Student Athletes, Sudden Cardiac Death, and Lifesaving Legislation: A Review of the Literature

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ABSTRACT
Purpose: The purpose of this article is to present findings of a literature review examining the use of automatic external defibrillators (AEDs) for student athletes experiencing sudden cardiac arrest and variances in state legislation regarding the mandatory placement of AEDs in school gymnasiums and athletic fields.
Methods: A broad search of computerized databases was conducted utilizing PubMed, Medline, CINHAHL, and the Cochrane Databases, which provided a broad but not exhaustive review of the current literature related to student athletes, sudden cardiac death, and the use of AEDs. The articles were evaluated and graded using Stetler’s strength of evidence guidelines.
Findings: A total of 17 articles are included in this literature review (Stetler’s Grade I, n = 1; Grade II, n = 2; Grade III, n = 2; Grade IV, n = 5; Grade V, n = 3; and Grade VI, n = 4). The literature produced few meta-analyses of controlled studies, experimental studies, and quasi-experimental studies on the topic of student athletes at risk for sudden cardiac death. The majority of the literature is based on expert opinion, case reports, and retrospective data sets. The literature does support the correlation of early cardiopulmonary resuscitation and defibrillation with increased survival rates among persons experiencing sudden cardiac arrest.
Conclusions: Additional evidence-based research is needed to support the long-term outcomes of AED legislation and its utility in sparing the lives of student athletes. However, the evidence supporting early intervention, a coordinated emergency plan, and rapid emergency medical services response is conclusive enough to warrant state or federal legislation mandating that AEDs be present in all school gyms and athletic fields. J Pediatr Health Care. (2015) 29, 233-242.

KEY WORDS
Automatic external defibrillator, student athlete, sudden cardiac death, legislation

Sudden cardiac arrest (SCA) is a leading cause of death in children and young adults, accounting for 10,000 deaths in this age group annually in the United States (Sudden Cardiac Arrest Foundation, 2014). A primary cause of death in young athletes is SCA during exercise. Seventy-five percent of all fatalities that occur during sports in the United States are cardiovascular related. It is estimated that the incidence of SCA in young persons ranges from 0.5 to 20 per 100,000 person-years (Meyer et al., 2012). Student athletes who experience SCA are predominantly male, and most cases occur during physical activity or shortly after the activity. Few epidemiological studies on death in
TABLE 1. Stetler’s strength of evidence guidelines

<table>
<thead>
<tr>
<th>Grade</th>
<th>Grade criteria</th>
<th>No. of grades out of 17 articles</th>
<th>% of grades out of 17 articles</th>
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<tr>
<td>I</td>
<td>Meta-analysis of multiple controlled studies</td>
<td>1</td>
<td>5.9</td>
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<tr>
<td>II</td>
<td>Individual experimental study</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>III</td>
<td>Quasi-experimental study such as nonrandomized controlled single group pre-post test, time series, or matched case-controlled studies</td>
<td>2</td>
<td>11.8</td>
</tr>
<tr>
<td>IV</td>
<td>Nonexperimental study, such as correlational descriptive research and qualitative or case studies</td>
<td>5</td>
<td>29.4</td>
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<tr>
<td>V</td>
<td>Case report or systematically obtained, verifiable quality, or program evaluation data</td>
<td>3</td>
<td>17.6</td>
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<tr>
<td>VI</td>
<td>Opinions of respected authorities or the opinions of an expert committee, including their interpretation of non–research-based information</td>
<td>4</td>
<td>23.5</td>
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young athletes have been performed, and most are retrospective in nature and are subject to reporting bias. Prospective studies from Veneto, Italy, estimate that annual SCA incidence is 2.3 per 100,000 person-years for all causes and 2.1 per 100,000 person-years for cardiovascular causes (Patel & Elliott, 2012).

Many states lack legislation mandating the presence of automated external defibrillators (AEDs) within school gyms and their availability on athletic fields. Currently, there are large variances in AED legislation from state to state, with few states addressing the presence of AEDs at school sporting events. Additionally, there are no firm guidelines or regulations surrounding emergency preparedness in the event of a sudden cardiac event or legislation regarding pre-participation screening of athletes.

The purpose of this systematic review was to identify current research related to the risk of sudden cardiac death (SCD) among student athletes and the use of AEDs to reduce SCD among this population, with a particular focus on mandatory state and federal AED legislation.

Early action programs and the availability of AEDs have reduced the incidence of death in airports and casinos across the United States (Link & Estes, 2012). With this proven track record, the presence of AEDs on school athletic fields and in gyms would provide safer sports involvement for athletes at risk for SCA, as well as those who may currently be undiagnosed.

METHODS

A comprehensive search of the literature was conducted via Medline, CINAHL, PubMed, the Cochrane Databases, and the THOMAS Database available through the Library of Congress. Although the search of the literature was broad, it was not an exhaustive search. The following search terms were used: student athletes AND sudden cardiac death; student athletes AND automatic external defibrillators; sudden cardiac death AND automatic external defibrillators; automatic external defibrillators AND legislation.

Articles were reviewed with an overall goal of finding a group of articles that focused specifically on student athletes at risk for SCD and the use of AEDs to prevent SCD. Expert opinion, consensus statements, reviews, and qualitative and quantitative studies were included in this review. Articles had to be published in English and had to focus specifically on SCD and AEDs, student athletes and SCD, or AED legislation. Articles were excluded if they did not focus on SCD and AEDs, if there was no mention of SCD related to athletics, if the research design was unclear or of poor quality, and if the argument presented was not well reasoned or clear. The articles were further screened to determine patterns, directions, similarities, and differences among the articles within the sample.

The search yielded 17 articles that were evaluated according to Stetler’s (2001) strength of evidence guidelines. The grading is outlined in Table 1. The majority of the articles reviewed received grades of IV, V, and VI. This finding indicates that few meta-analyses of controlled studies, experimental studies, and quasi-experimental studies have been performed on the topic of student athletes at risk for SCD and AED legislation mandating that AEDs be available in all school gyms and athletic fields. The majority of the research is based on expert opinion, case reports, and retrospective data sets.

RESULTS

The original literature search located 32 articles. These 32 articles were screened for inclusion/exclusion criteria, four articles were added after reviewing references from the 32 articles, and 19 articles were subsequently eliminated for a final total of 17 articles. These 17 articles were retained for this review and divided into subcategories, including systematic reviews (n = 4), prevalence and risk (n = 6), interventions (n = 2), and problem solving and strategies (n = 5; Table 2).

Review of Legislation

Legislation regarding defibrillation varies widely from state to state within the United States. Public access defibrillation (PAD) policies are effective in all 50 of the United States in some capacity. These policies consist of 13 elements that make up a PAD program. Currently, no state mandates that all 13 elements be represented within their respective programs. Eighteen percent require 10 elements, and 31% require three or fewer...
TABLE 2. Reviewed article summaries

<table>
<thead>
<tr>
<th>Reference</th>
<th>Relevant findings</th>
<th>Grade</th>
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<tr>
<td>Aufderheide et al. (2006)</td>
<td>The authors make recommendations regarding state AED legislative wording, including immunity for lay responders, effective training of lay rescuers, link with EMS, and ongoing quality improvement. The authors also provide sample legislative wording to assist policymakers in rewriting state legislation. Finally, the authors propose that effective AED legislation would save lives by reducing time from collapse to CPR and defibrillation. Ideal timing to give care is within 3 to 5 minutes of the collapse.</td>
<td>VI</td>
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<td>Corrado et al. (2006)</td>
<td>The authors reported 55 SCDs in screened athletes and 265 SCDs in unscreened nonathletes during the study period. The annual incidence of SCD in athletes decreased by 89%, but the incidence of SCD among the nonathletes who were not screened did not change significantly. The risk of SCD in the prescreening period was 0.56 and decreased to 0.21 in the late screening period. The decrease in mortality is attributed to more athletes with cardiomyopathies being diagnosed and restricted from sports through preparticipation screenings.</td>
<td>II</td>
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<tr>
<td>Drezner et al. (2008)</td>
<td>Over the 7-year period, 486 SCAs were identified among grade school, middle school, high school, and college-aged youth, demonstrating 69 cases per year. The survival rate was 11%; 83% of the subjects were male and 17% were female. The authors suggest improved emergency response and access to AEDs as areas to consider for improved outcomes for U.S. youth who experience an SCA.</td>
<td>V</td>
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<td>Drezner et al. (2009)</td>
<td>Of the 2,084 schools surveyed, 1,710 high schools have an on-site AED program. Eighty-three percent of the schools with an AED program also have an emergency response plan for SCA. However, only 40% practice and review the plan on an annual basis with school responders. Thirty-six of the 1,710 schools reported SCA events. The 36 SCA victims included 14 high school student athletes and 22 older nonstudents such as employees and spectators. No cases were reported in student nonathletes. Of the 36 SCA cases, 35 were witnessed, 34 received bystander CPR, and 30 received an AED shock. Twenty-three SCA victims survived to hospital discharge, including 9 of the 14 student athletes and 14 of the 22 older nonstudents. These data support the use of school-based AED programs because these programs increase survival for both student athletes and older nonstudents.</td>
<td>IV</td>
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<td>Drezner et al. (2013)</td>
<td>The authors recorded 59 cases of SCA during the study, including 26 cases in students and 33 in adults. A total of 39 cases occurred at an athletic facility during training or competition; 55 cases were witnessed, and 54 received prompt CPR. An AED was applied in 50 cases, and a shock was delivered on-site in 39 cases. Overall, 71% of the SCA victims survived to hospital discharge, including 22 of 26 students and 20 of 33 adults. Sixteen of 18 student-athletes and 8 of 9 adults who experienced SCA during physical activity survived to hospital discharge.</td>
<td>IV</td>
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<td>Gilchrist et al. (2012)</td>
<td>No states mandate all 13 PAD program elements, 18% require at least 10 elements, and 31% require 3 or fewer elements. All states provide some level of protection to AED users, 60% require PAD maintenance, 59% require EMS notification, 55% impose training requirements, and 41% require medical oversight. Very few states require a quality improvement process. Overall, the review found that PAD programs are positioned to fail and that regular maintenance, notification of EMS, and required training should be mandatory for all programs to ensure success and saved lives. The authors suggested that policymakers pass legislation requiring strategic placement of AEDs and PAD registries coordinated with EMS to reduce the time from collapse to shock.</td>
<td>IV</td>
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<td>Goldberger et al. (2008)</td>
<td>The authors found that some noninvasive techniques produce a higher yield in terms of risk stratification. Other techniques are not as discriminatory. Therefore, clinicians must choose wisely when assessing risk in this patient population and consider the cost along with the reduction in mortality.</td>
<td>VI</td>
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<td>Kelly et al. (2011)</td>
<td>The authors identified a high incidence of significant arrhythmias, with 657 patients undergoing 680 interventions. Three hundred twenty-four patients were excluded. Eleven elite athletes were identified. The most common presenting symptoms were palpitations and syncope. Diagnoses included AV re-entry tachycardia, AV node re-entry tachycardia, complete heart block, sinus node dysfunction, vasovagal syncope, and pre-excitation atrial fibrillation. Patients were treated with the following interventions: implantable loop recorder, diagnostic electrophysiology study, including radiofrequency ablation, cryoablation, and pacemaker implantation. Ten children were able to return to competitive sports after the interventions. No deaths occurred.</td>
<td>V</td>
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<td>Leslie et al. (2012)</td>
<td>The authors found that screening for all 3 conditions would reduce SCD risk by 3.6 to 7.5 $\times 10^{-5}$ with projected life expectancy increases of 0.8 to 1.6 days per screened individual. The cost-effectiveness of screening was found to be $91,000 to $204,000 per life-year. Overall it was determined that the cost for targeted cardiac screening was high compared with the relative health benefit associated with the screening.</td>
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### TABLE 2. Continued.

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<th>Reference</th>
<th>Relevant findings</th>
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<td>Link &amp; Estes (2012)</td>
<td>The authors determined that the current data are limited and largely observational. Standard definitions of competitive athletes and athletic SCD are needed. The authors propose the development of national registries of athletic SCD and express a need for randomized trials of screening and restriction to assess the effects. They also suggest prospectively collecting cost and outcomes data related to screening and restriction and the long-term effects of athletic restriction. There is a need for more evidence to develop proven strategies to prevent athletic SCD; such strategies are not currently available.</td>
<td>VI</td>
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<td>Marjon et al. (2011)</td>
<td>The authors found that sports-related SCD represented 4.6 cases per million population per year. Six percent of cases occurred in young, competitive athletes. Sensitivity analyses showed an incidence ranging from 5 to 17 new cases per million population per year. More than 90% of cases happened during recreational sports. The subjects were young, and the majority were men (95%). Ninety-three percent of the cases were witnessed. Bystander CPR was started in only 50.7% of cases. The use of bystander CPR and cardiac defibrillation were the strongest independent predictors of survival to hospital discharge.</td>
<td>III</td>
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<td>Maron &amp; Pelliccia (2006)</td>
<td>The authors found that specific cardiac diseases predispose athletes for SCD. Support of screening and cardiac surveillance is demonstrated, as well as the increased need within the current American society to develop a medicolegal framework to address the issue of athletic restriction in a litigious culture. Ultimately, the authors believe the risk of SCD outweighs the benefit of playing sports.</td>
<td>VI</td>
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<td>Meyer et al. (2012)</td>
<td>The authors reviewed 361 cases of OHCA (26 cases ages 0–2 years, 30 cases ages 3–13 years, 60 cases ages 14–24 years, and 245 cases ages 25–35 years) that were treated by EMS responders, for an overall incidence of 2.28 per 100,000 person-years (2.1 in ages 0–2 years, 0.61 in ages 3–13 years, 1.44 in ages 14–24 years, and 4.40 in ages 25–35 years). The most common causes of OHCA were congenital abnormalities (84.0% in ages 0–2 years and 21% in ages 3–13 years), presumed primary arrhythmia (23.5% in ages 14–24 years), and coronary artery disease (42.9% in ages 25–35 years). The overall survival rate was 26.9% (3.8% in ages 0–2 years, 40.0% in ages 3–13 years, 36.7% in ages 14–24 years, and 27.8% in ages 25–35 years). Survival increased throughout the study period from 13.0% in 1980–1989 to 40.2% in 2000–2009 (p &lt; .001).</td>
<td>IV</td>
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<td>Migliore et al. (2012)</td>
<td>The authors identified 2,765 children, of whom 229 required further evaluation. Thirty-three percent of male athletes and 35% of female athletes ages 10 to 18 years were found to have diagnoses consistent with significant cardiac disease. T-wave inversion was found in 158 children. Increasing age, body mass index in the 10th percentile or less, and puberty were found to correlate strongly with reduction in T-wave inversion. Of the 158 children with T-wave inversion, 4 were diagnosed with a cardiomyopathy that would put them at increased risk for SCD.</td>
<td>II</td>
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<td>Rho &amp; Page (2007)</td>
<td>The authors found that response time from collapse to shock within 3–5 minutes provided higher survival outcomes, as did rapid initiation of CPR. The authors also found that an emergency response plan and a formalized relationship with EMS increased survival rates. The authors advocate the widespread distribution of AEDs combined with increased public awareness and CPR training. Liability and litigation concerns should be addressed through legislation at the federal and state level. The cost of AEDs has become reasonable and makes them more attainable by individual sites as part of their maintenance and insurance programs.</td>
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<td>Rothmier et al. (2007)</td>
<td>One hundred eighteen of 409 schools responded to the survey. Fifty-four percent of those schools had an AED in the school. AEDs were funded by donations (60%), by the school district (27%) and by the school or athletic department (11%). Coaches (78%) were the most likely to receive AED training, followed by administrators (72%), school nurses (70%), and teachers (48%). Only 25% of schools coordinated the implementation of AEDs with an outside medical agency, and only 6% of schools coordinated with the local EMS. The estimated probability of AED use to treat SCA was 1 in 154 schools per year.</td>
<td>IV</td>
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<td>Sealy et al. (2010)</td>
<td>The authors reviewed the literature and 2,401 PPE results over a 5-year period. Sixty-five percent of male athletes and 35% of female athletes ages 10 to 18 years were found to have diagnoses consistent with significant cardiac disease. Forty-three percent had diagnoses that have been associated with SCD in athletes as described in the 36th Bethesda guidelines. Diagnoses were discovered based on the presence of murmurs, chest pain, and a positive family history. Male gender was also a positive factor. The authors concluded that basic vital signs were not conclusive as a screening tool for SCD.</td>
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Note. AED = automatic external defibrillator; AV = atrioventricular; CPR = cardiopulmonary resuscitation; EMS = emergency medical services; OHCA = out-of-hospital cardiac arrest; PAD = public access defibrillation; PPE = pre-participation examination; SCA = sudden cardiac arrest; SCD = sudden cardiac death.
elements (Gilchrist et al., 2012). Meanwhile, SCA is the leading cause of death in young athletes who are exercising. The numbers are likely underestimated because until recently there was no mandatory reporting system within the United States. However, based on media reports, insurance claims, and searches of electronic databases, it is estimated that the incidence of SCD in young athletes in the United States ranges from 0.3 to 0.6 per year (Drezner, 2009).

Nationally, the nonprofit group Simon’s Fund has worked aggressively since 2009 to enact the Sudden Cardiac Prevention Act in each state across the United States. Although the act does not address AED availability or pre-participation screening, it does address three lifesaving components, including parental review of SCA information and signature for all public school athletes before sports involvement; an online annual training SCA course for all public school coaches; and the expectation that coaches must remove any player who exhibits cardiovascular signs and symptoms during play, with the student being unable to return to play until he or she is cleared by a medical professional. To date, Simon’s Fund has introduced the legislation in 11 states, with six states signing the bill into law (Simon’s Fund, 2014).

At the federal level, there are currently two bills pending in the House of Representatives that mention AEDs. The first bill, H. R. 2135, seeks to amend the current Public Health Service Act to provide immunity to anyone who uses an AED to save someone’s life. The second bill, H. R. 2308, is focused on providing cardio-pulmonary resuscitation (CPR) training and AED education to all students in primary and secondary schools across the country (Congress.gov, 2014). Neither bill refers to mandatory AED placement at student athlete sporting events.

Additionally, when examining AED legislation, the question of pre-participation screening also comes up as a viable lifesaving measure for all student athletes. Current research reveals many benefits of pre-participation screening, but the cost involved in performing these screenings and the risk for false-positive results remains an ethical challenge for school administrators and health practitioners alike (Corrado et al., 2006).

Review of the Literature
One regional review in the state of Washington investigating out-of-hospital cardiac arrest (OHCA) in subjects ages 0 to 35 years found the overall incidence of OHCA treated by emergency medical services (EMS) to be 2.28 per 100,000 person-years (Meyer et al., 2012). The incidence was highest in persons ages 14 years and older. The most common causes of OHCA were congenital abnormalities (84.0% in 0- to 2-year-olds and 21% in 3- to 13-year-olds), presumed primary arrhythmia (23.5% in 14- to 24-year-olds), and coronary artery disease (42.9% in 25- to 35-year-olds). The overall survival rate was 26.9% (3.8% in 0- to 2-year-olds, 40.0% in 3- to 13-year-olds, 36.7% in 14- to 24-year-olds, and 27.8% in 25- to 35-year-olds). Survival increased throughout the study period, from 13.0% in 1980–1989 to 40.2% in 2000–2009 (p < .001; Meyer et al., 2012).

Another area of interest is the use of pre-participation screening for all young athletes prior to engaging in regular sports activity. Pre-participation screening takes the sports physical examination and adds testing elements to the screening in an attempt to identify athletes at risk. The American College of Cardiology Foundation published the 36th Bethesda Guidelines in 2005, which described specific cardiac conditions that would place a competitive athlete at increased risk for SCD. The goal of the 36th Bethesda Guidelines was to formally develop consensus recommendations regarding the eligibility of athletes with known cardiac conditions for competition in organized sports and to present these considerations in a user-friendly format for clinicians (Maron & Zipes, 2005). After these recommendations were published, the interest in pre-participation screening increased as a result of the ethical and legal implications associated with restricting young athletes from sports (Drezner, 2009).

Significant cardiac disease has been detected through pre-participation screenings; one review identified 65% of male and 35% of female athletes ages 10 to 18 years with significant cardiac disease diagnosed on physical examination. Of those identified, 43% had diagnoses consistent with SCD in athletes as described in the Bethesda Guidelines. The diagnoses were determined based on physical examinations and patient histories, with positive findings including heart murmurs, chest pain, and positive family history (Sealy, Pekerak, Russ, Sealy, & Goforth, 2010). However, this review demonstrates that further testing with electrocardiogram (ECG) and echocardiogram is indicated because detection through basic vital signs is not a conclusive screening tool.

Although the numbers clearly indicate that student athletes are at risk for SCD and a plan to save lives is needed, only 60% of states require AED maintenance, 59% require EMS notification, 55% require AED training, 41% require some form of medical oversight, and very few states require a quality improvement process for their PAD programs (Gilchrist et al., 2012). These systems have the potential to fail based on the risk to students and the reduced percentage of services available to provide assistance. Legislation is necessary to ensure that AEDs are strategically placed within sporting facilities and that PAD registries are developed and effectively coordinated with EMS to reduce the response times in the event of a SCA (Gilchrist et al., 2012).

Risk/Prevalence
The prevalence of SCD in student athletes in the United States is difficult to estimate because mandated registries have not historically existed to collect this data. It is thought to be underestimated because studies
estimates have varied widely and because of the lack of a formal reporting system for sudden juvenile athletic deaths (Drezner, 2009). The University of Washington, through grant funding, has established the National Registry for AED Use in Sports. However, the program relies on schools across the United States to register SCDs within their school systems through the registry’s Web site (Drezner, Toresdahl, Rao, Huszti, & Harmon, 2013). Without this registry being mandated by federal law, there remains a risk for underreporting. Additionally, as a result of recent joint efforts through the National Institutes of Health and the Centers for Disease Control and Prevention, a Sudden Death in the Young Registry has been established. This registry launched in early 2014 and will track sudden deaths related to cardiovascular disease and epilepsy in the 0- to 24-year-old age groups across 15 states (Mitka, 2013). Limitations of this registry include no particular focus on student athletes or AED availability and a limited geographical study area.

In the Veneto region of Italy, a regional registry is used to track sudden juvenile cardiac death. In young, competitive athletes aged 12 to 35 years, the baseline incidence for SCD was 3.6 per 100,000 prior to implementing a national screening program consisting of history, physical examination, and ECG testing. From 1979 to 2004 the incidence of SCD among athletes in this age group decreased 89%. Further, the risk of SCD in the prescreening period was 0.56, and this risk decreased to 0.21 in the late screening period. The decrease in mortality was attributed to the increased sport restriction for athletes with cardiomyopathies (Corrado et al., 2006). Of note, the use of ECG testing in the Italian pre-participation screening has been used to identify underlying cardiomyopathies related to the findings of T-wave inversion on the ECG. In one sample of 229 children with positive ECG findings, 33 were diagnosed with an underlying cardiovascular disease and epilepsy in the 0- to 24-year-old age groups across 15 states (Mitka, 2013). Limitations of this registry include no particular focus on student athletes or AED availability and a limited geographical study area.

In the United Kingdom, special attention has been directed at assessing athletes for the risk of arrhythmia and using cardiac interventions to reduce the risk of SCD. In one study, from 1997 to 2007, in a sample of 337 patients between the ages of 10 and 17 years, 11 elite athletes were identified as presenting with significant cardiac arrhythmias for which they underwent intervention. The most common presenting symptoms were palpitations and syncope. The most frequent diagnoses included atrioventricular re-entry, tachycardia, atrioventricular node re-entry tachycardia, complete heart block, sinus node dysfunction, vasovagal syncope, and pre-excitation atrial fibrillation. The patients were treated with the following interventions: implantable loop recorder, diagnostic electrophysiology study with radiofrequency ablation, cryoablation, and pacemaker implantation. Of the 11 athletes, 10 were able to return to competitive sports after the interventions, and no deaths occurred (Kelly, Kenny, Martin, & Stuart, 2011).

In France, in a 5-year study investigating persons ages 10 to 75 years who experienced a sports-related SCD, it was found that sports-related SCD represented 4.6 cases per million/population per year. Six percent of the cases occurred in young, competitive athletes. Sensitivity analyses showed an incidence ranging from 5 to 17 new cases per million/population per year. More than 90% of the cases happened during recreational sports. The subjects were young, and 95% of the subjects were men. Of note, 93% of the cases were witnessed, but bystander CPR was started in only 30.7% of cases. The use of bystander CPR and cardiac defibrillation were the strongest independent predictors for survival to hospital discharge (Marion et al., 2011).

Over a 7-year period in the United States, data related to exercise-induced SCD survival trends among youth were collected. Four hundred eighty-six SCAs were identified among grade school, middle school, high school, and college-aged youth, with 69 cases per year with a 14% incidence. The survival rate was 11%; 83% of the subjects were male and 17% were female (Drezner, Chun, Harmon, & Derminer, 2008).

Also in the United States, a 6-year cross-sectional study addressed the prevalence of AED and location requirements, AED funding and training, and coordination of AED placement with local EMS in high schools across the country. Fifty-four percent of the schools had an AED in the school. AEDs were funded by donations (60%), by the school district (27%), and by the school or athletic department (11%). Coaches (78%) were the most likely to receive AED training, followed by administrators (72%), school nurses (70%), and teachers (48%). Only 25% of schools coordinated the implementation of AEDs with an outside medical agency, and only 6% of schools coordinated with the local EMS. The estimated probability of AED use to treat SCA was 1 in 154 schools per year (Rothmier, Drezner, & Harmon, 2007).

Most recently, Drezner and colleagues conducted a 2-year prospective observational study using data from the National Registry for AED Use in Sports to evaluate high schools, the number of SCAs per school, and survival to hospital discharge of all persons who experienced an SCA. The study included 2,149 high schools, with 87% of the schools having an AED program. Ninety-five percent of the schools reported data the entire 2 years. Over the 2-year period, 59 cases of SCA were reported. Forty-four percent of the cases occurred in students, and of those students, 69% were student athletes. An AED was used in 85% of the cases, and 85% of all students and 89% of student athletes survived to hospital discharge (Drezner et al., 2013).

**Interventions**

The most common underlying cardiac abnormalities associated with SCD include hypertrophic
cardiomyopathy, coronary artery anomalies, arrhythmogenic right ventricular cardiomyopathy, Marfan syndrome, myocarditis, dilated cardiomyopathy, Brugada syndrome, long QT syndrome, and Wolff-Parkinson-White syndrome. The American Heart Association (AHA) and the European Society of Cardiology (ESC) currently recommend pre-participation screening for athletes engaging in organized sports that require a high level of training and competition, which can potentially place more strain on the heart. The AHA and ESC currently recommend a directed history and physical examination of the athlete to assess for cardiac murmur, previous syncopal event, chest pain with exercise, and a family history of early SCD. The ESC additionally recommends ECG screening as part of the examination; however, the AHA does not currently advocate ECG screening because of increased costs and limited resources for large numbers of athletes (Higgins, Ananaba, & Higgins, 2013).

It has been shown that utilizing ECG screening in asymptomatic athletes who had ECG findings suggestive of hypertrophic cardiomyopathy, Wolff-Parkinson-White syndrome, and long QT syndrome reduces SCD risk by 3.6 to 7.5 years with projected life expectancy increases of 0.8 to 1.6 years per screened individual. However, the cost-effectiveness analyses have demonstrated high cost in relation to the relative health benefits of ECG screening (Leslie et al., 2012).

New recommendations have emerged that focus on primary and secondary prevention of SCD in young athletes. Primary prevention includes pre-participation screening for all athletes with known cardiac abnormalities that place them at increased risk for SCD and appropriate medical management of these conditions to reduce the risk of SCD. Secondary prevention focuses on the mandatory and strategic placement of AEDs within athletic facilities to respond quickly to an unpredictable SCA (Higgins et al., 2013).

The AHA has advocated for early response mechanisms related to SCAs since the 1990s, specifically early onset CPR and defibrillation, which have been shown to increase survival rates. Over a 5-year period from 1995 to 2000, all 50 states passed regulations and laws focusing on lay responder AED programs. The Cardiac Arrest Survival Act was also signed into federal law in 2000. However, discrepancies in state and federal legislation have persisted and confounded efforts to delineate AED legislation and improve SCA survival rates. The AHA has issued a position statement regarding AED legislation for use by policymakers to assist in reducing barriers to effective AED legislation. The statement outlines the key program components for state AED legislation and identifies the essential elements for community AED programs, as outlined in Table 2. Additionally, wording suggestions are made to overcome policy obstacles. The overall goal of the AHA position statement is to promote legislation that reduces mortality rates from SCA by implementing programs that will promote immediate bystander CPR and early defibrillation within 3 to 5 minutes of a victim’s collapse (Aufderheide et al., 2006; Box).

**Strategies/Problem Solving**

Strategies to reduce rates of SCD in student athletes have been explored, but not in great depth or breadth in the United States. One strategy to combat SCD in student athletes involves the level of emergency response preparedness within high schools in the United States.

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**BOX. American Heart Association four essential elements of community automatic external defibrillator programs**

1. Planned and practiced response
   - Overseen by a person with experience and expertise in resuscitation programs
   - Program director determines the number of AEDs and locations
   - Placement should be within a 1-minute brisk walk of the activity site
   - Location should be highly visible

2. Training of anticipated rescuers in CPR and use of the AED
   - Train individuals who are likely to be present at events or throughout the day
   - The goal of training is to ensure one trained rescuer is available at all times
   - Training focuses on early recognition, calling 9-1-1, early CPR and defibrillation, and safe use of the AED
   - Training simulation should occur

3. Link to the local EMS system
   - The local EMS dispatch center should be notified of the AED program and the type and location of AEDs on site
   - Develop a reporting procedure with local EMS to share patient information

4. A process of continuous quality improvement, including a plan for on-site AED maintenance and readiness-for-use checks
   - Quality improvement protocols must be in place to evaluate the response time of the program
   - Goal should be ≤ 90 seconds from arrival of the AED at the victim’s side to the initial shock being delivered
   - Factors that increase the time to the first shock must be eliminated

Note. AED = automatic external defibrillator; CPR = cardiopulmonary resuscitation; EMS = emergency medical services.
Studies have shown that 83% of high schools with an AED program also have an emergency response plan for SCA. However, only 40% practice and review the plan on an annual basis with school responders. Additionally, the schools that have activated their emergency response systems have treated both student athlete victims and nonstudent sport spectators. Ninety-seven percent of the SCA cases were witnessed. Student athletes represented 39% of the victims, and older nonstudent spectators represented 61% of the cases. In 94% of the cases, the victim received bystander CPR, and 83% received a shock from an AED. Data were consistent for survival to hospital discharge, with 64% of the student athletes and 63% of the nonstudent spectators surviving (Drezner, Rao, Heistand, Bloomingdale, & Harmon, 2009).

For student athletes with known cardiomyopathies, suggestions have been made to risk stratify these patients through noninvasive techniques such as ECG, Holter monitoring, and exercise testing. However, it remains unclear how to best utilize these tests and correlate the findings appropriately to ensure the student athletes are properly stratified (Goldberger et al., 2008). Additionally, the decision to restrict a student athlete from competitive play is an emotional one for both the athlete and the family. Although it is known that specific cardiovascular diseases predispose a patient for SCD, there is no medicolegal framework within the United States to protect care providers from litigious efforts if a family is disgruntled by an athletic restriction. Therefore, practitioners must be thoughtful with the screening and cardiac surveillance process for high-risk student athletes (Maron & Pelliccia, 2006).

The development of practice-based guidelines for the athlete to prevent SCD is another area that has received attention. However, investigations worldwide have been primarily observational, no formal definitions for competitive athlete or athletic SCD have been described, and national registries do not exist in all countries. Overall, there is not enough evidence at this time to support practice-based guidelines for student athletes at risk for SCD (Link & Estes, 2012). Until practice guidelines are developed, widespread availability of AEDs and PADs seems to be the most appropriate strategy for reducing SCD in student athletes. Response time from collapse to shock, within 3 to 5 minutes, produces higher survival outcomes, as does rapid initiation of CPR. An emergency response plan and a formalized relationship with EMS also increase survival rates. Therefore, the widespread distribution of AEDs, combined with increased public awareness and CPR training, has the potential to save lives (Rho & Page, 2007).

The implementation of increased access to AEDs creates liability and cost issues. Liability and litigation concerns can appropriately be addressed through legislation at the federal and state level. The cost of AEDs has become reasonable and makes them more attainable by individual sites as part of their maintenance and insurance programs. Legislative efforts can also be used to support state or federal funding for AED access (Rho & Page, 2007).

**PRACTICE IMPLICATIONS**

Overwhelmingly, the review of the literature reveals that more evidence-based research is needed to support the long-term outcomes of AED legislation and its utility in sparing the lives of student athletes. Although data indicate that decreased time from collapse to initiation of CPR and early defibrillation saves lives and leads to increased hospital discharges after a sudden cardiac event, these data have not been well correlated to the school setting and athletic events. Few authors have investigated the state and federal legislative efforts related to AED programs within schools or communities as a whole.

Common themes among researchers is the necessity of SCA/SCD student athlete mandatory registries to track events, the importance of early intervention with CPR and access to early defibrillation through the use of AEDs to increase survival, and the necessity of an organized emergency response team (Drezner et al., 2013). The repetitive nature of these findings implies that health care providers, school officials, athletic coaches, and legislators must work together to ensure that AED programs are available in every school and that AEDs are easily accessible within sporting facilities. The most effective way to ensure this measure is through proper state and federal legislation.

The state legislation sponsored by the Simon’s Fund organization is an important step in raising awareness among parents and coaches of student athletes. Using a model similar to this could be equally effective for introducing AED legislation related to student athletes and supporting mandatory AED registries for primary and high schools across the United States.

Additionally, health care providers must be cognizant of the importance of pre-participation sport screening and the use of noninvasive testing methods when permissible to effectively identify student athletes at risk. Currently, no pre-participation legislation is in place in any state across the country. The cost and concern relating to false-positive results have been a
hindrance to support of this effort. However, a cost analysis of the preventative testing and examination costs versus the cost of young lives lost each year warrants further investigation.

Drezner and colleagues (2013) determined that 1 out of 70 high schools have an SCA each year, with half of the victims being students or student athletes. Most student athletes (85%) will survive the SCA if it is witnessed, the emergency chain of command is initiated immediately, and an AED is readily available. Additionally, survival rates have been shown to be higher in schools that have an established response plan in place. These findings indicate that SCD in student athletes can be avoided; however, it is difficult to ensure that all schools have an AED and response plan without mandated state or federal legislation.

**FUTURE RESEARCH SUGGESTIONS**

Based on the literature review, sufficient evidence exists to push forward with continued research and efforts to raise awareness of AED education and early defibrillation. In an effort to identify student athletes at risk, more studies are needed to determine the frequency with which students who have underlying cardiovascular disease are identified through routine pre-participation screening. Further research is necessary to determine the reliability of noninvasive testing measures such as ECG in diagnosing athletes at risk for SCD and how testing measures can be coordinated to ensure sensitivity and specificity.

In line with pre-participation screening and testing measures is the issue of cost. The current research and the AHA have discerned that the cost of testing outweighs the benefit of identifying student athletes at risk for SCD. Further cost analyses are warranted to determine the accuracy of this claim in the United States. Other countries have proven that lives have been saved through use of pre-participation screening and testing measures. With the evolution of the Affordable Care Act in the United States, further investigation is warranted to determine if cost analyses are more feasible under the new health care legislation.

Evidence is most lacking in the legislative arena. Health care providers, researchers, and advocates must utilize the recommendations put forth by the AHA to develop legislation at the state and federal level to ensure that AEDs are made available to all student athletes at all athletic facilities. The lack of legislative knowledge may be a hindrance to many persons in a position to make effective change. Therefore, continuing education must be offered or supported within multiple health care and educational disciplines to ensure that persons who are in a position to affect change are well equipped to do so through proper alliance with legislators.

Overall, further research is warranted in relation to the topic of student athletes, SCD, and AED legislation, but the fact remains that early intervention, a coordinated emergency plan, and a rapid EMS response save lives. Therefore, legislation should move forward to ensure that AEDs are present at all school gyms and athletic fields.

**REFERENCES**


