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Title: Out-of-hospital Cardiac Arrest in Schools. A Systematic Review

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Out-of-hospital Cardiac Arrest in Schools. A Systematic Review

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Abstract

Background: Out-of-hospital cardiac arrest (OHCA) in children and adolescents is rare, with a minority of cases occurring at school. When OHCA does occur at school it is more likely to affect an adult than a student. Developing comprehensive strategies to treat cardiac arrest occurring at schools would be helped by accurate data regarding its epidemiology.

Methods: A systematic review was undertaken. An electronic search strategy of MEDLINE and EMBASE databases was devised and relevant papers reporting data on school-based OHCA incidence and/or outcome in both adults and children were identified. Further articles were obtained from the bibliographies of these papers and from related articles.

Results: Nine studies were included in the systematic review. Cardiac arrest incidence was one per 23.8 – 284.1 schools per year. Cardiac arrest incidence amongst students, reported in some studies, was 0.17 – 4.4 per 100,000 students per year. Studies also reported, although not universally, rates of witnessed OHCA (25.0% - 97.2%), VF (57.4% - 67.6%),

bystander CPR (25.0% - 94.4%) and Automated External Defibrillator (AED) use (23.4% - 91.5%). Survival to hospital discharge or at one month was between 31.9% and 71.2%.

Conclusion: Cardiac arrest in schools is rare, and more likely to occur in adults than children. Outcomes are better than OHCA occurring at other locations, probably due to the high proportion of witnessed arrests and high rates of bystander CPR. It is likely that school-based AEDs will rarely be needed, but have the potential to make a dramatic impact on outcome.

Introduction

Out-of-hospital cardiac arrest (OHCA) in children and adolescents is a rare, but devastating event, with incidence rates between 3.0 and 9.0 per 100,000 per year reported in international studies. [1-6] Life-years lost and healthcare costs for survivors are very high, [7] and the emotional burden incalculable.

Children over one year of age who suffer OHCA have double the odds of survival compared to adults [6] with better rates of survival and good neurological outcome in those of school age. [8] Only a minority of these OHCA occur specifically whilst the victim is at school – just 4.4% of all cases of paediatric OHCA and 13.1% of those in a public location. [9]

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Risk factors for sudden cardiac arrest (SCA), particularly in younger victims, include male sex and athletic activity. [10-13] Many cardiac arrests occur in those without known underlying health problems, and in some cases a definitive cause for the cardiac arrest cannot be found even after autopsy. [14-16] With such uncertainty about who is at risk there must be emphasis on the best strategies to maximise the chances of neurologically-intact survival in those who do suffer cardiac arrest.

Early bystander CPR and prompt defibrillation improve survival, largely because patients are more likely to have a favourable rhythm when defibrillation is attempted. [17-18] AEDs are appropriate for use in children, [19] but the clinical and cost-effectiveness of placing AEDs on school grounds is unclear. More information about the epidemiology of OHCA occurring in schools would help guide policy and planning. This will, of course, include adult victims, such as teachers, parents and other visitors, as well as children.

The aim of this systematic review is to identify evidence about the occurrence and outcome of all cardiac arrests occurring in schools, both in children and adults.

Methods

The systematic review was structured according to the PRISMA Systematic Review Checklist, [20] and registered on the PROSPERO international prospective register of systematic reviews (Record ID: CRD42015016188). [21]

Search Strategy

Relevant search terms were identified during a scoping search and use of PubMed PubReMiner (http://hgserver2.amc.nl/cgi-bin/miner/miner2.cgi) and the US National Library for Health's Medical Subject Headings Browser (http://www.nlm.nih.gov/mesh/MBrowser.html). These were used to inform an electronic search strategy across MEDLINE (Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) 1946 to Present) and EMBASE (1974 to 2015 February 6) (Wolter Kluwers Health, http://ovidsp.uk.ovid.com). No date limits were set: potentially relevant papers across the entire time-period covered by the databases could be considered. Details of the electronic search are available in the Supplementary File. Potential articles of interest were identified for full-text evaluation by appraisal of title and abstract by a single reviewer (CMS). Further articles were sought by bibliography search of these full-texts, and by the 'related articles' feature and free-text searches of both PubMed (http://www.ncbi.nlm.nih.gov/pubmed/) and Google Scholar (http://scholar.google.co.uk).

Papers that reported some measure (incidence or absolute number) of cardiac arrest occurring at schools in adults and children, were included. Schools were defined as institutions usually accepting students up to the age of 18 years. All types of study were considered – the nature of the topic being reviewed, and findings from an initial scoping review, made it highly likely that relevant studies would be observational in nature. English language studies with no limits on publication date were considered.

Papers were excluded if they did not attempt to characterise all school-based OHCA. For example, studies reporting only on deaths, survivors, successful AED use, specific student groups (e.g. student athletes), or OHCA not limited to those occurring at school were excluded.

A data table was constructed containing:

- Study characteristics: prospective / retrospective data collection, data collection method, type of school(s) studied
- Numbers of school-based OHCA: overall numbers, and those among students and adults separately
- Incidence: however reported (number of events per schools, per 100,000/year for students or staff if reported)

- Outcomes: Survival (overall; in students; in adults), however reported (e.g. to hospital discharge, to one month; neurological status if reported)

Due to the observational and heterogeneous nature of the studies included, meta-analysis was not performed. A narrative assessment of the key limitations and risk of biases has been reported in this review.

Results

Electronic searches were performed on 9th February 2015 and returned 877 results (221 from MEDLINE and 656 from EMBASE). After removing duplicates, the total was 819 unique articles. Ten articles [9, 22-30] were selected for full text review. Additional search strategies yielded six additional papers for full-text review. [10, 31-35] See **Figure 1.**

Of these 16 articles, nine were included in the final review: seven identified through MEDLINE and EMBASE searches [9, 22-26, 30] and two from additional search strategies [32-33]. These are presented in **Table 1.** Seven articles [10, 27-29, 31, 34-35] were excluded**.** In addition, three articles [36-38] available *only* as conference abstracts were identified (i.e. those not subsequently published as full-texts). Very limited information could be obtained from these abstracts, and this is presented in the Supplementary File.

Main findings from full-text articles

The incidence of cardiac arrest in schools (estimated in all but one [22] of the studies) was between 1 per 23.8 and 1 per 284.1 schools per year. Incidence rates in students ranged from 0.17 to 4.4 per 100,000 per year. [9, 23-25, 30] Two studies reported an incidence in staff members of 0.51 [30] and 4.3 [9] per 100,000 per year. The incidence rate in other adults could not be calculated, as the denominator (total number of adults frequenting the school) was not known.

Survival rates to hospital discharge [9, 22, 24-25] or at one month, [30] ranged from 31.9% to 71.2%. One further paper reported that none out of four cardiac arrest victims at school were alive one year after the event. [33] Only Nishiuchi et al reported on good neurological outcome, which the authors defined as Cerebral Performance Category 1 or 2. This was achieved (at one month) by 32.3% of victims. [30]

Where reported, the cardiac arrest was witnessed in between 25.0% to 93.2% of cases [22, 25, 32-33] and bystander CPR occurred in 25.0% to 94.4% of cases. [22, 25, 30, 32-33] High rates of VF were seen (57.4% [22] and 67.6% [30]) and AED deployment ranged from 23.4% to 91.5%. [22-24, 30, 32] In the papers that reported the proportion of victims actually shocked with an AED, rates were between 14.7 and 88.9%. [23-25, 30, 32] The majority of victims (between 67.6% and 86.1%) were male. [9, 25, 30, 32]

Assessment of Bias in Included Studies

A critical appraisal of individual full-text articles is presented in **Table 2.** All of the articles were case-series and, as such, are considered very low quality evidence according to the GRADE (Grades of Recommendation, Assessment, Development and Evaluation) system for appraising the quality of evidence. [39] Tools for assessing observational or non-randomised studies, such as the Newcastle-Ottawa Scale [40] and the Cochrane Risk of Bias Tool (for non-randomised studies) [41], are not entirely appropriate for this review as they are applicable to studies with groups that can be compared (e.g. cohort or case-control studies). Nevertheless, relevant elements of these tools have been used to structure the critical appraisal of included articles in **Table 2.**

Four studies reported on all types of schools [9, 22, 30, 33] and five on high schools only. [23-26, 32] In all but one paper [32] data was collected retrospectively, and sources of data varied. Thus, there are many opportunities for under– or misreporting (in questionnaire or interview based studies) or under-detection or misclassification (in studies that reviewed paper or electronic records of cardiac arrest cases). Only one paper reported neurological outcome [30] and only one gave any indication about long-term survival in victims. [33] Incidence rates, where presented for students and/or staff, can only ever be an estimate and will not allow for those that attend part-time.

The papers by Drezner et al [25, 32], Meredith et al. [23] and Watson et al. [24] were particularly prone to selection bias as they included only schools that belonged to an athletic association – thus potentially attracting more athletic students and staff/coaches and predisposing towards a higher risk of cardiac arrest. Indeed, in Drezner et al. 2009 [25] all of the enrolled schools had at least one AED, and all of the student cardiac arrests occurred in athletes. In this paper the incidence of cardiac arrest amongst students was reported at 4.4 per 100,000 per year, compared to a range of just 0.17 – 0.66 per 100,000 students per year reported in other studies. [9, 23-24, 30] Absolute numbers of cardiac arrests in all studies were low, so it would only take a few additional events to alter the incidence substantially.

Cardiac arrest terminology differed across the papers. Five used the term 'sudden cardiac arrest' (SCA), [23-25, 30, 32] two 'cardiac arrest' [22, 26] and two 'OHCA'. [9, 33] The term 'SCA' implies a higher chance of cardiac-origin events, but it was not always clear whether other non-traumatic cardiac arrest events were included or not. Reporting arrests of cardiac origin only might over-estimate the utility of AEDs in schools.

Discussion

The available evidence suggests that cardiac arrests at schools are rare events. Cardiac arrest and subsequent use of an AED are more likely in adults on school grounds than in children. Only a small proportion of all OHCA will occur in schools – Lotfi et al. reported that 58/23,597 (0.25%) cardiac arrests occurred at school in a 16-year time period (and only 8/23,597 or 0.03% occurred in students aged 3-18 years); [9] Swor et al. reported 47/30,603 (0.15%) in five years; [22] and Muraoka et al. reported 4/1,112 (0.36%) in six years. [33]

High rates of witnessed cardiac arrest, bystander CPR, VF and survival were reported in the included studies. Results of attempted resuscitation compare favourably with reported survival of 2-11% from other studies across four continents. [42] This includes those papers specifically on paediatric or adolescent populations, [8] where witnessed arrest rates of 19-37%, bystander CPR rates of 3-52%, VF/VT rates of 2-11% and survival of 4.7%-16% have been reported. Studies that report specifically on bystander witnessed OHCA report higher rates of VF/VT and survival. VF rates of 55.7% and survival of 32.2% (24.8% with good neurological outcome at one month) have been reported in bystander-witnessed OHCA occurring in school-aged children. [43] The key seems to be reaching victims early, which is likely to happen in an enclosed public environment such as a school. A review of 9,453 all-location bystander-witnessed OHCA (in all age groups) found that rates of VF were high overall (50.2%) but higher still in school-based OHCA (83.9%). [31]

The likelihood of a cardiac arrest occurring or using an AED at a school is therefore very low. However, the relatively high chance of reaching a young and otherwise fit victim promptly, in a shockable rhythm, and with a better chance of survival than most other victims of OHCA makes the idea of placing AEDs in schools very persuasive to many. There is the potential for even better survival given that AEDs were not deployed in all cases in the studies included in this review. [22, 26, 30, 32] Increased rates of survival in those presenting in VF/VT (12/23, 52.2%) compared to non-VF-VT (2/11, 18.2%) were reported by Nishiuchi et al. [30] and have been reported extensively elsewhere in the past. Drezner and colleagues [32] reported survival rates of 80% if the school's AED was used compared to 50% if EMS' AED was used (unadjusted odds ratio for survival of 4.0, p = 0.03). In one study a mean time interval from collapse to shock of 1.8 minutes in adults and 3.6 minutes in students was achieved by bystanders using an on-site AED (although this data was only reported in selected cases). [25] In contrast, EMS response times reported in the included studies were between 5 and 9.2 minutes, [24-25, 30, 32] with one paper reporting median time-to-EMS-shock as 10 minutes for students and 7 minutes for adults. [30]

Schools are community centres that are often frequented by significant numbers of people not directly associated with the school. If a school is considered a convenient location for a Public Access Defibrillator available to the wider community, then the utility of an AED may be greater. From the studies in this systematic review, many adult cardiac arrest victims on school grounds (17/20, 85% [30] and 32/50, 68% [9]) were not staff

members, and a sizeable proportion of cardiac arrests at schools happened outside normal school hours. [9, 22]

If AEDs are purchased and deployed by schools, they should ideally be used in the context of a co-ordinated response plan to cardiac arrest. Unadjusted odds for survival of 4.6 were reported from cardiac arrest in schools that had an emergency response plan compared to those that did not. [32] Training must be an important part of this, including the recognition of cardiac arrest. Seizure-like activity was reported commonly at the time of school cardiac arrest, [25] and Swor et al. reported 3 cases where an AED was not used because of confusion caused by seizure-like activity or agonal breathing at the time of collapse. [22]

Bystander CPR is more likely to be given by those who have had some training, [44] and schools provide access to a large captive audience in a structured learning environment. Older students can learn and practise resuscitation skills effectively, [45-46] and the benefits of training large number of students to perform CPR and use an AED would extend beyond the school, creating a generation of trained bystanders who can disseminate their knowledge further. 17 states in the US mandate CPR training for students [44] but efforts to introduce this in the UK have been unsuccessful. However, voluntary initiatives are trying to improve CPR training in schools. [47]

The cost-effectiveness of AED deployment and emergency response programmes is more difficult to gauge. It is likely that many AEDs in schools will remain unused. Rothmier et al. reported specifically on AED usage at schools and estimated the chance of an AED being used at just 0.65% per year. [28] The American Heart Association estimated that a programme including emergency response planning, CPR training and AED deployment would cost schools $1.6 – 3.3 million per life saved. [48] Another project estimated that an AED would have to save one student life per year to be considered cost-effective at a threshold of $100,000 for each quality-adjusted life year saved, although this did not account for adult cardiac arrest victims in schools. [49] Further, since these two articles [48-49] were published much training material can be accessed online and AEDs are less expensive to purchase, potentially reducing costs considerably.

Limitations

Much of the data in the studies included were collected retrospectively with a significant chance of cases of OHCA being over- or under-reported. Differences in student populations and reporting of outcome measures make meaningful comparison between studies difficult. The quality of evidence from case-series is generally regarded as very low [39], but it does represent the best evidence on this topic currently available.

There is probably more information available, as yet unreported in the literature, about OHCA occurring in schools. Established systems are required for prospective data collection from a number of sources (e.g. schools, media, EMS, hospitals) and OHCA registries reporting according to the Utstein style. [50] In the UK, the Department of Health estimate that there are 88 deaths each year from SCA in children under the age of 18, although it is not known how many of those occur at school. [51] A research database standardising data collection about OHCA (Warwick Medical School's Out of Hospital Cardiac Arrest Outcomes project) could help provide such data about incidence and outcomes from cardiac arrests in schools in the UK in the future. [52]

Conclusion

Cardiac arrests in schools are rare, and more likely to occur in adults than in children. Good survival can be achieved, and this is likely due to the patient population and high rates of witnessed arrests, bystander CPR and VF/VT at first rhythm check. AEDs in schools would seldom be deployed, but there is a high likelihood that they would be effective if used appropriately.

Conflict of interests

None known. No funding was received for this work.

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Figure 1: Study Selection Process

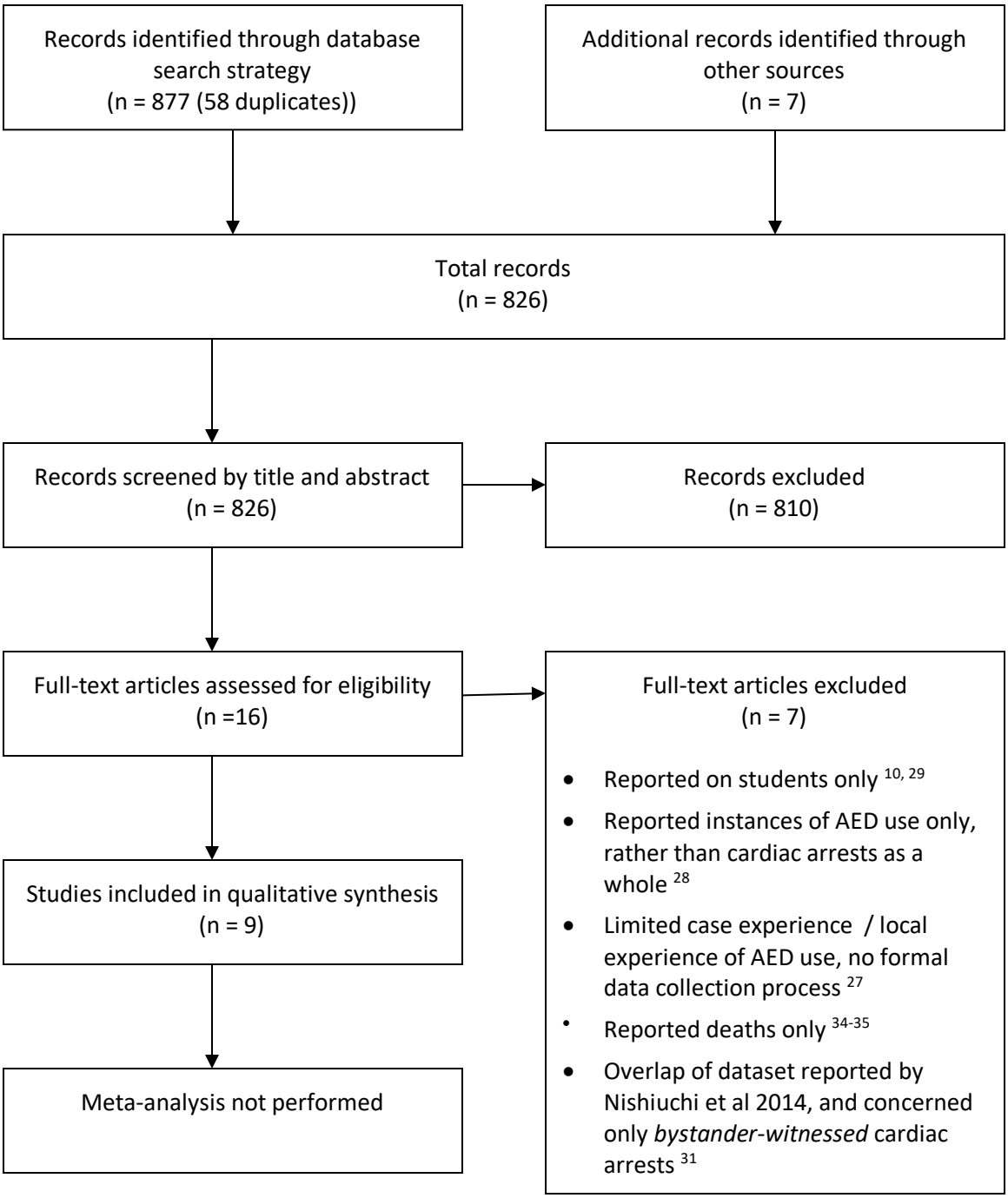

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Table 1: OHCA in Schools – Full-Text Studies Included in Systematic Review

Study	Study Characteristics	OHCA (n)			Incidence			Survival *		
		Overall	Students	Adults	School	Students (per 100,000/yr)	Staff (per 100,000/yr)	Overall	Students	Adults
Nishiuchi et al 2014 [30] Osaka, Japan (2005-2009)	Retrospective data collection Registry review Elementary, junior high and high schools	34	14	20 (3 staff)	1 per 284.1 schools/yr	0.23	0.51	14/34 (41.2%) (one month) 11/34 (32.3%) CPC 1 or 2	4/14 (28.6%) (one month) 4/14 (28.6%) CPC 1 or 2	10/20 (50.0%) (one month) 7/20 (35.0%) CPC 1 or 2
Drezner et al 2013 [32] USA (2009-2011)	Prospective data collection School-reported incidence of cardiac arrest High schools enrolled in National Registry for AED Use in Sports	59	26	33	1 per 73 schools/yr	NR	NR	42/59 (71.2%)	22/26 (84.6%)	20/33 (60.6%)
Watson et al 2013 [24] Tennessee, USA (2011)	Retrospective data collection Survey High schools in Tennessee Secondary School Athletic Association	22	6	16	1 per 48.6 schools/yr	0.66	NR	15/22 (68.1%)	3/6 (50%)	12/16 (75.0%)
Meredith et al 2013 [23] Tennessee, USA (2006)	Retrospective data collection Survey High schools in Tennessee Secondary School Athletic Association	21	5	16	1 per 61.2 schools/yr	0.47	NR	NR	NR	NR

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Study	Study Characteristics	OHCA in schools (n)			Incidence			Survival to hospital discharge*		
		Overall	Students	Adults	School	Students (per 100,000/yr)	Staff (per 100,000/yr)	Overall	Students	Adults
Swor et al 2013 [22] USA (2006-2011)	Retrospective data collection Registry review K-12 schools	47	16	31	NR	NR	NR	15/47 (31.9%)	NR	NR
Drezner et al 2009 [25] USA (2006-2007)	Retrospective data collection Survey High schools enrolled in National Registry for AED Use in Sports	36	14	22	1 per 23.8 schools/yr	4.4	NR	23/36 (63.9%)	14/22 (63.6%)	9/14 (64.3%)
Lotfi et al 2007 [9] Seattle and King County, USA (1990-2005)	Retrospective data collection Registry review Pre-school, elementary, middle and high schools	58	8	50 (18 staff)	1 per 167 schools/yr	0.17	4.33	19/58 (32.7%)†	3/8 (37.5%)†	16/50 (32.0%)†
Muraoka et al 2006 [33] Takatsuki City, Japan (1999-2004)	Retrospective data collection Registry review All schools in area	4	NR	NR	1 per 175.4 schools/yr	NR	NR	0 (0.0%) (one year)	NR	NR
Jones et al 2005 [26] Iowa and California (USA) (2001-2002)	Retrospective data collection Survey Public high schools	3	2	1	1 per 49 schools/yr	NR	NR	NR	NR	NR

***** **Nishiuchi et al [30] reported survival at one month; Muraoka et al [33] at one year; in all other papers it is survival to hospital discharge**

† **Data not in original paper, obtained after contact with corresponding author**

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CPC = cerebral performance category
NR = not reported
OHCA = out-of-hospital cardiac arrest

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Table 2: Key Sources of Bias in Included Studies

Study	Case Definition and Selection Bias	Information or Detection Bias	Response Bias	Other
Nishiuchi et al 2014 [30]	All non-traumatic "sudden cardiac arrest" – not further defined. Cases "resuscitated and transported by Emergency Medical Services" All schools included	Retrospective data collection. Registry Review – relies on accurate data input Potential for exclusion of cases note transported by Emergency Medical Services (e.g. futility) Data not verified with school reports	–	–
Drezner et al 2013 [32]	All non-traumatic "sudden cardiac arrest" defined: Primary cardiac origin only; confirmed unconscious with absent pulse and respirations; *or* Commotio Cordis Only schools enrolled in National Registry for AED use in Sports approached to participate	Prospective data collection School-reported events. Specific definition of "sudden cardiac arrest" (e.g. absent pulse and respirations). Both could result in under-reporting Did not verify school reports with other data sources	Only 2149 high schools (of approximately 19,000 member schools) participated. (Exact number of potential responders not specified in text, inferred from Drezner et al 2009 [25]	Schools asked to update a survey on their Emergency Response Plan before participating in study – in itself might affect the response to cardiac arrest, AED use and survival
Meredith et al 2013 [24]	Sudden cardiac arrest – not further defined Only schools that were a member of a high-school athletic association were approached	Retrospective data collection Survey and follow-up telephone interview – potential under-reporting of events Did not verify school reports with other data sources	Response rate only 257/378 (68.0%)	No survival or other outcome data reported

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Study	Case Definition and Selection Bias	Information or Detection Bias	Response Bias	Other
Watson et al 2013 [23]	Sudden cardiac arrest – not further defined Only schools that were a member of a high-school athletic association were approached	Retrospective data collection Survey and follow-up telephone interview – potential under-reporting Did not verify school reports with other data sources	Response rate only 214/396 (54.0%)	–
Swor et al 2013 [22]	"Cardiac arrests" – not further defined. Term 'SCA' used frequently All K-12 schools included	Retrospective data collection Registry review of cases – relies on accurate data input; structured telephone interview follow-up. Potential for mis-classifcation and under-reporting Location verified with Emergency Medical Services data	Telephone interview in only 30/47 (63.8%) of cases	–
Drezner et al 2009 [25]	Sudden cardiac arrest – not further defined. Only schools enrolled in National Registry for AED use in Sports approached to participate Student cardiac arrests occurred exclusively in athletes	Retrospective data collection Web-based questionnaire – potential under-reporting Did not verify school reports with other data sources	Data from only 1710/18,974 (9.0%) potential responders were analysed	–

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Study	Case Definition and Selection Bias	Information or Detection Bias	Response Bias	Other
Lotfi et al 2007 [9]	Out-of-hospital cardiac arrest: treated by Emergency Medical Services, non-traumatic, aged ≥ 3 years All public and private schools	Retrospective data collection Registry review – relies on accurate data input. Potential for mis-classification Data verified from several sources (school, hospital, death certificates)	–	–
Muraoka et al 2006 [33]	Out-of-hospital cardiac arrest resuscitated by Emergency Medical Services	Retrospective data collection Registry review – relies on accurate data input. Potential for mis-classification Potential for exclusion of cases note transported by Emergency Medical Services (e.g. futility) Data not verified with school reports	–	Subgroup analysis of all OHCA in a specific area: study not primarily designed to record OHCA occurring specifically at school
Jones et al 2005 [26]	Cardiac arrest – so defined if: "anybody collapsed, became unconscious, required performance of cardiopulmonary resuscitation, and required transportation to the local hospital" Public high school with ≥ 75 students. 100 randomly selected from each of two areas. Private and smaller schools excluded	Retrospective data collection Telephone survey about "medical events requiring Emergency Medical Services" with follow-up to determine if there was a cardiac arrest – potential for under-reporting	Responses from 147/200 (74.0%) schools analysed	No survival data available

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