Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

Effectiveness of Emergency Response Planning for Sudden Cardiac Arrest in United States High Schools With Automated External Defibrillators

Jonathan A. Drezner, Ashwin L. Rao, Justin Heistand, Megan K. Bloomingdale and Kimberly G. Harmon

Circulation published online Jul 27, 2009;
DOI: 10.1161/CIRCULATIONAHA.109.855890
Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 72514
Copyright © 2009 American Heart Association. All rights reserved. Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org

Data Supplement (unedited) at:
http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.109.855890/DC1

Subscriptions: Information about subscribing to Circulation is online at
http://circ.ahajournals.org/subscriptions/

Permissions: Permissions & Rights Desk, Lippincott Williams & Wilkins, a division of Wolters Kluwer Health, 351 West Camden Street, Baltimore, MD 21202-2436. Phone: 410-528-4050. Fax: 410-528-8550. E-mail:
journalpermissions@lww.com

Reprints: Information about reprints can be found online at
http://www.lww.com/reprints

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

Effectiveness of Emergency Response Planning for Sudden Cardiac Arrest in United States High Schools With Automated External Defibrillators

Jonathan A. Drezner, MD; Ashwin L. Rao, MD; Justin Heistand, MD;
Megan K. Bloomingdale; Kimberly G. Harmon, MD

***Background*—**US high schools are increasingly adopting automated external defibrillators (AEDs) for use in campus settings. We analyzed the effectiveness of emergency response planning for sudden cardiac arrest (SCA) in a large cohort of US high schools that had onsite AED programs.

***Methods and Results*—**A cohort of US high schools with at least 1 onsite AED was identified from the National Registry for AED Use in Sports. A school representative completed a comprehensive survey on emergency planning and provided details of any SCA incident occurring within 6 months of survey completion. Surveys were completed between December 2006 and July 2007. In total, 1710 high schools with an onsite AED program were studied. Although 83% (1428 of 1710) of schools have an established emergency response plan for SCA, only 40% practice and review the plan at least annually with potential school responders. A case of SCA was reported by 36 of 1710 schools (2.1%). The 36 SCA victims included 14 high school student athletes (mean age, 16 years; range, 14 to 17 years) and 22 older nonstudents (mean age, 57 years; range, 42 to 71 years) such as employees and spectators. No cases were reported in student nonathletes. Of the 36 SCA cases, 35 (97%) were witnessed, 34 (94%) received bystander cardiopulmonary resuscitation, and 30 (83%) received an AED shock. Twenty-three SCA victims (64%) survived to hospital discharge, including 9 of the 14 student athletes and 14 of the 22 older nonstudents.

***Conclusions*—**School-based AED programs provide a high survival rate for both student athletes and older nonstudents who suffer SCA on school grounds. High schools are strongly encouraged to implement onsite AED programs as part of a comprehensive emergency response plan to SCA. **(*Circulation*. 2009;120:518-525.)**

Key Words: death, sudden ■ defibrillation ■ resuscitation ■ schools ■ students

American Heart Association. Circulation

Sudden cardiac arrest (SCA) is the leading cause of death in the United States and afflicts ≈300 000 persons annually.[1] The single greatest determinant of survival after SCA is the time from collapse to defibrillation, with survival rates declining 7% to 10% per minute with every minute that defibrillation is delayed.[2,3] Historically, survival rates to hospital discharge from out-of-hospital SCA in US cities using conventional emergency response systems are <5%.[4–6] Several studies of early defibrillation through public access to automated external defibrillators (AEDs) have demonstrated a survival benefit for out-of-hospital SCA. In these studies, use of AEDs by trained or untrained bystanders and nontraditional responders produces survival rates from 41% to 74% if cardiopulmonary resuscitation (CPR) is provided and defibrillation occurs within 3 to 5 minutes of collapse.[7–15]

Editorial see p 461
Clinical Perspective on p 525

SCA is also the leading cause of death in exercising young athletes, accounting for more than half of all deaths.[16–18] Sudden cardiac death in a young athlete is a devastating event with tremendous impact on the family, local community, school, and athletic team. An athlete's tragic death during sports training or competition frequently stimulates debate on the adequacy of emergency planning at athletic events. Survival after exercise-related SCA in young persons is poor; the survival rate measured during a 7-year period in the United States was only 11%.[19] Thus, many schools and athletic programs have reevaluated their emergency response planning for SCA and implemented onsite school AED programs.

The presence and timely access of AEDs in schools and at sporting venues provide a means of early defibrillation not only for student athletes but also for spectators, coaches, officials, event staff, and other attendees on campus in the event of an unexpected SCA. Through education and training, school-based AED programs also may lead to improved recognition of SCA by school staff, a greater number of trained responders on school grounds, and an increased likelihood of providing early CPR and early defibrillation in

Received February 2, 2009; accepted May 26, 2009.
From the Departments of Family Medicine (J.A.D., A.L.R., M.K.B., K.G.H.) and Pediatrics (J.H.), University of Washington, Seattle.
The online-only Data Supplement is available with this article at http://circ.ahajournals.org/cgi/content/full/CIRCULATIONAHA.109.855890/DC1.
Correspondence to Jonathan A. Drezner, MD, Associate Professor, Department of Family Medicine, 4245 Roosevelt Way NE, University of Washington, Box 354775, Seattle, WA 98105. E-mail jdrezner@fammed.washington.edu
© 2009 American Heart Association, Inc.

***Circulation* is available at http://circ.ahajournals.org** **DOI: 10.1161/CIRCULATIONAHA.109.855890**

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

Table 1. Proportion of US High Schools With AED Programs That Train School Staff in CPR or AED Use and Include Staff in Annual Practice of the EAP for SCA

	CPR Trained, %	AED Trained, %	Practice EAP, %
Coaches	80	72	34
School nurses	75	71	22
Administrators	64	63	30
Teachers	49	45	22

the management of SCA. However, prior studies suggest that high schools often acquire AEDs without developing a corresponding emergency response plan for SCA, and the efficacy of early defibrillation in young competitive athletes remains uncertain.[20,21] Overall, little is known about the effectiveness of early defibrillation programs to treat SCA in the school setting. Therefore, we examined the adequacy of emergency response planning and the effectiveness of AED use for SCA in US high schools with onsite AED programs.

Methods

This study was a cross-sectional survey using the National Registry for AED Use in Sports (http://www.aedsports.com). This registry consists of a Web-based questionnaire and database management system, including a comprehensive survey on emergency planning for SCA and specific questions about AED prevalence, location, cost, use, and outcomes and the details of any resuscitation for SCA. The registry aims to monitor emergency response planning and AED use in the school and athletic setting.

Letters requesting participation in the study were sent to 18 974 member high schools from the National Federation of High Schools in December 2006 and again in March 2007. A school representative (principal, athletic director, or certified athletic trainer) was invited to complete a comprehensive survey on emergency response planning for SCA and to provide details and outcomes of any AED use for SCA occurring within 6 months of survey completion.

Of the 18 974 high schools recruited, 2084 (11%) completed the survey. Of the 2084 responding high schools, 1710 (82%) had at least 1 AED on school grounds, and 356 (17%) had no AED (<1% unknown). The high proportion of schools with AED programs responding to this survey likely reflects a responder bias toward schools with AEDs being more willing or interested to participate in the study and may represent, in part, a growing trend toward school-based AED programs. Although the overall response rate was low, the substantial total number of high schools responding with AEDs (n=1710) allows analysis of an important subgroup of US high schools most likely to have an established emergency response plan for SCA. Close examination of this large cohort of schools with AED programs has the potential to identify existing deficiencies in school emergency response plans that can be improved.

All responding schools with at least 1 onsite AED were included for examination of the adequacy of their emergency response planning for SCA and review of past incidents of AED use. The elements defining an adequate emergency response plan for SCA were based on national consensus recommendations.[22–24] We included only cases of AED use for SCA that occurred within 6 months of survey completion. Additional analyses were directed toward the details of resuscitation in cases of SCA. Any school reporting a case of SCA in a student athlete was also contacted by phone to review survey responses and to clarify the details of resuscitation. All surveys were completed between December 2006 and July 2007.

The primary outcome measure for effectiveness was survival to hospital discharge after SCA. Secondary outcome measures relative

Table 2. Case Details of SCA in 14 High School Student Athletes

Case	Age, y	Gender	Race	Sport	Duration of Exercise Before SCA, min	Exercise Intensity	Witnessed Collapse	Location of Defibrillator
1	17	M	White/Caucasian	Basketball	7.5	Easy	Yes	At venue, accessible to public
2	16	M	White/Caucasian	PE class	10–15	Easy	Yes	At venue, accessible to public
3	15	M	White/Caucasian	Baseball	60–90	Intense	Yes	At venue, accessible to athletic trainer and medical personnel
4	14	F	White/Caucasian	Volleyball	45–60	Moderate	Yes	At venue, accessible to athletic trainer and medical personnel
5	17	M	White/Caucasian	Football	45–60	Intense	Yes	At venue, accessible to public
6	15	F	White/Caucasian	Track/cross-country	45–60	Moderate	Yes	At venue, accessible to athletic trainer and medical personnel
7	15	M	White/Caucasian	Basketball	Unknown	Moderate	Yes	At venue, accessible to public
8	17	M	Asian/Pacific Islander	PE class	10–15	Easy	Yes	Brought to site from nearby venue/building
9	16	M	Black/African American	Basketball	Unknown	Unknown	Yes	At venue, accessible to athletic trainer and medical personnel
10	17	M	White/Caucasian	Crew	45–60	Moderate	Yes	At venue, accessible to public
11	17	M	White/Caucasian	Basketball	60–90	Easy	Yes	Brought by responding EMS
12	16	M	White/Caucasian	Football	15–30	Moderate	Yes	Brought by responding EMS
13	14	M	Black/African American	Basketball	30–45	Intense	Yes	At venue, accessible to public
14	16	M	White/Caucasian	Wrestling	45–60	Moderate	Yes	Brought by responding EMS

NOS indicates not otherwise specified; PE, physical education; HCM, hypertrophic cardiomyopathy; CPVT, catecholaminergic polymorphic ventricular tachycardia; ARVC, arrhythmogenic right ventricular cardiomyopathy; LQTS, long-QT syndrome; ER, emergency room; AV, aortic valve; and LVH, left ventricular hypertrophy.

*Survived indicates survival to hospital discharge.

†Reported as immediate CPR after SCA.

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

to the adequacy of emergency response planning included the proportion of schools with an established emergency action plan (EAP) for SCA, CPR and AED training for coaches and other school staff members, and review and practice of the EAP at least once annually. Secondary outcome measures in cases of SCA included the presence of seizure-like activity after collapse, provision of bystander CPR, reported time to CPR and to initial shock deployment, and cause of SCA. This study was approved by the Human Subjects Division at the University of Washington.

The authors had full access to and take full responsibility for the integrity of the data. All authors have read and agree to the manuscript as written.

Results

Demographics

We identified 1710 high schools with at least 1 AED on school grounds from the National Registry for AED Use in Sports. The mean number of AEDs per school was 2.9. The mean number of student athletes reported at each school was 371. High schools were distributed across all 50 states, with 85% public schools and 14% private schools (not reported in 1%). Forty-six percent of schools were located in a rural community, 34% were suburban, 13% were urban, and 5% were inner city. Funding for the AED program was provided by a donation or grant in 49% of the schools, the school board or school district in 30% of schools, the athletic department in 10% of schools, and the school budget itself in 4%.

Adequacy of Emergency Response Planning

Eighty-three percent (1428 of 1710) of the high schools with an on-site AED program also have an established EAP for SCA, and 60% (861 of 1428) of the schools developed their EAP in consultation with their local emergency medical services (EMS). Eighty-eight percent (1518 of 1710) of schools have an established communication system at all athletic facilities to activate EMS (ie, call 9-1-1), but only 18% (263 of 1428) of schools post a written EAP at each athletic venue.

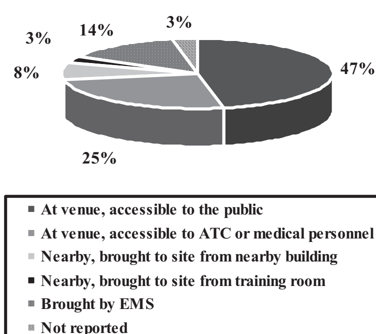

Figure 1. Location and access to AED. ATC indicates certified athletic trainer.

Table 1 shows the proportion of schools that train their coaches, school nurses, administrators, and teachers in CPR or AED use. Athletic coaches were the most likely to receive CPR training (80%) and AED training (72%). Only 40% (684 of 1710) of schools practice and review their EAP to a SCA at least once annually with potential school first responders. Coaches were included in the rehearsal of the EAP in only 34% of schools (Table 1).

Table 2. Continued

Seizure-Like Activity After Collapse	Time From Arrest to CPR, s	Time From Arrest to First Shock, s	Shock Deployed	Total Shocks, n	Outcome	Diagnosis
No	75	105	Yes	5	Survived*	Cardiomyopathy NOS
No	0†	135	Yes	1	Survived	HCM
Yes	105	150	Yes	1	Survived	CPVT
No	0	165	Yes	1	Survived	ARVC
Yes	30	195	Yes	1	Survived	Presumed primary arrhythmia
Yes	30	75	Yes	2	Survived	LQTS
Unknown	Unknown	Unknown	Unknown	Unknown	Lived 5 d, died in hospital	Viral myocarditis
Yes	105	165	Yes	4	Died at scene	Presumed primary arrhythmia
Yes	345	45	Yes	2	Survived	Presumed primary arrhythmia
Yes	105	105	Yes	1	Died in ER	Presumed primary arrhythmia
No	300	660	Yes	1	Survived	HCM
Unknown	0	Unknown	Yes	1	Died at scene	HCM
No	30	75	Yes	1	Died at scene	AV stenosis
Yes	30	690	Yes	1	Survived	Idiopathic LVH

American Heart Association. Fighting Heart Disease and Stroke
Circulation
Journal of the American Heart Association

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

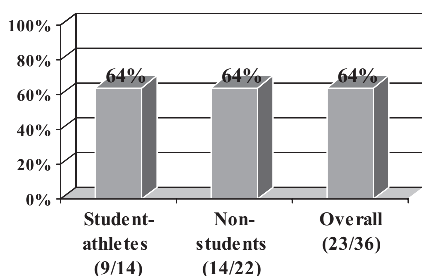

Figure 2. Survival to hospital discharge after SCA in high schools with AEDs.

AED Use for SCA

Thirty-six of the 1710 schools (2.1%) reported an incident of SCA within 6 months of completing the survey (July 2006 through July 2007). The 36 SCA victims included 22 older nonstudents (ie, spectators, teachers, staff, coaches, or officials) with a mean age of 57 years (range, 42 to 71 years) and 14 high school student athletes with a mean age of 16 years (range, 14 to 17 years). No SCA cases in a student nonathlete were reported. Twelve of the 14 cases of SCA in student athletes occurred during organized sports activity, and 2 cases occurred during recreational exercise in a physical education class (Table 2). The victims in these 2 cases were also members of a high school sports team and were reported as occurring in student athletes.

Thirty-three of the 36 schools (92%) with an incident of SCA had an established EAP, although only 18 of 36 (50%) reported practicing their EAP at least once annually. The SCA occurred at a basketball facility in 10 cases (28%), recreation/fitness facility in 7 cases (19%), classroom building in 5 cases (14%), football facility in 5 cases (14%), baseball facility in 3 cases (8%), and theater, official's locker room, cafeteria, main office, and hallway near an athletic facility in 1 case each (not reported in 1 case). Fifteen of the 36 cases (42%) occurred during an official athletic game or competition, 8 (22%) during an organized practice or athletic training session, 3 (8%) during recreational exercise, and 9 (25%) during or after school hours unrelated to a sporting event (not reported in 1 case).

Thirty-five of the 36 cases (97%) of SCA were witnessed, and 34 of 36 (94%) received bystander CPR. The first responder(s) to the SCA victim were a certified athletic trainer in 47% of cases, coach in 33%, teacher in 17%, team physician in 14%, and school nurse in 11%. The AED used in the resuscitation was located at the venue and accessible to the public or medical personnel in 72% of cases and brought to the site from a nearby building or the athletic training room in an additional 11% of cases (Figure 1). In 14% of cases, arriving EMS personnel provided the defibrillator despite the school having an AED on school grounds.

Survival

The AED deployed a shock in 30 of 36 cases (83%), and 12 victims received multiple shocks (mean, 1.7 shocks; range, 1 to 5 shocks). Of the 30 SCA victims who received defibrillation, 20 (67%) survived to hospital discharge. Overall, 23 of 36 SCA victims (64%) survived to hospital discharge, including 9 of 14 student athletes and 14 of 22 older nonstudents (Figure 2).

Details of Resuscitation in Student Athletes With SCA

Twelve male and 2 female student athletes suffered SCA within 6 months of survey completion. Given a mean of 371 student athletes at the 1710 schools, the total number of high school student athletes in this cohort was ≈634 410 over a 6-month period, or 14 SCA events in 317 205 person-years. Thus, the annual incidence of SCA in a high school student athlete estimated from this study is 4.4 in 100 000.

The specific activity at the time of SCA was basketball (n=5), football (n=2), physical education class (n=2), baseball (n=1), jogging (n=1), volleyball (n=1), rowing (n=1), and wrestling (n=1). The duration of exercise before SCA was reported in 12 cases, with a mean of 42 minutes and median of 52.5 minutes (range, 7.5 to 90 minutes). The intensity of exercise before SCA was reported as easy (ie, warm-up) in 4 cases, moderate (ie, practice) in 6 cases, and intense (ie, competition) in 3 cases and was not reported in 1 case.

All 14 cases of SCA in a student athlete were witnessed. Brief seizure-like activity was reported in 7 of 14 athletes (50%) after collapse, and a pulse and/or respirations were perceived after collapse in 8 of 14 cases (57%) for a mean duration of 2.2 minutes and median of 1.25 minutes (range, 0.25 to 5.25 minutes). Thirteen of 14 cases (93%) received bystander CPR. In 3 cases, the AED was applied before the initiation of CPR. The time from SCA to initiation of CPR was reported in 13 cases, with a mean of 1.5 minutes and median of 0.5 minutes (range, 0 to 5.75 minutes). Thirteen of the 14 student athletes (93%) with SCA received a shock. Although ECG data were not available for review, AED shock deployment in 13 of the 14 cases suggests that the initial rhythm after collapse in student athletes with SCA was predominantly ventricular fibrillation or ventricular tachycardia. The time from SCA to initial shock deployment was reported in 12 cases, with a mean of 3.6 minutes and median of 2.4 minutes (range, 0.75 to 11.5 minutes). Multiple shocks were required in 4 cases, with a mean of 1.7 shocks and median of 1 shock (range, 1 to 5 shocks).

EMS personnel were not on site before the SCA in any case. The time to EMS arrival at the site of arrest was reported in 11 cases, with a mean of 8.2 minutes and median of 8 minutes (range, 5.5 to 13.5 minutes). A structural cardiac disorder was reported in 8 of 14 cases (57%), hypertrophic cardiomyopathy in 3 cases, and myocarditis, aortic stenosis, arrhythmogenic right ventricular cardiomyopathy, cardiomyopathy not otherwise specified, and idiopathic left ventricular hypertrophy in 1 case each. A primary electric disorder was reported in 6 of 14 cases (43%), presumed primary arrhythmia (autopsy or structural workup negative) in 4 cases, long-QT syndrome in 1 case, and catecholaminergic polymorphic ventricular tachycardia in 1 case. The details of each case, the outcome, and the cause of the arrest in student athletes with SCA are shown in Table 2.

Details of Resuscitation in Older Nonstudents With SCA

Twenty-two cases of SCA (19 male, 3 female victims) occurred in older persons on school grounds. Fourteen of the

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

Table 3. Comparison of Case Details of SCA in High School Student Athletes and Older Nonstudents

SCA Victims	Age (Range), y	Witnessed Collapse, n/N (%)	Seizure-Like Activity After Collapse, n/N (%)	Bystander CPR, n/N (%)	Time From Arrest to CPR, Mean; Median; Range, min	Shock Deployed, n/N (%)	Time From Arrest to First Shock, Mean; Median; Range, min	Survival to Hospital Discharge, n/N (%)
High school student athletes (n=14)	16 (14–17)	14/14 (100)	7/12 Reported (58)	13/14 (93)	1.5; 0.5; 0–5.75	13/14 (93)	3.6; 2.4; 0.75–11.5	9/14 (64)
Older nonstudents (n=22)	57 (42–71)	21/22 (95)	5/17 Reported (29)	21/22 (95)	0.8; 0.75; 0–1.75	19/22 (86)	1.8; 1.75; 0.5–3.25	14/22 (64)

22 cases (64%) occurred during an official school-sponsored athletic game or competition. The SCA victims included 9 spectators, 3 teachers, 2 coaches, 2 athletic officials, 1 secretary, 1 support staff member, and 4 other attendees on campus.

Twenty-one of the 22 cases (95%) were witnessed. Brief seizure-like activity was reported in 5 of 22 individuals (23%) after collapse. Twenty-one of the 22 cases (95%) received bystander CPR. The time from SCA to initiation of CPR was reported in 15 cases, with a mean of 0.8 minutes and median of 0.75 minutes (range, 0 to 1.75 minutes). Nineteen of the 22 older nonstudents with SCA (86%) received a shock, suggesting that the initial rhythm shortly after collapse was predominantly ventricular fibrillation or ventricular tachycardia. The time from SCA to initial shock deployment was reported in 13 cases, with a mean of 1.8 minutes and median of 1.75 minutes (range, 0.5 to 3.25 minutes). Multiple shocks were required in 8 cases, with a mean of 1.8 shocks and median of 1 shock (range, 1 to 3 shocks).

EMS personnel were on site before the SCA in 4 of the 22 cases (18%). The reported time to EMS arrival at the site of arrest for the other 18 cases was a mean of 6.8 minutes (median, 5.5 minutes; range, 0.5 to 15 minutes). Coronary artery disease or acute myocardial infarction was reported as the cause of SCA in 7 cases. Aortic valve stenosis, congestive heart failure, and an anomalous coronary artery were reported as the cause of SCA in 1 case each. The cause of SCA was unknown or not reported in 12 cases; however, given the age of this group, it is likely that the majority of these cases were due to coronary artery disease. The details of each case of SCA in older nonstudents are shown in Table I of the online-only Data Supplement. Table 3 summarizes the details of resuscitation in both high school student athletes and older nonstudents with SCA.

Discussion

This is the largest study of emergency response planning for SCA in US high schools. Although some deficiencies in emergency response planning were identified, a high survival rate for both student athletes and older nonstudents with SCA was reported in high schools with onsite AED programs. Several studies have demonstrated a survival benefit through public-access defibrillation programs through early CPR and rapid availability of an AED for use by trained or untrained rescuers. In all of these studies, the survival rate for an SCA victim with ventricular fibrillation or ventricular tachycardia if treated promptly with defibrillation is consistently >60% (Table 4).[7,9–11]

This is also the first study to suggest an apparent survival benefit from early defibrillation in young athletes with SCA. Prior reports have shown a lower-than-expected survival rate in young athletes with SCA.[11,19,21,25] In a small cohort of 9 collegiate athletes with SCA, only 1 athlete survived (11%) despite early reported defibrillation in most cases.[21] The lower survival rate reported in collegiate athletes may be accounted for in part by the smaller proportion of SCA victims treated with onsite AEDs and the smaller proportion of victims who received defibrillation. EMS was not on school grounds at the time of SCA in any student athlete, and the average reported time to EMS arrival was >8 minutes, suggesting that defibrillation would have been significantly delayed if schools did not have AEDs.

Collapse of a young athlete during practice or competition is a relatively uncommon event, but delayed recognition of SCA by first responders can lead to critical delays in initiating CPR and defibrillation. This study suggests that half of young athletes with SCA have brief myoclonic activity after collapse that could be mistaken for a seizure. In addition, athletes with SCA were perceived to have either ongoing respirations or a pulse for an average of 2 minutes after collapse in more than half of the cases. Although it is not possible to determine whether these reports are accurate, it is well established that rescuers may mistake agonal or occasional gasping for normal breathing or may falsely identify

Table 4. Comparison of Public-Access Defibrillation Studies

	Casinos[10]	Airlines[9]	Airports[7]	NCAA Division I Universities[11]	US High Schools
Cases of SCA, n	148	36	21	35	36
Immediate resuscitation rate, % (n/N)	48 (71/148)	36 (13/36)	52 (11/21)	54 (19/35)	64 (23/36)
Cases of VF/VT, n	105	15	18	21*	30*
Resuscitation rate if shock deployed, % (n/N)	63 (66/105)	87 (13/15)	61 (11/18)	71 (15/21)	67 (20/30)

NCAA indicates National Collegiate Athletic Association; VF/VT, ventricular fibrillation/ventricular tachycardia.
*Presumed VF/VT because AED deployed a shock.

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

the presence of a pulse.[26,27] Thus, a high suspicion of SCA must be maintained for any collapsed and unresponsive athlete and an AED applied as soon as possible for rhythm analysis and defibrillation if indicated.[22]

Public access to AEDs in schools provides a means of early defibrillation and improved survival not only for student athletes but also for other persons on school grounds who suffer SCA. This study found that ≈2 in 50 high schools can expect an SCA event each year. This finding is consistent with prior studies in which the annual probability of SCA occurring in a high school ranged from 0.8% to 2.1%.[20,28,29] This study also demonstrated that the majority of SCA events occur in older persons such as employees, spectators, and other visitors on campus rather than in students or student athletes and that the majority of SCA events occur during a school-sponsored athletic game, competition, or practice.

The exact incidence of SCA in young athletes is unknown. In the United States, estimates are limited by the lack of a mandatory reporting system for juvenile sudden death, and past studies vary widely as a result of differences in the methods of data collection and the age and population studied. Previous estimates of the incidence of sudden cardiac death in young competitive athletes in the United States range from 0.3 to 0.6 per 100 000 athletes per year and have relied heavily on search of public media reports, other electronic databases, and catastrophic insurance claims.[18,30] These studies have potentially underestimated the true incidence of sudden cardiac death because of incomplete detection of all cases. This study found an annual incidence of SCA in high school student athletes of 4.4 in 100 000. Although this estimate may be influenced by responder bias, it is consistent with recent findings from a prospective, population-based study of pediatric out-of-hospital cardiac arrest in which the incidence of SCA caused by cardiovascular disease in adolescents (age, 14 to 24 years) was found to be 3.75 in 100 000.[31] It is also consistent with findings from the Veneto region of Italy, which uses a regional registry for juvenile sudden death and where a baseline incidence of sudden cardiac death in young competitive athletes (age, 12 to 35 years) of 3.6 in 100 000 was found before the implementation of a national screening program.[32]

Comprehensive emergency planning is needed in high schools to ensure an efficient and structured response to SCA. Several national guidelines have provided recommendations for emergency preparedness for SCA in schools and advocated for placement of AEDs in the school and athletic setting.[22–24,33] In 2002, the National Athletic Trainers' Association released a position statement recommending any organization or institution sponsoring athletic activities to develop and implement a written emergency plan for SCA, including acquisition of necessary emergency equipment and training of involved personnel in CPR and AED use.[23] In 2004, the American Heart Association issued consensus recommendations for the Medical Emergency Response Plan in Schools, stating that every school that cannot reliably achieve an EMS call-to-shock interval of <5 minutes should have an AED program.[24] In 2005, the American College of Cardiology 36th Bethesda Conference suggested that every school that sponsors scholastic sports activities should have access to a defibrillator within 5 minutes of collapse.[33] In addition, in 2007, an interassociation task force provided consensus recommendations for emergency preparedness for SCA in high school and college athletic programs, strongly recommending access to AEDs with a target goal of <3 to 5 minutes from collapse to first shock.[22]

Essential elements of emergency planning for SCA include training anticipated responders in CPR and AED use, establishing an effective communication system, ensuring access to early defibrillation, coordinating and integrating onsite responder and AED programs with the local EMS system, and practicing and reviewing the response plan.[22] Although all of the high schools in this study had an onsite AED, many deficiencies in emergency planning were identified and could be improved. Only 60% of schools in this study developed their emergency plan in consultation with their local EMS, and fewer than half of schools actually practice and review their plan with school staff and potential onsite responders. In addition, half of school-based AEDs were funded by donations or a grant. It is critical that schools that receive donated AEDs also develop and implement a comprehensive emergency plan for SCA.

The presence of AEDs in US high schools is a growing trend.[20,34] The desire to protect student athletes from a catastrophic event also has prompted many states, including New York, Texas, Ohio, and Georgia, to pass legislation mandating that every school have at least 1 working AED on site.[35] It appears that the success of public-access defibrillation and school-based AED programs supports an evolving standard in favor of school AED programs.

Study Limitations

This study involved a cross-sectional survey of US high schools with at least 1 onsite AED. Only schools with AEDs were included to investigate a cohort of schools most likely to have developed an emergency response plan for SCA. Although survey questions were carefully worded in an attempt to capture all cases of SCA (both deaths and survivors), it is possible that schools with an SCA event, or those with a good outcome from SCA, were more likely to respond to the survey.

The use of self-reported data is another limitation in evaluating the details and timing of resuscitation efforts after SCA. The time frame for SCA cases was limited to within 6 months of survey completion in an attempt to reduce recall bias. Still, details of the resuscitation and time estimates may have been misreported. However, in 83% of cases, an AED was available on site or within close proximity, and it is likely that early defibrillation was achieved given the high survival rate.

At present, there is no universally accepted monitoring system of SCA in schools or young athletes in the United States. Thus, cases of SCA may have gone undetected in this study, and there was no comparison group of high schools without AEDs that would be more dependent on a conventional EMS response. A large, prospective study of US high schools is currently underway through the National Registry for AED Use in Sports to further investigate emergency

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

planning and outcomes of SCA in US high schools with and without onsite AED programs.

Conclusions

School-based AED programs provide a high survival rate for both students and nonstudents who suffer SCA on school grounds. SCA can be effectively treated through prompt recognition of SCA, a coordinated emergency response, the presence of a trained rescuer to initiate CPR, and early defibrillation. Myoclonic activity is common after SCA in young athletes and should not be mistaken for a seizure. High schools are in a unique situation to have trained targeted responders such as athletic trainers, coaches, and other school staff present during school hours and at school-sponsored athletic practices and competitions where the majority of SCA cases occur. Increased efforts should be made to ensure adequate emergency response planning for SCA in schools, including CPR and AED training for likely first responders, access to early defibrillation through onsite AEDs, and routine practice and review of the response plan. Prompt availability to AEDs is the evolving standard and should be encouraged in US high schools.

Acknowledgments

The investigators are grateful to the National Operating Committee on Standards for Athletic Equipment for partially funding the National Registry for AED Use in Sports and the study of emergency response planning for SCA in the school and athletic setting. The opinions expressed herein are those of the authors and do not necessarily reflect the opinions of the National Operating Committee on Standards for Athletic Equipment.

Source of Funding

This work was supported by the National Operating Committee on Standards for Athletic Equipment.

Disclosures

None.

References

1. Rosamond W, Flegal K, Furie K, Go A, Greenlund K, Haase N, Hailpern SM, Ho M, Howard V, Kissela B, Kittner S, Lloyd-Jones D, McDermott M, Meigs J, Moy C, Nichol G, O'Donnell C, Roger V, Sorlie P, Steinberger J, Thom T, Wilson M, Hong Y. Heart disease and stroke statistics–2008 update: a report from the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. *Circulation*. 2008;117: e25–e146.
2. Larsen MP, Eisenberg MS, Cummins RO, Hallstrom AP. Predicting survival from out-of-hospital cardiac arrest: a graphic model. *Ann Emerg Med*. 1993;22:1652–1658.
3. American Heart Association in Collaboration with the International Liaison Committee on Resuscitation. Guidelines 2000 for cardiopulmonary resuscitation and emergency cardiovascular care, part 4: the automated external defibrillator: key link in the chain of survival. *Circulation*. 2000;102(suppl): I-60–I-76.
4. Becker LB, Ostrander MP, Barrett J, Kondos GT. Outcome of CPR in a large metropolitan area: where are the survivors? *Ann Emerg Med*. 1991; 20:355–361.
5. Gallagher EJ, Lombardi G, Gennis P. Effectiveness of bystander cardiopulmonary resuscitation and survival following out-of-hospital cardiac arrest. *JAMA*. 1995;274:1922–1925.
6. Bobrow BJ, Clark LL, Ewy GA, Chikani V, Sanders AB, Berg RA, Richman PB, Kern KB. Minimally interrupted cardiac resuscitation by emergency medical services for out-of-hospital cardiac arrest. *JAMA*. 2008;299:1158–1165.
7. Caffrey SL, Willoughby PJ, Pepe PE, Becker LB. Public use of automated external defibrillators. *N Engl J Med*. 2002;347:1242–1247.
8. Hallstrom AP, Ornato JP, Weisfeldt M, Travers A, Christenson J, McBurnie MA, Zalenski R, Becker LB, Schron EB, Proschan M. Public-access defibrillation and survival after out-of-hospital cardiac arrest. *N Engl J Med*. 2004;351:637–646.
9. Page RL, Joglar JA, Kowal RC, Zagrodzky JD, Nelson LL, Ramaswamy K, Barbera SJ, Hamdan MH, McKenas DK. Use of automated external defibrillators by a U.S. airline. *N Engl J Med*. 2000;343:1210–1216.
10. Valenzuela TD, Roe DJ, Nichol G, Clark LL, Spaite DW, Hardman RG. Outcomes of rapid defibrillation by security officers after cardiac arrest in casinos. *N Engl J Med*. 2000;343:1206–1209.
11. Drezner JA, Rogers KJ, Zimmer RR, Sennett BJ. Use of automated external defibrillators at NCAA Division I universities. *Med Sci Sports Exerc*. 2005;37:1487–1492.
12. Weaver WD, Hill D, Fahrenbruch CE, Copass MK, Martin JS, Cobb LA, Hallstrom AP. Use of the automatic external defibrillator in the management of out-of-hospital cardiac arrest. *N Engl J Med*. 1988;319: 661–666.
13. White RD, Asplin BR, Bugliosi TF, Hankins DG. High discharge survival rate after out-of-hospital ventricular fibrillation with rapid defibrillation by police and paramedics. *Ann Emerg Med*. 1996;28:480–485.
14. Myerburg RJ, Fenster J, Velez M, Rosenberg D, Lai S, Kurlansky P, Newton S, Knox M, Castellanos A. Impact of community-wide police car deployment of automated external defibrillators on survival from out-of-hospital cardiac arrest. *Circulation*. 2002;106:1058–1064.
15. White RD, Bunch TJ, Hankins DG. Evolution of a community-wide early defibrillation programme experience over 13 years using police/fire personnel and paramedics as responders. *Resuscitation*. 2005;65:279–283.
16. Maron BJ. Sudden death in young athletes. *N Engl J Med*. 2003;349: 1064–1075.
17. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980–2006. *Circulation*. 2009;119:1085–1092.
18. Van Camp SP, Bloor CM, Mueller FO, Cantu RC, Olson HG. Nontraumatic sports death in high school and college athletes. *Med Sci Sports Exerc*. 1995;27:641–647.
19. Drezner JA, Chun JS, Harmon KG, Derminer L. Survival trends in the United States following exercise-related sudden cardiac arrest in the youth: 2000–2006. *Heart Rhythm*. 2008;5:794–799.
20. Rothmier JD, Drezner JA, Harmon KG. Automated external defibrillators in Washington State high schools. *Br J Sports Med*. 2007;41:301–305.
21. Drezner JA, Rogers KJ. Sudden cardiac arrest in intercollegiate athletes: detailed analysis and outcomes of resuscitation in nine cases. *Heart Rhythm*. 2006;3:755–759.
22. Drezner JA, Courson RW, Roberts WO, Mosesso VN Jr, Link MS, Maron BJ. Inter-association task force recommendations on emergency preparedness and management of sudden cardiac arrest in high school and college athletic programs: a consensus statement. *Heart Rhythm*. 2007;4: 549–565.
23. Andersen J, Courson RW, Kleiner DM, McLoda TA. National Athletic Trainers' Association position statement: emergency planning in athletics. *J Athl Train*. 2002;37:99–104.
24. Hazinski MF, Markenson D, Neish S, Gerardi M, Hootman J, Nichol G, Taras H, Hickey R, OConnor R, Potts J, van der Jagt E, Berger S, Schexnayder S, Garson A Jr, Doherty A, Smith S. Response to cardiac arrest and selected life-threatening medical emergencies: the medical emergency response plan for schools: a statement for healthcare providers, policymakers, school administrators, and community leaders. *Circulation*. 2004;109:278–291.
25. Maron BJ, Gohman TE, Kyle SB, Estes NA III, Link MS. Clinical profile and spectrum of commotio cordis. *JAMA*. 2002;287:1142–1146.
26. ECC Committee, Subcommittees, and Task Forces of the American Heart Association. 2005 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation*. 2005;112(suppl):IV-1–IV-203.
27. Eberle B, Dick WF, Schneider T, Wisser G, Doetsch S, Tzanova I. Checking the carotid pulse check: diagnostic accuracy of first responders in patients with and without a pulse. *Resuscitation*. 1996;33:107–116.
28. Jones E, Vijan S, Fendrick AM, Deshpande S, Cram P. Automated external defibrillator deployment in high schools and senior centers. *Prehosp Emerg Care*. 2005;9:382–385.
29. Lotfi K, White L, Rea T, Cobb L, Copass M, Yin L, Becker L, Eisenberg M. Cardiac arrest in schools. *Circulation*. 2007;116:1374–1379.
30. Maron BJ, Gohman TE, Aeppli D. Prevalence of sudden cardiac death during competitive sports activities in Minnesota high school athletes. *J Am Coll Cardiol*. 1998;32:1881–1884.

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

31. Atkins DL, Everson-Stewart S, Sears GK, Daya M, Osmond MH, Warden CR, Berg RA, for the Resuscitation Outcomes Consortium Investigators. Epidemiology and outcomes from out-of-hospital cardiac arrest in children: the Resuscitation Outcomes Consortium Epistry–Cardiac Arrest. *Circulation*. 2009;119:1484–1491.
32. Corrado D, Basso C, Pavei A, Michieli P, Schiavon M, Thiene G. Trends in sudden cardiovascular death in young competitive athletes after implementation of a preparticipation screening program. *JAMA*. 2006;296:1593–1601.
33. Myerburg RJ, Estes NA III, Fontaine JM, Link MS, Zipes DP. Task Force 10: automated external defibrillators. *J Am Coll Cardiol*. 2005;45:1369–1371.
34. Berger S, Utech L, Hazinski MF. Lay rescuer automated external defibrillator programs for children and adolescents. *Pediatr Clin North Am*. 2004;51:1463–1478.
35. England H, Weinberg PS, Estes NA III. The automated external defibrillator: clinical benefits and legal liability. *JAMA*. 2006;295:687–690.

CLINICAL PERSPECTIVE

Sudden cardiac arrest is the leading cause of death in exercising young athletes. Several US guidelines provide recommendations for emergency planning for sudden cardiac arrest and advocate for the placement of automated external defibrillators in the school and athletic setting. Many schools have not implemented automated external defibrillator programs because of financial limitations, liability concerns, or both. Of the 11% of high schools responding to this survey, 82% had an automated external defibrillator on school grounds. Of those with automated external defibrillators, 82% had an emergency action plan in place, and 2.1% had had a sudden cardiac arrest event within the preceding 6 months. Victims were older nonstudents, including teachers, staff, and spectators, or student athletes. No arrests were reported in student nonathletes. The majority of victims survived to hospital discharge. This study provides further support for the implementation of automated external defibrillators programs in US high schools.

Circulation
Journal of the American Heart Association

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

SUPPLEMENTAL MATERIAL:

MS ID#: CIRCULATIONAHA/2009/855890

Effectiveness of Emergency Response Planning for Sudden Cardiac Arrest in United States High Schools with Automated External Defibrillators

Jonathan A. Drezner, M.D., Ashwin L. Rao, M.D., Justin Heistand, M.D., Megan K. Bloomingdale, and Kimberly G. Harmon, M.D.

University of Washington – Seattle, WA

Author Correspondence:

Jonathan A. Drezner, M.D.

Associate Professor, Department of Family Medicine

4245 Roosevelt Way N.E.

University of Washington, Box 354775

Seattle, WA 98105

W 206-598-2883

Fax 206-616-6652

Email: jdrezner@fammed.washington.edu

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

Supplemental Table. Case Details of SCA in 22 Older Non-Students

Case	Age/ Gender	Race	Location/Setting of SCA	SCA Victim	Witnessed collapse	Location of defibrillator
1	Unk M	Black/African American	Basketball facility during official game	Spectator	Yes	At venue, accessible to athletic trainer and medical personnel
2	45 M	White/ Caucasian	Basketball facility during official game	Spectator	Yes	At venue, accessible to public
3	58 M	White/ Caucasian	Basketball facility during official game	Spectator	Yes	At venue, accessible to public
4	70 M	White/ Caucasian	Football facility during official game	Spectator	Yes	Unk
5	71 M	White/ Caucasian	Basketball facility during official game	Spectator	Yes	At venue, accessible to public
6	Unk F	White/ Caucasian	Unspecified athletic competition	Spectator	Yes	Brought by responding EMS
7	Unk M	White/ Caucasian	Basketball facility during official game	Spectator	Yes	At venue, accessible to public
8	73 M	White/ Caucasian	Baseball facility during official game	Spectator	Yes	At venue, accessible to athletic trainer and medical personnel
9	62 M	White/ Caucasian	Football facility during official game	Spectator	Yes	At venue, accessible to athletic trainer and medical personnel
10	63 M	White/ Caucasian	Classroom building	Teacher	Yes	At venue, accessible to public
11	62 M	White/ Caucasian	Classroom building	Teacher	Yes	At venue, accessible to public
12	49 M	White/ Caucasian	Classroom building	Teacher	Yes	Brought by responding EMS
13	55 F	White/ Caucasian	Classroom building	School secretary	No	At venue, accessible to public
14	42 M	White/ Caucasian	Unspecified athletic competition	Coach	Yes	Brought to site from nearby venue/building

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

15	42 M	Asian/Pacific Islander	Basketball facility during official game	Coach	Yes	At venue, accessible to athletic trainer and medical personnel
16	55 M	White/ Caucasian	Football facility during official game	Attendee on campus	Yes	At venue, accessible to athletic trainer and medical personnel
17	26 M	Hispanic/ Latino	Classroom building	Attendee on campus	Yes	Brought to site from nearby venue/building
18	70 F	White/ Caucasian	Theater facility during choir performance	Attendee on campus	Yes	At venue, accessible to public
19	Unk M	White/ Caucasian	Non-sporting event at recreation/fitness facility	Attendee on campus	Yes	At venue, accessible to public
20	Unk M	White/ Caucasian	Basketball facility during official game	Athletic official	Yes	At venue, accessible to public
21	64 M	White/ Caucasian	Officials' locker room during athletic competition	Athletic official	Yes	Brought to site from nearby venue/building
22	60 M	White/ Caucasian	Cafeteria	School support staff	Yes	At venue, accessible to public

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

Supplemental Table. (continued)

Case	Seizure-like activity after collapse	Time from arrest to CPR (seconds)	Time from arrest to first shock (seconds)	Shock deployed	Total number of shocks	Outcome	Diagnosis
1	Yes	30	30	Yes	3	Survived*	Unk
2	No	105	165	Yes	1	Survived	Unk
3	No	75	45	Yes	1	Survived	AV stenosis
4	No	105	Unk	Yes	1	Died at scene	CAD/MI
5	No	Unk	Unk	Yes	1	Died during hospitalization	Unk
6	Unk	30	Unk	Yes	1	Survived	Unk
7	Yes	30	195	Yes	Unk	Survived	Unk
8	Yes	Unk	No shock	No	NA	Died during hospitalization	Unk
9	No	75	165	Yes	1	Survived	CAD/MI
10	No	45	30	Yes	2	Died in ER	CAD/MI
11	No	0†	Unk	Yes	3	Survived	Unk
12	No	No CPR	No shock	No	NA	Survived	CAD/MI
13	No	30	105	Yes	3	Survived	CHF
14	Unk	75	195	Yes	2	Survived	Unk

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009

15	No	75	135	Yes	3	Survived	Unk
16	No	Unk	Unk	Yes	1	Survived	Unk
17	Yes	45	75	Yes	1	Died at scene	Unk
18	Unk	Unk	Unk	Yes	1	Died during hospitalization	CAD/MI
19	Unk	Unk	Unk	Unk	Unk	Died in ER	Unk
20	Yes	30	105	Yes	1	Survived	CAD/MI
21	Unk	No CPR	75	Yes	3	Died in ER	CAD/MI
22	No	0	105	Yes	3	Survived	Anomalous coronary artery

SCA=sudden cardiac arrest; CPR=cardiopulmonary resuscitation; Unk=Unknown; M=male; AV=aortic valve; CAD/MI=coronary artery disease/myocardial infarction; F=female; EMS=emergency medical services; ER=emergency room.

*Survived indicates survival to hospital discharge.

[†]Reported as immediate CPR after SCA.

Downloaded from circ.ahajournals.org at CONS CALIFORNIA DIG LIB on July 29, 2009