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original research

High School Automated External Defibrillator Programs as Markers of Emergency Preparedness for Sudden Cardiac Arrest

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Context: School-based automated external defibrillator (AED) programs have demonstrated a high survival rate for individuals suffering sudden cardiac arrest (SCA) in US high schools.

Objective: To examine the relationship between high schools having an AED on campus and other measures of emergency preparedness for SCA.

Design: Cross-sectional study.

Setting: United States high schools, December 2006 to September 2009.

Patients or Other Participants: Principals, athletic directors, school nurses, and certified athletic trainers represented 3371 high schools.

Main Outcome Measure(s): Comprehensive surveys on emergency planning for SCA submitted by high school representatives to the National Registry for AED Use in Sports from December 2006 to September 2009. Schools with and without AEDs were compared to assess other elements of emergency preparedness for SCA.

Results: A total of 2784 schools (82.6%) reported having 1 or more AEDs on campus, with an average of 2.8 AEDs per school; 587 schools (17.4%) had no AEDs. Schools with an enrollment of more than 500 students were more likely to have an AED (relative risk [RR] = 1.12, 95% confidence interval [CI] = 1.08, 1.16, $P < .01$). Suburban schools were more likely to have an AED than were rural (RR = 1.08, 95% CI = 1.04, 1.11, $P < .01$), urban (RR = 1.13, 95% CI = 1.04, 1.16, $P < .01$), or inner-city schools (RR = 1.10, 95% CI = 1.04, 1.23, $P < .01$). Schools with 1 or more AEDs were more likely to ensure access to early defibrillation (RR = 3.45, 95% CI = 2.97, 3.99, $P < .01$), establish an emergency action plan for SCA (RR = 1.83, 95% CI = 1.67, 2.00, $P < .01$), review the emergency action plan at least annually (RR = 1.99, 95% CI = 1.58, 2.50, $P < .01$), consult emergency medical services to develop the emergency action plan (RR = 1.18, 95% CI = 1.05, 1.32, $P < .01$), and establish a communication system to activate emergency responders (RR = 1.06, 95% CI = 1.01, 1.08, $P < .01$).

Conclusions: High schools with AED programs were more likely to establish a comprehensive emergency response plan for SCA. Implementing school-based AED programs is a key step associated with emergency planning for young athletes with SCA.

Key Words: sudden cardiac death, defibrillation, resuscitation, emergency planning, athletes, students

Key Points

- This is the largest study of emergency planning in US high schools to date and the first to analyze the effect of having automated external defibrillators (AEDs) on other aspects of emergency planning for sudden cardiac arrest.
- United States high schools with AED programs were more likely to ensure access to early defibrillation, establish emergency action plans, consult local emergency medical services, review and regularly rehearse the emergency action plan, and implement a communication system to activate emergency services.

Sudden cardiac arrest (SCA) remains the leading cause of sudden death in exercising young athletes.[1] According to the National Federation of State High School Associations, student-athletes in US high schools participated in 7.5 million sport seasons during the 2008–2009 school year.[2] Although preparticipation cardiovascular screening is required in most athletic settings, it cannot detect every athlete at risk for SCA, making secondary prevention of sudden cardiac death a critical component of strategies to reduce sudden death in sports.[3] Early defibrillation with automated external defibrillators (AEDs) has been well established as the foremost treatment of SCA in the general population.[4] Only recently have data become available on the effectiveness of defibrillation in young athletes with high school AED programs, demonstrating a 64% survival rate after SCA in student-athletes.[5] Appropriately, AEDs have become the cornerstone of emergency response planning for SCA in high schools.

However, being prepared to respond to SCA extends beyond having access to early defibrillation. An adequate emergency response begins with establishing a comprehensive emergency action plan (EAP), consulting local emergency medical services (EMS), establishing a communication system to activate emergency services, training school staff and anticipated responders in cardiopulmonary resuscitation (CPR), and reviewing and rehearsing the emergency response regularly.[6,7]

We sought to determine if having an AED on a high school campus was a predictive marker of the school's comprehensive emergency preparedness for SCA and to

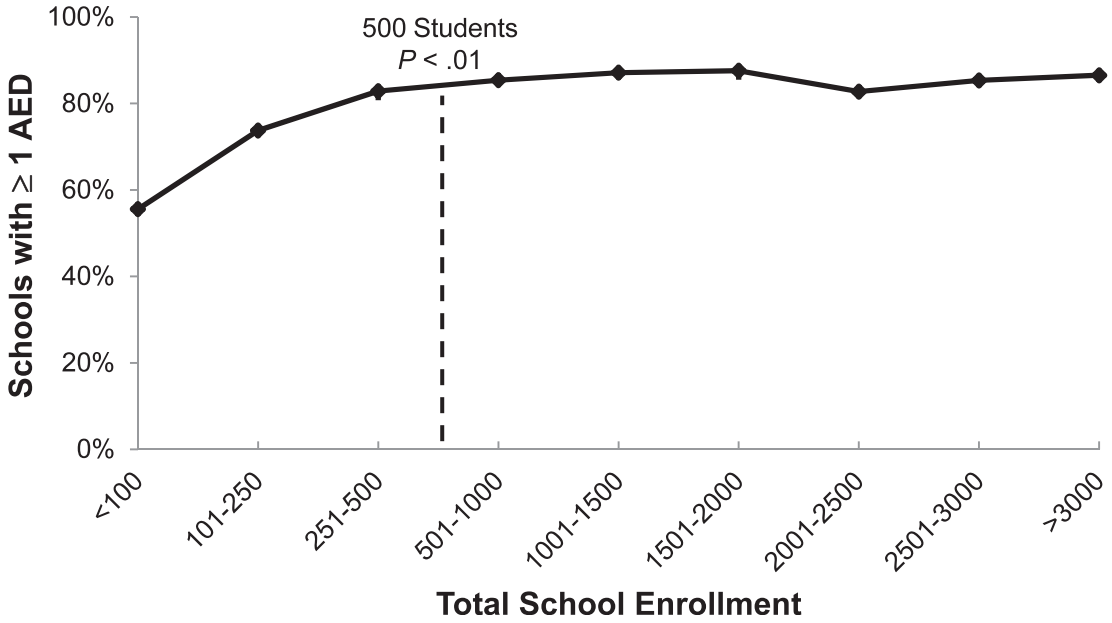

Figure 1. Automated external defibrillator (AED) prevalence by school enrollment.

compare the demographics of high schools with and without AEDs.

METHODS

Data were obtained from the National Registry for AED Use in Sports (www.aedsports.com), which was established in 2006 to monitor emergency response planning for SCA and AED use in the school and athletic settings. The registry consists of a Web-based questionnaire and database-management system, including a comprehensive survey on the elements of emergency planning for SCA and specific questions about AED prevalence, location, and obstacles to implementation.

From December 2006 to September 2009, a total of 3371 high schools from all 50 states participated in the National Registry for AED Use in Sports and were included in this study. Surveys were completed by school representatives, including principals, athletic directors, school nurses, and certified athletic trainers. Schools with and without AEDs were compared using χ^2 analysis of the core elements of emergency planning for SCA. These elements included determining early access to defibrillation at each athletic facility (defined as less than 3–5 minutes from time of collapse to first shock), establishing an EAP to respond to an SCA, consulting the local EMS in development of the EAP, establishing a communication system to activate EMS, providing formal CPR training for coaches, and practicing and reviewing the response plan annually.

The study was approved by the Division of Human Subjects at the University of Washington.

RESULTS

Presence of AEDs

A total of 2784 schools (82.6%) reported having 1 or more AEDs on campus, with an average of 2.8 AEDs per school; 587 schools (17.4%) had no AEDs. A minority of school representatives submitted incomplete emergency planning surveys; in these cases, the information provided was included in the analysis. Of the schools with a total enrollment greater than 500, 86.0% reported having at least 1 AED, compared with 76.8% of schools with less than 500 students (relative risk [RR] = 1.12, 95% confidence interval [CI] = 1.08, 1.16, $P < .01$; Figure 1). By school location, an AED was present in 81.1% of rural schools, 87.5% of suburban schools, 79.7% of urban schools, and 77.3% of inner-city schools. Suburban schools were more likely to have an AED than were rural (RR = 1.08, 95% CI = 1.04, 1.11, $P < .01$), urban (RR = 1.10, 95% CI = 1.04, 1.16, $P < .01$), and inner-city schools (RR = 1.13, 95% CI = 1.04, 1.23, $P < .01$; Table 1). Of the participating public schools, 83.2% had at least 1 AED, compared with 79.6% of private schools (RR = 1.04, 95% CI = 0.99, 1.10, $P = .06$; Table 2).

Funding for and Obstacles to Obtaining AEDs

The majority of schools (51.8%) obtained AEDs through donations or grants. For the schools that purchased an AED, the median cost was $1251 to $1500. The median yearly cost associated with having an AED (installation, maintenance, replacement parts) was less than $250. For schools without AEDs, 38.4% (n = 571) had not addressed the need for AEDs (Figure 2). The primary obstacle to obtaining AEDs in schools without them (n = 534) was financial resources (80.7%). Additional obstacles included medical-legal concerns (27.9%), uncertainty of where to place the AED (14.2%), and school policy (12.7%) (Figure 3).

AED Location, Integration, and Training

The most common locations for placing an AED were the basketball facility (41.3%), athletic training room (37.0%), nurse's office (32.2%), classroom building (27.8%), and football facility (18.7%). A total of 51.6% of schools integrated their AEDs with EMS such that an EMS dispatcher was aware of the location of the AED. The school staff most commonly trained in AED use were

Table 1. Likelihood of Having an Automated External Defibrillator on Campus by School Location

Have 1 or More Automated External Defibrillators on Campus?	Rural (A)	Suburban (B)	Urban (C)	Inner City (D)
Yes, No. (%)	1269 (81.1)	915 (87.5)	373 (79.7)	136 (77.3)
No, No.	296	131	95	40
Total, No.	1565	1046	468	176

Relative Probability of Having an Automated External Defibrillator on Campus	95% Confidence Interval	*P* Value
A versus B: 0.93	0.90, 0.96	<.01
A versus C: 1.02	0.97, 1.07	.50
A versus D: 1.05	0.97, 1.14	.22
B versus C: 1.10	1.04, 1.16	<.01
B versus D: 1.13	1.04, 1.23	<.01
C versus D: 1.03	0.94, 1.13	.50

coaches (74.3%), school nurses (72.7%), athletic trainers (65.5%), administrators (63.8%), and teachers (46.6%). The school nurse was the person responsible for AED maintenance in 56.7% of schools with AEDs.

Emergency Preparedness in Schools With and Without AEDs

Access to Early Defibrillation. A total of 84.6% of schools with AEDs reported having access to early defibrillation at every sporting venue (defined as less than 3–5 minutes from time of collapse), compared with 24.5% of schools without AEDs who depended on EMS response times (RR = 3.45, 95% CI = 2.97, 3.99, $P < .01$; Table 3).

Emergency Action Plan. Most of the schools with AEDs (86.5%) had established an EAP, compared with 47.4% of schools without AEDs (RR = 1.83, 95% CI = 1.67, 2.00, $P < .01$). Of the schools with an EAP, 67.8% of schools with AEDs developed the EAP in consultation with local EMS, compared with 57.6% of schools without AEDs (RR = 1.18, 95% CI = 1.05, 1.32, $P < .01$). Of the schools with AEDs and EAPs, 40.9% regularly practiced or rehearsed the plan, compared with 12.7% of schools without AEDs (RR = 3.21, 95% CI = 2.57, 4.00, $P < .01$).

Communication System. A total of 90.3% of schools with AEDs and 86.6% of schools without AEDs had established communication systems to activate EMS (RR = 1.06, 95% CI = 1.01, 1.08, $P < .01$).

Training in CPR. Coaches were selected to represent potential first responders when measuring schools' training of key staff members in CPR. A total of 79.8% of schools with AEDs and 78.1% of schools without AEDs trained coaches in CPR (RR = 1.02, 95% CI = 0.96, 1.09, $P = .49$).

DISCUSSION

Sudden cardiac arrest is the leading cause of death in young athletes during sport competition and training.[1,8] Emergency planning for SCA is critical to ensure a rapid, organized, and efficient response to a collapsed athlete.[6] A number of national associations have published guidelines to assist schools in their emergency planning, including an Inter-Association Task Force,[6] the American Heart Association,[9] and the National Athletic Trainers' Association.[10] These guidelines emphasize the importance of access to early defibrillation, often with the use of an AED, within the framework of a comprehensive and rehearsed EAP.

The single greatest factor affecting survival from SCA is the time interval from cardiac arrest to defibrillation.[4] In the United States, historical survival rates from out-of-hospital cardiac arrest are less than 5%.[11–13] Survival after SCA has been greatly improved by lay rescuer and public-access defibrillation programs designed to shorten the time interval from SCA to delivery of shock.[14–22] These programs train lay rescuers and nontraditional first responders in CPR and AED use and place AEDs in public locations where the risk for SCA is high. Rapid defibrillation in public settings such as casinos, airlines, and airports has led to survival rates ranging from 41% to 74% if bystander CPR was provided and defibrillation occurred within 3 to 5 minutes of collapse.[14–22] Drezner et al[5] reported on a cohort of 1710 US high schools with on-site AED programs and found similar survival rates in patients who suffered SCA on school grounds. Thirty-six cases of SCA were described, with 23 victims (64%) surviving to hospital discharge, including student-athletes and older nonstudents, such as spectators and school staff.[5]

On any given school day, the American Heart Association estimates that 20% of the US adult and pediatric population enters a school campus.[9] Thus, schools are likely a strategic location to implement public-access defibrillation programs to improve survival from out-of-hospital cardiac arrest.

This is the largest study of emergency planning in US high schools to date and the first study to analyze the effect of having AEDs on other aspects of emergency planning for SCA. Schools with at least 1 AED were more likely to be prepared to respond to an SCA on campus. These schools were nearly 3.5 times more likely to ensure access to early

Table 2. Likelihood of Having an Automated External Defibrillator on Campus by School Type

Have 1 or More Automated External Defibrillators on Campus?	Public	Private
Yes, No. (%)	2401 (83.2)	364 (79.6)
No, No.	484	457
Total, No.	2885	93

Relative Increased Probability of Public School Having Automated External Defibrillator	95% Confidence Interval	*P* Value
1.04	0.99, 1.10	.06

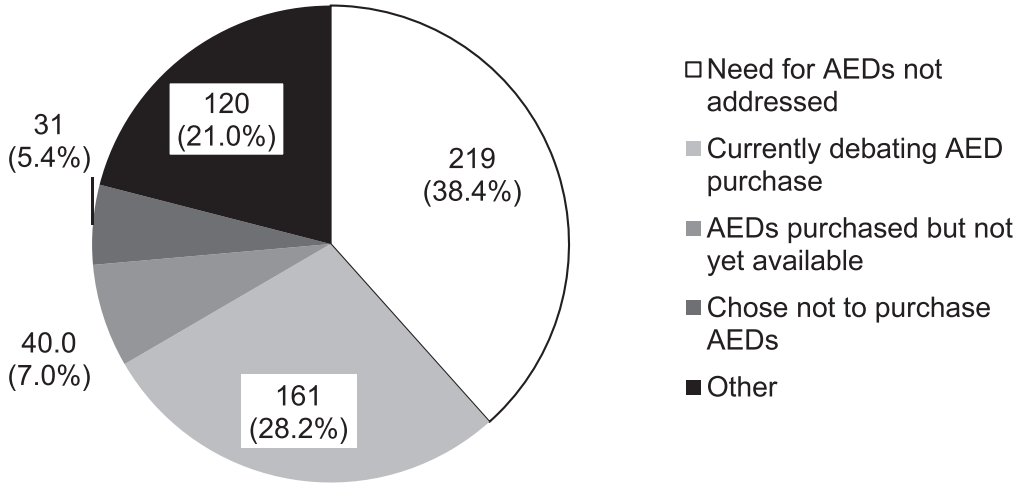

Figure 2. Reasons given by US high schools for not having an automated external defibrillator (AED) on campus.

defibrillation, nearly 2 times as likely to have an EAP, and more than 3 times more likely to review and rehearse their EAPs. Schools with AEDs were also more likely to develop their EAPs in coordination with local EMS and to establish a communication system to activate EMS.

When we compared schools with and without AEDs, the prevalence of coaches trained in CPR did not differ. This may be related to the widespread requirement in many states and school districts that coaches be trained in CPR.

This study illustrates that many high schools are not prepared to respond to an SCA or have significant deficiencies that could be improved. Roughly 1 in 5 schools did not have an AED, half of schools without AEDs did not have any EAP for SCA, less than half of schools with an EAP regularly reviewed and rehearsed the plan, and 1 in 5 high schools did not train their coaches in CPR.

This study was not designed to measure the true prevalence of AEDs in high schools, and responder bias likely explains the high proportion of participating schools with AEDs. Schools that participated in the National Registry for AED Use in Sports also may be biased toward having more developed emergency planning for SCA on a school campus. Thus, the results presented may represent a best-case scenario and overrepresent actual emergency preparedness in high schools throughout the country. However, any responder bias would apply to participating schools both with and without AEDs and does not account for the differences seen in this study. In addition, because of the cross-sectional survey design, we could not identify a pattern of how schools progress in their emergency preparedness. Specifically, we could not tell whether more-prepared schools were more likely to obtain AEDs or if the schools that obtained AEDs later became better prepared in other elements of emergency planning. Nonetheless, the presence of AEDs in high schools is clearly associated with better overall emergency preparedness for SCA.

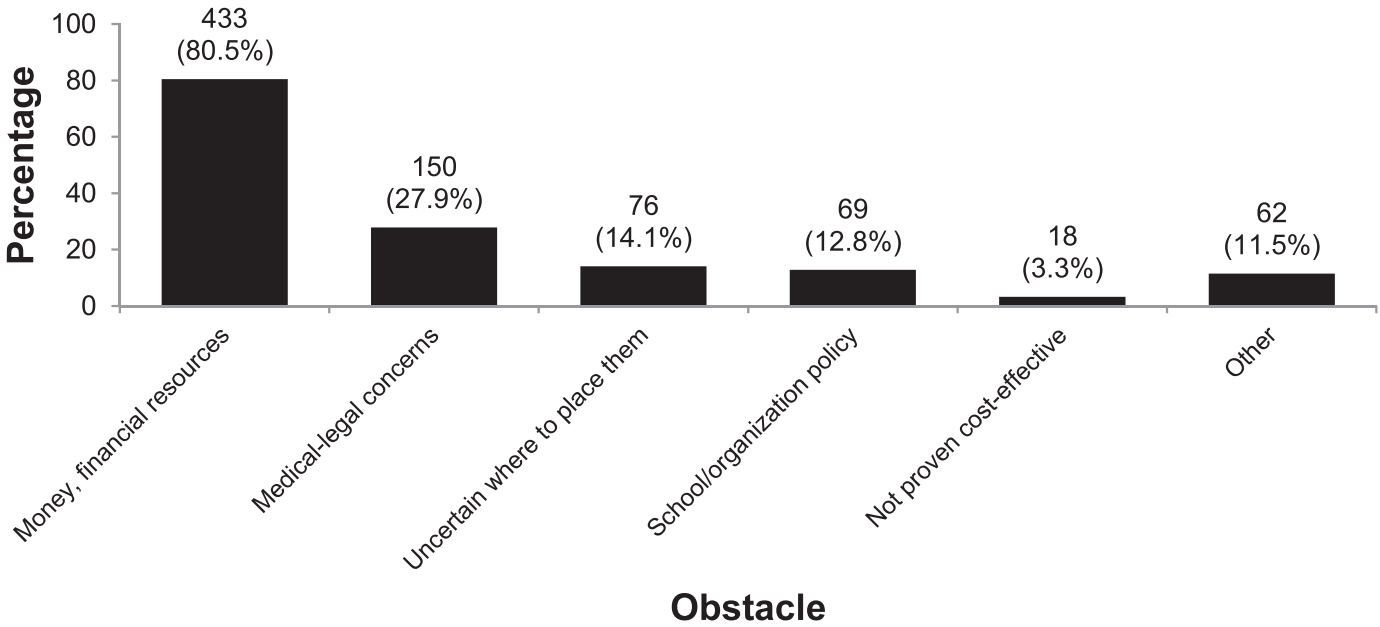

Figure 3. Obstacles to obtaining automated external defibrillators in 571 US high schools.

Table 3. Comparison of Preparedness of Schools With and Without Automated External Defibrillators on Campus

Preparedness Item	Automated External Defibrillators on Campus, No.		Relative Probability if Automated External Defibrillator on Campus	95% Confidence Interval	*P* Value
	≥1 (n = 2784)	0 (n = 587)			
Access to early defibrillation?[a]					
Yes, No. (%)	2265 (84.6)	135 (24.6)	3.45	2.97, 3.99	< .01
No, No.	412	415			
Total, No.	2677	550			
Established emergency action plan?					
Yes, No. (%)	2301 (86.5)	263 (47.4)	1.83	1.67, 2.00	< .01
No, No.	359	292			
Total, No.	2660	555			
Regular review and rehearsal of emergency action plan?					
Yes, No. (%)	1027 (46.2)	59 (23.2)	1.99	1.58, 2.50	< .01
No, No.	1196	195			
Total, No.	2223	254			
Emergency action plan developed with emergency medical services?					
Yes, No. (%)	1404 (67.8)	137 (57.6)	1.18	1.05, 1.32	< .01
No, No.	666	101			
Total, No.	2070	238			
Established communication system?					
Yes, No. (%)	2454 (90.3)	498 (86.6)	1.06	1.01, 1.08	< .01
No, No.	265	77			
Total, No.	2719	575			
Coaches trained in cardiopulmonary resuscitation?					
Yes, No. (%)	2184 (79.8)	209 (78.0)	1.02	0.96, 1.09	.49
No, No.	554	59			
Total, No.	2738	268			

[a] Defined as <3–5 minutes from time of collapse to delivery of first shock.

CONCLUSIONS

United States high schools with AED programs were more likely to establish a comprehensive emergency response plan for SCA than high schools without AED programs. These schools were more likely to ensure access to early defibrillation, establish an EAP, consult local EMS, review and rehearse the EAP regularly, and develop a communication system to activate EMS. School-based AED programs are a key link associated with comprehensive emergency planning for SCA in high schools. Significant potential remains for nationwide improvement in preparedness for SCA in US high schools.

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