Outcomes from sudden cardiac arrest in US high schools: a 2-year prospective study from the National Registry for AED Use in Sports

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ABSTRACT

Background Sudden cardiac arrest (SCA) is the leading cause of death in athletes during exercise. The effectiveness of school-based automated external defibrillator (AED) programmes has not been established through a prospective study.

Methods A total of 2149 high schools participated in a prospective observational study beginning 1 August 2009, through 31 July 2011. Schools were contacted quarterly and reported all cases of SCA. Of these 95% of schools confirmed their participation for the entire 2-year study period. Cases of SCA were reviewed to confirm the details of the resuscitation. The primary outcome was survival to hospital discharge.

Results School-based AED programmes were present in 87% of participating schools and in all but one of the schools reporting a case of SCA. Fifty nine cases of SCA were confirmed during the study period including 26 (44%) cases in students and 33 (56%) in adults; 39 (66%) cases occurred at an athletic facility during training or competition; 55 (93%) cases were witnessed and 54 (92%) received prompt cardiopulmonary resuscitation. A defibrillator was applied in 50 (85%) cases and a shock delivered onsite in 39 (66%). Overall, 42 of 59 (71%) SCA victims survived to hospital discharge, including 22 of 26 (85%) students and 20 of 33 (61%) adults. Of 18 student-athletes 16 (89%) and 8 of 9 (89%) adults who arrested during physical activity survived to hospital discharge.

Conclusions High school AED programmes demonstrate a high survival rate for students and adults who suffer SCA on school campus. School-based AED programmes are strongly encouraged.

INTRODUCTION

Sudden cardiac arrest (SCA) is the leading cause of death in the USA and afflicts over 350 000 persons annually.[1] Survival following out-of-hospital cardiac arrest is critically dependent on prompt recognition, early cardiopulmonary resuscitation (CPR) and access to early defibrillation.[2 3] Public access defibrillation (PAD) programmes are designed to shorten the time interval from cardiac arrest to defibrillation by the strategic placement of automated external defibrillators (AEDs) in public locations. Several studies have demonstrated improved survival with use of AED by trained or untrained lay responders within the first minutes following SCA.[4–9]

SCA is also the leading cause of sudden death in young athletes during exercise.[10 11] The risk of SCA is increased during physical activity in individuals of all ages with underlying cardiovascular disorders.[12–15] The tragic and unexpected death of a young person during sport remains a highly visible and devastating event for the general public and the medical community and invariably stimulates review of emergency preparations at athletic events. The placement of AEDs in schools and at athletic venues has become the cornerstone of emergency response planning and the prevention of sudden cardiac death in young athletes.[16–18] School-based AED programmes provide a means of early defibrillation for students as well as adults who suffer SCA on school campus. A study of 1710 high schools equipped with onsite AEDs reported a 64% survival rate in student-athletes as well as adults who suffered SCA on school campus.[17] However, limitations of the study were its cross-sectional design and potential for responder bias to influence the results.

The purpose of this study was to prospectively monitor a large cohort of US high schools to determine the outcomes of SCA in schools and the potential effectiveness of school-based AED programmes.

METHODS

Study design

High schools enroled in the National Registry for AED Use in Sports participated in a prospective observational study from 1 August 2009 to 31 July 2011. The National Registry for AED Use in Sports was developed in 2005 to monitor emergency planning and outcomes from SCA in the university athletic setting and expanded in 2006 to monitor SCA in US high schools. The registry consists of a web-based questionnaire and database management system including a comprehensive survey on emergency response planning for SCA and additional questions regarding the details of any SCA or AED use.

At the beginning of the study, each school confirmed their participation and was asked to update their survey on emergency response planning. Schools were asked to report any case of SCA or AED use that occurred on school campus. Schools were contacted quarterly by email as a reminder throughout the study period. At the conclusion of the study, each school was asked to confirm their participation in the 2-year study and reaffirm the number of cases of SCA or AED use (if any) reported. Non-responding schools were contacted by email on three additional occasions. For all non-responding schools, attempts were made to contact

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each school directly by phone to confirm their participation in the 2-year study and document any cases of SCA or AED use.

For every reported case of SCA, the details of the case were reviewed directly with the school to ensure the accuracy of the information provided and that the case occurred during the study period. Details of the resuscitation were reviewed with a school staff member familiar with the emergency response, such as a school administrator, athletic director, nurse, coach or certified athletic trainer. In some instances, publicly available media reports of the incident were reviewed to supplement the information provided. Potential cases of SCA were included only if the event occurred on school campus and within the study period, was non-traumatic (except commotio cordis) and of primary cardiac origin and if the victim was confirmed unconscious with absent pulse and respirations.

Study outcomes

The primary outcome measure was survival to hospital discharge. Additional data variables collected included witnessed arrest, provision of bystander CPR, school AED use, responding emergency medical services (EMS) defibrillator use, shock deployment, location of SCA and the age, sex, ethnicity and sport (if applicable) of the victim.

Statistical analysis

Descriptive statistics such as proportions and means were used to describe the data, as appropriate. A post hoc univariate logistic regression analysis was performed to determine factors associated with survival to hospital discharge. Specifically, we compared survival rates in schools with onsite AED use versus schools where the defibrillator used was brought by responding EMS. We also compared survival in schools with an established emergency action plan for SCA versus schools with no emergency action plan. The study was not powered to compare schools with and without an AED programme. This study was approved by the Human Subjects Division at the University of Washington.

RESULTS

Participants

A total of 2149 high schools distributed throughout all 50 states participated in the study. The mean school enrolment was 963 and the mean number of student-athletes per school was 367. Schools were 86% public and 14% private and the location of the schools was 48% rural, 33% suburban, 15% urban and 4% inner city (table 1).

Of the 2149 schools 2045 (95%) confirmed their participation for the entire 2-year study period. The remaining 104 (5%) school representatives could not be reached after multiple attempts by email and phone.

Emergency planning

School-based AED programmes were present in 87% of participating schools. Of the schools with at least one AED, the mean number of devices per school was 3.1. Eighty-three per cent of schools had a written emergency action plan for SCA. Of schools with an emergency action plan, 67% consulted the local EMS when developing the plan. School personnel most likely to be trained in CPR were coaches (80% of schools), school nurses (77%), certified athletic trainers (68%) and administrators (65%). School personnel most likely to be trained in AED use were coaches (75% of schools), school nurses (74%), certified athletic trainers (65%) and administrators (65%). Only 45% of schools reviewed and practiced their emergency response to SCA at least once annually and only 20% of schools posted their emergency action plan at athletic venues.

Table 1 School demographics

School demographics (%)	
Setting	
Inner city	4
Urban	15
Suburban	33
Rural	48
Type	
Public	86
Private	14
Student enrolment	
Less than 500	37
501 to 1000	26
1001 to 1500	15
1501 to 2000	11
Greater than 2000	11
Student-athletes	
Less than 200	36
201 to 400	29
401 to 600	17
Greater than 600	18

Of the schools without AEDs, 263 schools indicated one or more obstacles to obtaining AEDs. The most common reasons for not having AEDs were limited financial resources (80%), medicolegal concerns (24%), uncertainty on where to place AEDs (13%), school policy (10%) and unproven cost-effectiveness (1%).

SCA cases

A total of 129 possible cases of SCA were reported. Of these, 59 cases of SCA were confirmed and included for further analysis; 69 cases were excluded: of these 32 occurred outside the study time period, 20 were determined not to be SCA, 13 occurred outside the school campus and 4 were induced by trauma (eg, head injury). One case could not be confirmed as the school representative and first responders could not be contacted. The annual incidence of SCA occurring in a high school was 1 in 73 schools/year.

Case demographics

Twenty-six (44%) cases occurred in students and 33 (56%) occurred in adults. The mean age was 16 years (range 13–20) in students and 56 years (range 20–80) in adults. Of the cases occurring in students, 18 (69%) were student-athletes and 8 (31%) non-athletes. Three (17%) of the cases in student-athletes were from commotio cordis (1 each in football, ice hockey and lacrosse). Of the cases occurring in adults, 10 (30%) were spectators, 9 (27%) visitors on campus, 7 (21%) school staff, 4 (12%) athletic officials and 3 (9%) coaches.

Forty-seven (80%) cases occurred in males. Of the cases occurring in student-athletes, 16 (89%) were male and 2 (11%) were female. SCA occurred equally in males and females in the eight cases of student non-athletes. Of the cases occurring in adults, 27 (82%) were male and 6 (18%) were female.

The ethnicity of persons suffering SCA was 49 (82%) Caucasian, 8 (14%) African-American/black, and 2 (4%) Hispanic. The ethnicity of student-athletes with SCA was 12

(67%) Caucasian, 5 (28%) African-American/black and 1 (6%) Hispanic.

Location and setting

Athletic facilities were the most common location of SCA, comprising 66% of cases (box 1). Twenty (34%) cases were during games and 19 (32%) cases were during practice or training. Twenty-seven (46%) cases were in persons participating in physical activity on the school campus such as student-athletes, officials and visitors using athletic facilities. Basketball and football were the most frequent sporting events in which SCA occurred with 13 and 9 cases, respectively. Other sports in which SCA occurred included baseball (3), track and field (3), ice hockey (2), soccer (2), softball (2), cheerleading (1), cross country (1), lacrosse (1), swimming (1), and wrestling (1). Of the cases that did not occur at a sporting event, 16 (27%) occurred in a classroom building and 4 (7%) occurred in a parking lot.

Emergency response

SCA was witnessed in 55 (93%) of overall cases and in all cases involving a student-athlete. The presence or absence of seizure-like activity was reported in 40 cases, with 36% of adults and 38% of student-athletes reported to have brief seizure-like activity after collapse. The most frequent school responders to the event were administrative staff (22), certified athletic trainers (21), lay visitors (19), school nurses (19), coaches (17) and teachers (17). EMS personnel were stationed onsite at the athletic venue prior to the SCA in three cases. The average estimated time to arrival of EMS when not prestationed onsite was 7.8 min. CPR was provided by lay responders or onsite EMS personnel in 54 (92%) cases.

School-based AED programmes were present in all but one of the schools reporting a case of SCA. A defibrillator was brought to the resuscitation in all cases. The source of the defibrillator used in the resuscitation was located onsite at the school in 41 (70%) cases, brought by responding offsite EMS in 15 (25%) cases and in 3 (5%) cases EMS was already onsite and provided the defibrillator. Application of the defibrillator was confirmed in 50 (85%) cases and a shock delivered onsite in 39 (66%) cases.

Box 1 Location of sudden cardiac arrest

Location of sudden cardiac arrest (number of cases)
Athletic facility (39)
Baseball field (3)
Student-athlete (2), spectator (1)
Football stadium (5)
Student-athlete (3), visiting adult athlete (1), spectator (1)
Gymnasium/basketball (13)
Spectator (5), student-athlete (3), visiting adult athlete (3), coach (1), official (1)
Gymnasium/cheerleading (1)
Student-athlete (1)
Gymnasium/other training (3)
Student-athlete (3)
Gymnasium/wrestling (1)
Spectator (1)
Cross country (1)
Student-athlete (1)
Hockey rink (2)
Student-athlete (1), visitor (1)
Lacrosse field (1)
Student athlete (1)
Soccer field (3)
Official (2), coach (1)
Softball field (2)
Spectator (1), official (1)
Swimming pool (1)
Student-athlete (1)
Track and field (3)
Student-athlete (2), coach (1)
Classroom building (16)
Student (8), school staff (5), visitor (3)
Parking lot (4)
School staff (2), spectator (1), visitor (1)

Survival

Overall, 42 of 59 (71%) SCA victims survived to hospital discharge, including 20 of 33 (61%) adults and 22 of 26 (85%) students (table 2). Survival in males was 75% and 58% in females. Of 18 student-athletes 16 (89%) survived to hospital discharge, as did 8 of 9 (89%) adults who arrested during physical activity (figure 1). Of the 39 cases where a shock was delivered onsite, 34 (87%) survived.

Eighty per cent of SCA victims survived to hospital discharge if the school supplied the AED used in the resuscitation versus 50% if the defibrillator was brought by responding offsite EMS (unadjusted OR 4.0, 95% CI (1.14 to 14.02), p value 0.03). The survival rate was 79% in schools with an established emergency action plan for SCA versus 44% in those without (unadjusted OR 4.6, 95% CI (1.04 to 20.48), p value 0·03). None of the unwitnessed cases of SCA survived to hospital discharge.

DISCUSSION

The single greatest factor affecting survival from SCA is the time interval from cardiac arrest to defibrillation.[19] In the USA, historical survival rates from out-of-hospital cardiac arrest using conventional EMS systems are less than 8%.[20–22] Survival following SCA has been greatly improved by lay rescuers and PAD programmes designed to shorten the time interval from SCA to shock delivery.[4–9] These programmes train lay rescuers and non-traditional first responders in CPR and AED use and place AEDs in public locations where risk for SCA is high.

The PAD trial found survival from out-of-hospital SCA doubled when lay responders were trained and equipped with AEDs compared with CPR alone.[5] The Resuscitation Outcomes Consortium Epistry Cardiac Arrest registry also demonstrated that bystander application of AED prior to EMS arrival nearly doubled the likelihood of survival following out-of-hospital SCA.[8] Other studies of rapid defibrillation in specific public settings such as casinos, airlines and airports have shown survival rates ranging from 41% to 74% if bystander CPR was provided and defibrillation occurred within 3–5 min of collapse.[4 6 7] Essential elements to the success of these programmes include training of anticipated responders in CPR and AED use, a structured and practiced response, and short response times.

This is the first large prospective study of PAD in the school setting. The results of this study demonstrate a high survival rate for victims of SCA on school campus and provide compelling support of school-based AED programmes. The high survival rates in this study are likely related to several factors known to increase the probability of survival from SCA. Over

Table 2 Survival from sudden cardiac arrest in US high schools

	Number of cases	Survival to hospital discharge
All cases	59	42 (71%)
Gender		
Male	47	35 (75%)
Female	12	7 (58%)
Ethnicity		
African-American	8	4 (50%)
Caucasian	47	34 (72%)
Hispanic	2	2 (100%)
Other	2	2 (100%)
Students		
All students	26	22 (85%)
Student-athletes	18	16 (89%)
Males	16	14 (88%)
Females	2	2 (100%)
Student non-athletes	8	6 (75%)
Setting		
Sporting event	40	32 (80%)
Game/competition	21	16 (76%)
Practice/training	19	16 (84%)
Non-sporting event	19	10 (53%)
Physical activity		
During physical activity	27	24 (89%)
Student-athletes	18	16 (89%)
Adults	9	8 (89%)
Not during physical activity	32	18 (56%)
Witnessed		
Witnessed	55	42 (76%)
Unwitnessed	4	0 (0%)
CPR		
Performed	54	39 (72%)
Not performed	5	3 (60%)
Source of AED used		
School	41	32 (78%)
EMS (offsite)	16	8 (50%)
EMS (onsite)	2	2 (100%)
Defibrillation onsite		
Shock delivered	39	34 (87%)
Shock not indicated	15	6 (40%)
AED not applied	3	2 (67%)
Unable to confirm	2	0 (0%)
Emergency action plan for SCA		
Established	47	37 (79%)
Not established	9	4 (44%)
Unable to confirm	3	1 (33%)

AED, automated external defibrillator; CPR, cardiopulmonary resuscitation; EMS, emergency medical services; SCA, sudden cardiac arrest.

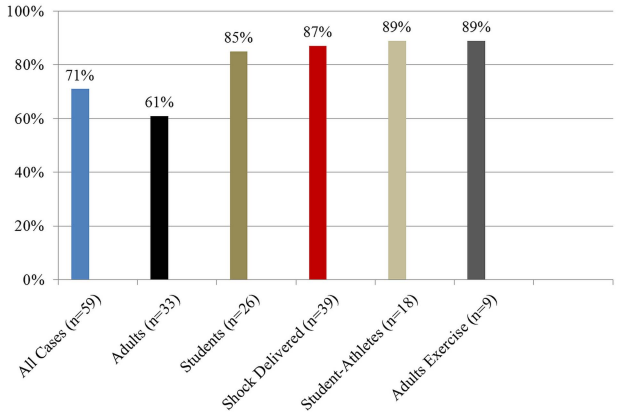

Figure 1 Survival to hospital discharge in students and adults with sudden cardiac arrest on a high school campus. Access the article online to view this figure in colour.

90% of cases were witnessed and received prompt CPR, 83% of schools had an established emergency action plan for SCA, school AEDs were readily accessible and used in nearly 70% of cases, and two-thirds of victims received defibrillation onsite.

Cases in which the school had AED but it was not used in the resuscitation (ie, responding EMS provided the defibrillator) also had a reasonably high survival rate. This may reflect that school-based AED programmes predict other important determinants of survival and better overall emergency planning for SCA. In a review of emergency planning for SCA in over 3300 high schools, schools with AED programmes were compared to schools without AED programmes and found to be more likely to ensure access to early defibrillation, establish an emergency action plan for SCA, review the emergency action plan at least annually, consult EMS in the development of the emergency action plan, and establish a communication system to activate emergency responders.[23]

On any given school day, as much as 20% of the combined US adult and child population can be found in schools.[24] Thus, schools have been identified as an important location to consider AED programmes.[24] Awareness regarding SCA in children and young athletes also has received increasing attention as a significant cause of mortality.[11 25 26] A working group of the National Heart, Lung and Blood Institute recently described sudden cardiac death in the young as a critical public health issue.[27] The cause of SCA in children and young athletes is typically the result of undiagnosed structural or electrical cardiovascular diseases, such as hypertrophic cardiomyopathy, anomalous coronary arteries and ion channel disorders.[11 28] Prior studies have reported that survival following exercise-related SCA in the young is poor.[29 30] This study suggests SCA in students and student-athletes is largely a survivable event through prompt treatment and access to AED.

While there is a growing trend towards AED placement in schools, school-based AED programmes are not yet a universal standard.[31] The primary obstacle for a school to implement an AED programme is financial concerns. Greater resource allocation towards emergency planning for SCA is needed to ensure widespread access to AEDs in the school setting. Given two-thirds of SCA on a school campus occurs at an athletic venue, prioritising AED placement to these locations should be considered if resources are limited.

This study is limited by the lack of a large control group of SCA cases in schools without an AED programme. With the increasing prevalence of AEDs in schools, establishing a sizeable cohort without AEDs is difficult. However, it is unlikely that the survival rate in schools without an AED programme would be similar. In a retrospective study of EMS treated SCA in schools, the survival rate was 39% in a community with a robust emergency response system.[32] Our study also did not follow SCA victims beyond hospital discharge and thus neurological outcomes are unknown. In previous PAD studies that assessed neurological outcome, the functional status of survivors was generally normal.[4 5] Lastly, although SCA is a highly visible event on a school campus, it is possible some cases of SCA were

not reported. The 95% confirmed 2-year follow-up in this study cohort suggests the potential for missed cases is small.

Past studies have suggested a survival benefit for school-based AED programmes but were limited by their retrospective or cross-sectional designs.[17 31 33 34] The prospective observational design in this study is similar to prior reports that established the benefit of early defibrillation and subsequently changed safety standards in specific public locations such as casinos, airlines and airports.[4 6 7] The number of SCA cases in these studies ranged from 21 to 148 and a high survival rate (61–87%) was consistently achieved across different study settings if the victim was found with a shockable rhythm and received defibrillation.[4 6 7] This study also demonstrated an 87% survival rate to hospital discharge if a shock was deployed.

CONCLUSIONS

High school AED programmes demonstrate a high survival rate for students as well as adults who suffer SCA on school campus. SCA is the leading cause of death in the USA and the leading cause of death in exercising young athletes. School-based AED programmes represent an important public safety measure and an effective strategy for the prevention of sudden cardiac death during sports. Schools are a strategic location to serve large concentrations of people at risk for SCA and school-based AED programmes should be strongly supported.

What are the new findings?

- Approximately 1 in 70 high schools will have a sudden cardiac arrest (SCA) on campus each year, and nearly half of these events will be in students or student-athletes.
- SCA in student-athletes is largely a survivable event (>85%) if the event is witnessed, the school has an established emergency action plan and the victim receives prompt cardiopulmonary resuscitation and early defibrillation from an automated external defibrillator (AED).
- Survival rates are higher in schools with an established emergency action plan for SCA versus those without (79% vs 44%; OR 4.6) and if an onsite AED is used versus an offsite AED provided by emergency medical services (80% vs 50%; OR 4.0).
- School-based AED programmes represent an important public safety measure and an effective strategy for the prevention of sudden cardiac death during sports.

How might it impact on clinical practice in the near future?

- Coaches, physical education teachers and other school staff responsible for supervising sports and physical activity in students should be trained in prompt recognition of sudden cardiac arrest (SCA), cardiopulmonary resuscitation and use of an AED.
- School sponsored sporting events should have an established emergency action plan for SCA and have a rapid access to an AED.
- School-based public access defibrillation programmes positively impact public safety standards for SCA and should be strongly encouraged.

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