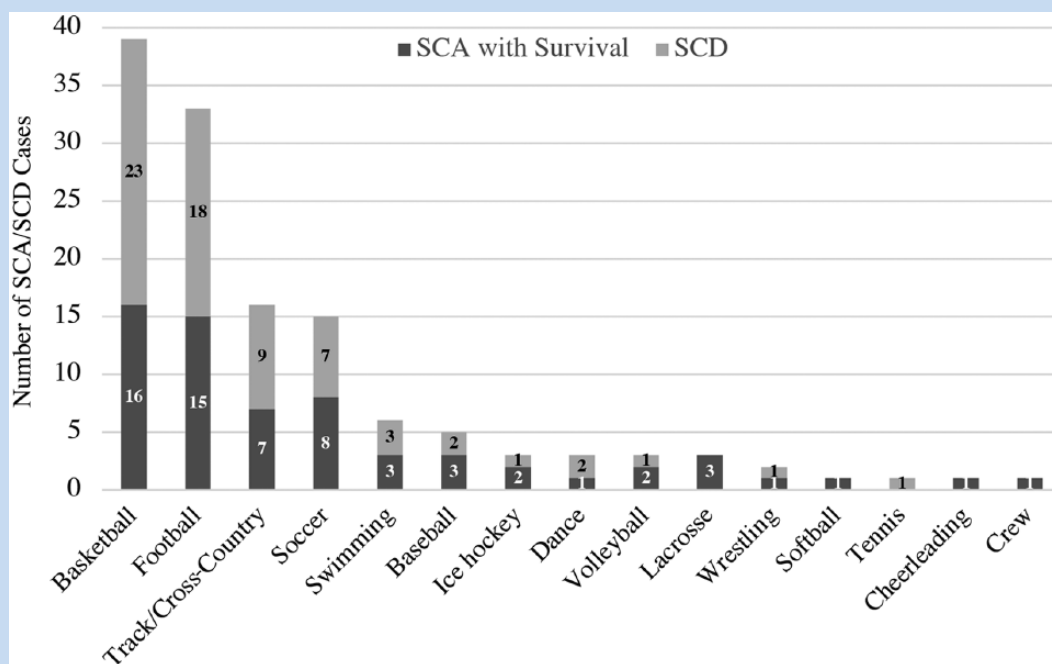


Figure 1. Sport information and survival for exercise-related sudden cardiac arrest and death in competitive athletes: July 1, 2014, to June 30, 2016 (N = 132). SCA, sudden cardiac arrest with survival; SCD, sudden cardiac death.

during a strength and conditioning session. Twenty-four (18%) cases occurred during other forms of exercise such as pick-up games, non-team sanctioned conditioning, or physical education class.

Survival Outcomes

The overall survival to hospital discharge was 48% (95% CI, 40%-57%; 64 survivors, 68 deaths). Survival was similar in males (54/111; 49%) versus females (10/21; 48%). However, survival was higher in white non-Hispanic/Latino (40/67; 60%) athletes versus black/African American (13/39; 33%) athletes (difference, 27%; 95% CI, 7%-45%; $P = 0.008$). Only 20% (3/15) of Hispanic/Latino athletes survived. Survival was also higher in white non-Hispanic/Latino versus all minority (18/59; 31%) athletes (difference, 29%; 95% CI, 13%-46%; $P = 0.001$).

Over half (55%) of all cases occurred in either basketball (39; 30%) or football (33; 25%) athletes, and 103 cases (78%) occurred in 4 sports (basketball, football, soccer, and track/cross-country) (Figure 1). Survival was similar in college (9/15; 60%) versus high school (42/78; 54%) athletes (difference, 6%; 95% CI, -21% to 33%; $P = 0.66$) or college versus middle school (12/28; 43%) athletes (difference, 17%; 95% CI, -14% to 48%; $P = 0.28$) (Figure 2). Thirteen of the 15 college cases occurred at NCAA institutions, with 1 case occurring at a National Association of Intercollegiate Athletics (NAIA) institution and 1 case at a community college. Within the NCAA cases, survival appeared higher at NCAA Division I institutions (6/8; 75%) compared with NCAA Division II or III institutions (2/5; 40%),

but the difference was not statistically significant (odds ratio [OR], 3.9; 95% CI, 0.25-87; $P = 0.29$).

Resuscitation Details

Resuscitation details for cases of SCA and SCD are shown in Table 2. Of the 132 cases, 123 (93%) were witnessed, 5 (4%) unwitnessed, and 4 (3%) unknown. Bystander CPR was confirmed in 79 (60%) cases, not provided in 8 (6%), and unknown in 45 (34%). In cases where bystander CPR was provided, 63% (50/79) of athletes survived. A certified athletic trainer was on-site at the time of SCA in 29 (22%) cases, not present in 19 (14%) cases, and unknown in 84 (64%) cases. In cases where a certified athletic trainer was on-site and immediately present to assist in the resuscitation, 83% (24/29) of athletes survived. A public access AED was available in 43 (33%) events and used in 37 (28%) cases. In cases where an on-site AED was used in the resuscitation, 89% (33/37) of athletes survived.

DISCUSSION

Cardiac arrest is the third-leading cause of death among all age groups in the United States, after cancer and heart disease,³⁰ and afflicts more than 350,000 individuals annually, including more than 7000 children and adolescents.²⁴ The probability of successful defibrillation for SCA caused by ventricular fibrillation diminishes rapidly over time, with survival declining approximately 10% every minute defibrillation is delayed.¹⁹ Across the United States, survival rates from out-of-hospital

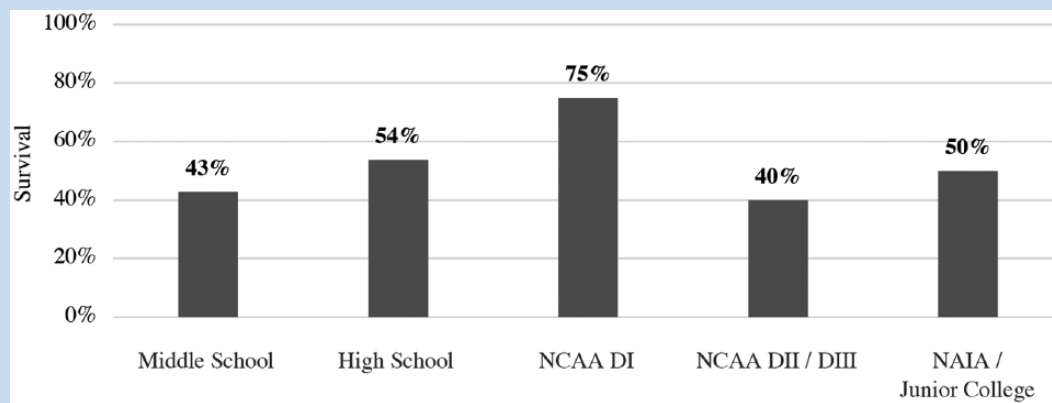


Figure 2. Survival for exercise-related sudden cardiac arrest by level of competition. NCAA, National Collegiate Athletic Association; DI, Division I; DII, Division II; DIII, Division III; NAIA, National Association of Intercollegiate Athletics.

cardiac arrest (OHCA) are <10% when dependent on traditional EMS systems.¹² In the HeartRescue Project, a multistate public health initiative focused on establishing statewide EMS systems to improve OHCA care in the community, overall survival to hospital discharge was only 11% for all rhythms, but 34% in the subgroup with bystander-witnessed OHCA and a shockable rhythm.³²

Early defibrillation has proven to be the critical link to improved outcomes.¹ Public access defibrillation programs in which an AED is available for bystander use demonstrate a median survival rate of 40%, with some programs demonstrating survival rates greater than 70%.² Historical survival rates for exercise-related SCA in the young, however, have not been as favorable. In a study examining survival trends from exercise-related SCA in the young in the US from 2000 to 2006, the overall survival rate was only 11% (55/486).⁶ Cities with more robust EMS systems have demonstrated improved survival from OHCA across the age spectrum. In a retrospective review of OHCA in individuals younger than 35 years of age in King County, Washington, from 1980 through 2008, 77 of 361 cases occurred during or within 1 hour of exercise, with a 38% survival rate to hospital discharge.²³ More recently, school-based AED programs have demonstrated markedly improved outcomes for exercise-related SCA in the young.^{3,9,10} One study reported an 89% (16/18) survival rate in high school student-athletes suffering SCA during exercise on school campus if promptly recognized and a local AED was used.¹⁰

This study examined contemporary survival outcomes in young competitive athletes with exercise-related SCA. While the mean survival rate of 48% is above the national average for OHCA and demonstrates progress toward improved outcomes, it is also more than 40% below survival rates reported in young otherwise healthy athlete populations when ideal resuscitation procedures occur. Indeed, when an AED was on-site and used in the resuscitation, 89% of athletes in this study survived.

Medical emergency response planning for SCA is universally supported as an effective strategy to prevent sudden death during

athletic activities.^{5,7,18} However, state and local requirements for medical emergency response planning in schools are often inadequate, and many schools have not implemented AED programs.²⁸ Barriers to implementing a school-based AED program have been previously defined, with financial resources listed as the leading obstacle.¹⁰ While this study was not designed to investigate the current status of medical emergency response planning or public access to AEDs in schools, these results do raise the possibility that socioeconomic disparities may have a significant impact on AED access or the presence of an athletic trainer in schools located in low-income communities with a higher proportion of minority students.

Racial differences in OHCA survival and prehospital care have been characterized in other studies. A systematic review and meta-analysis found that black/African American patients were less likely to have a witnessed arrest, receive bystander CPR, and survive OHCA in the United States.²⁷ Data from the Resuscitation Outcomes Consortium also demonstrated that OHCA occurring in predominantly black neighborhoods had lower rates of bystander CPR, lay responder AED use, and survival compared with OHCA in predominantly white neighborhoods.²⁹ Another study confirmed that bystander CPR was less likely in low-income black neighborhoods compared with high-income white neighborhoods.²⁶ Socioeconomic factors also may affect emergency planning and health outcomes in schools. In the state of Michigan, high schools in counties with lower socioeconomic status were less likely to have a cardiac emergency response plan.³³ In another study examining emergency preparedness for SCA in high schools, urban and inner-city schools were less likely than suburban schools to have an AED.³¹

The goal of school-based AED programs is to allow access to an AED within 3 minutes of an emergency (ie, collapse to first shock).⁵ In this study, 4 sports (basketball, football, soccer, and track/cross-country) represented 78% of exercise-related SCA. This information provides an important guide to AED location and prioritization, especially in schools with limited resources.

Table 2. Resuscitation details for exercise-related sudden cardiac arrest and death in competitive athletes^a

	Sudden Cardiac Arrest With Survival (n = 64)	Sudden Cardiac Death (n = 68)	Total (N = 132)
Witnessed arrest?			
Yes	62 (97)	61 (90)	123 (93)
No	1 (2)	4 (6)	5 (4)
Unknown	1 (2)	3 (4)	4 (3)
Bystander CPR performed?			
Yes	50 (78)	29 (43)	79 (60)
No	4 (6)	4 (6)	8 (6)
Unknown	10 (16)	35 (51)	45 (34)
Public access to AED?			
Yes	37 (58)	6 (9)	43 (33)
No	4 (6)	4 (6)	8 (6)
Unknown	23 (36)	58 (85)	81 (61)
AED used?			
Yes	33 (52)	4 (6)	37 (28)
No	16 (25)	16 (24)	32 (24)
Unknown	15 (23)	48 (71)	63 (48)
Certified ATC on-site?			
Yes	24 (38)	5 (7)	29 (22)
No	9 (14)	10 (15)	19 (14)
Unknown	31 (48)	53 (78)	84 (64)
EMS defibrillator used			
Yes	10 (16)	5 (7)	15 (11)
No	23 (36)	1 (1)	24 (18)
Unknown	31 (48)	62 (91)	93 (71)

AED, automated external defibrillator; ATC, certified athletic trainer; CPR, cardiopulmonary resuscitation; EMS, emergency medical services.

^aData obtained between July 1, 2014, and June 30, 2016. Data provided as n (%) unless indicated otherwise.

In 2015, the Institute of Medicine issued a report characterizing the public health impact of cardiac arrest in the United States and outlined specific recommendations to improve survival.¹² The Institute of Medicine recommends programs that promote public awareness and a culture of action regarding the recognition and treatment of OHCA. Public health initiatives to improve bystander and first

responder interventions through general population training in CPR and AED use have been shown to increase bystander and first responder provision of CPR, shorten time to defibrillation, and improve outcomes in patients with OHCA.^{11,14} When compared with defibrillation longer than 10 minutes after OHCA, the odds of survival increased more than 7-fold (OR, 7.73) if defibrillation occurred in fewer than 2 minutes, and

increased nearly 4-fold (OR, 3.78) if defibrillation occurred within 2 to 5 minutes after OHCA.¹⁴

Schools are in a unique position to implement CPR-AED education and training and improve the likelihood of an effective bystander response. In this study, 93% of exercise-related SCA in young athletes was witnessed, providing a critical opportunity where a rapid and coordinated emergency response should be the standard of care. Education in the recognition of SCA and CPR-AED training for coaches and staff responsible for student-athletes should be required. School-based AED programs, in combination with a fully developed and practiced emergency response plan for SCA, should be a universal public safety measure to ensure timely access to a defibrillator for both students and adults who suffer SCA on a school campus. Most states also require by law CPR instruction for students prior to graduation from high school, although there is currently no standardized method of implementation, and only 63% perform AED training.⁴

Limitations

This study has many limitations that should be recognized in interpreting the results. Reporting of SCA in young athletes is not mandatory in the United States, and many cases may have been missed, which could affect the reported survival outcomes. In cases of SCA in the young, acquisition of additional case details, medical records, and autopsy reports is challenging. While this study had processes in place to contact families and schools after a case was identified, in many circumstances, next-of-kin or school staff would not respond or were hesitant to provide consent for records or discuss the case in detail. Thus, many of the factors that influence survival after SCA were unknown and/or missing, which hampered statistical comparisons, possibly inflicting bias.

CONCLUSION

SCA in a young athlete is largely a survivable event when a proper emergency response is initiated with access to an AED. The time between onset of arrest and provision of care is critical to survival. Exercise-related SCA in young competitive athletes is typically witnessed, providing an opportunity for rapid resuscitation, and strategic efforts to increase bystander and first responder CPR and early defibrillation are warranted. Public access defibrillator programs should be universal in schools and at youth sporting facilities and have the potential to further improve survival rates in young athletes, with many life-years saved.

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