

## Epidemiology of Sudden Death in Organized Youth Sports in the United States, 2007–2015

By: Brad D. Endres, Zachary Y. Kerr, Rebecca L. Stearns, [William M. Adams](#), Yuri Hosokawa, Robert A. Huggins, Kristen L. Kucera, and Douglas J. Casa

Endres B, Kerr ZY, Stearns RL, Adams WM, Hosokawa Y, Huggins RA, Kucera KL, Casa DJ. Epidemiology of Sudden Death in Organized Youth Sports in the United States, 2007-2015. *Journal of Athletic Training*. 2019;54(4):349-355. <https://doi.org/10.4085/1062-6050-358-18>

\*\*\*© 2019 National Athletic Trainers' Association. Reprinted with permission. No further reproduction is authorized without written permission from National Athletic Trainers' Association. This version of the document is not the version of record. Figures and/or pictures may be missing from this format of the document. \*\*\*

### Abstract:

**Context:** Sudden death in sport at the high school and collegiate levels has been described extensively in the literature. However, few epidemiologic data exist on the incidence of sudden death specifically in American youth sport before secondary school athletics. **Objective:** To describe the epidemiology of sudden death in organized youth sports in the United States from 2007 through 2015. **Design:** Descriptive epidemiology study. **Setting:** Organized American youth sports. **Patients or Other Participants:** Cases of sudden death that occurred in youth athletes 17 years of age and younger in non-high school organized sports were included. **Data Collection and Analysis:** Information on sudden deaths between August 1, 2007, and December 31, 2015, was obtained via LexisNexis and other publicly available news or media reports. Total youth sport participation rates from 2007 to 2015 were provided by the Sport & Fitness Industry Association. Athlete age, sex, sport, level of play, event type, date of death, setting, and official and speculated causes of death were examined. Data are presented as deaths per year, percentage of total sudden deaths, and deaths per 10 million participants. **Results:** From 2007 to 2015, 45 sudden deaths were reported in American youth sports. The mean age of patients was  $13 \pm 2$  years. The overall incidence rate was 1.83 deaths/10 million athlete-years. Males experienced a greater number of sudden deaths than females ( $n = 36/45$ , 80%). Basketball had the highest number of sudden deaths from 2007 to 2015, with a total of 16 occurrences. The most frequent cause of sudden death was cardiac related ( $n = 34/45$ , 76%). Most sudden deaths occurred during practices ( $n = 32/45$ , 71%). **Conclusions:** Sudden deaths in organized youth sports in the United States from 2007 through 2015 were most often experienced during practices by males, were cardiac related, and occurred while playing basketball. These findings are similar to those in high school and collegiate sports. This study affirms the need for further epidemiologic research into sudden deaths at the organized youth sport level.

**Keywords:** pediatric sports medicine | injury surveillance | catastrophic injury | sport safety

### Article:

### **Key Points**

- More than two-thirds of sudden deaths occurred during practices.
- Similar to previous findings in high school and collegiate sports, the majority of sudden deaths in youth sports occurred in males, affected those in the sport of basketball, and were cardiac related.
- Our findings support the need for continued surveillance of sudden deaths in youth sports.

Sports participation in the United States continues to be popular among youth athletes. In 2015 alone, 28 646 000 youth athletes between the ages of 6 and 17 years participated in sports.<sup>1</sup> With such a large number of athletes, it may come as little surprise that many injuries are also attributed to sport participation. Numerous authors<sup>2-5</sup> have used emergency room data to report the epidemiology of athletic injuries at the youth level. For example, Meehan and Mannix<sup>4</sup> found that 459 000 sport-related, life-threatening injuries occurred among youth athletes between the ages of 6 and 18 years. These injuries accounted for 40% of all life-threatening injuries in this age group. Unfortunately, some life-threatening injuries due to sport participation resulted in death. Nalliah et al<sup>5</sup> showed that 30 Americans between the ages of 13 and 19 years died as a result of sport-related injuries in 2008. However, they did not specify if these deaths occurred during nonorganized recreational sports, organized youth sports, or high school athletics.

Sudden death in sports at the high school and collegiate levels has been described extensively in the literature.<sup>6-10</sup> Currently, the top 4 causes of sudden death in organized high school and collegiate sports in the United States are sudden cardiac arrest, traumatic brain injury, exertional heat stroke, and exertional sickling.<sup>6,9,11</sup> These 4 causes of sudden death in sport are responsible for more than 90% of all sudden deaths in these settings, with sudden cardiac death (SCD) comprising 75% of all sport-related deaths.<sup>6,9</sup> Additional findings suggest that males have an overall higher incidence of sudden death than females at both the high school (0.28 per 100 000 participants versus 0.13 per 100 000 participants) and collegiate levels (2.03 per 100 000 participants versus 1.79 per 100 000 participants), respectively.<sup>9</sup> Although researchers<sup>5,10,12,13</sup> have investigated the epidemiology of sudden death in young athletes, these studies tend to cluster the sudden death data for 6- to 17-year-old youth athletes who were not participating in high school athletics with those who were participating in high school and collegiate athletics. As a result, generalizations of current reported incidence rates of sudden death among young athletes may be inaccurate.

To our knowledge, no previous authors have described the epidemiology of sudden deaths in organized middle school, youth league, and recreational youth sports (athletes 6 to 17 years old) in the United States. Furthermore, participation data for this setting have not been used to describe the incidence of sudden death. Therefore, the purpose of our study was to describe the epidemiology of sudden death among athletes aged 6 to 17 years participating in organized middle school, youth league, or recreational sports in the United States. Specifically, our intent was to examine distributions of characteristics related to the athlete (age and sex), event (sport, level of play, event type), and sudden death (year, setting, official cause, and speculated cause of death).

## **METHODS**

## *Study Design*

We used a descriptive epidemiologic design that was approved by the Institutional Review Board at the University of Connecticut. Organized youth sports were classified into 3 divisions: organized youth leagues, middle school athletics, and organized recreational youth sports (eg, marathons, triathlons). High school student-athletes who were younger than age 18 while participating in school-sanctioned athletics were not included because the epidemiology of sudden deaths among high school student-athletes has already been well described in the literature.<sup>9,14,15</sup>

## *Acquisition of Case Data*

We defined *sudden death* as a death that occurred either while the athlete was engaged in sport participation or as the result of sport participation (eg, a head impact incurred during American football that led to death in the emergency department). Sudden death data from cases occurring between August 1, 2007, and December 31, 2015, were obtained via 2 methods: (1) a search using the LexisNexis Academic Database and (2) other Internet searches (eg, Google) of publicly available news reports. The search for sudden death cases began in August of 2013 using the terms *death, fatality, exercise, race, sport, practice, and game*. Information related to the athlete (age, sex), event (sport, level of play, event type), and death (date, location, official cause, and speculated cause of death) was obtained. Deaths were reviewed by researchers (B.D.E., R.L.S.) and classified into 5 event types (cardiac/cardiovascular, exertional/heat/environmental, traumatic injury, other, or inconclusive/unknown). If an official cause of death was not provided in the media source, 1 member of the research team (B.D.E.) reviewed all available information and provided a speculated cause of death. For example, if an official cause of death was not reported for an athlete who collapsed and died despite an advised shock from an automated external defibrillator, the case was classified as *cardiac*. Through these methods, we were able to obtain 97% (438 of 450 total measures) of the descriptive measures listed earlier for each patient included in this study. The missing measures consisted of 10 cases of unknown official causes of death and 2 cases of “inconclusive” speculated causes of death.

Included were deaths that (1) were reported in publicly available media outlets; (2) occurred between August 1, 2007, and December 31, 2015; (3) affected athletes between the ages of 6 and 17 years; and (4) occurred during sanctioned middle school sporting events, in organized youth sport leagues, or organized recreational athletic events or training for said events. Excluded were deaths that (1) occurred in athletes who were younger than 6 years of age or older than 17 years of age; (2) occurred outside of organized middle school, youth league or recreational sport or training for said events; or (3) occurred during sanctioned high school or collegiate athletic events.

Because of the variability of sport settings for youth sports in the United States, sudden deaths were categorized as follows: (1) middle school athletics, (2) organized youth sport leagues, or (3) youth athlete participation in organized recreational athletic events or training for said events.

## *Acquisition of Participation Data*

The total number of youth sport participants between the ages of 6 and 17 years in 111 team and individual sports from 2007 through 2015 was provided by the Sport & Fitness Industry Association (SFIA).<sup>1</sup> The SFIA obtains participation data annually via online interviews from a nationwide sample of individuals and households in the US Online Panel of over 1 million people operated by Synovate/IPSOS (New York, NY). For context, their 2015 sample consisted of 5067 individuals and 5711 households representing people aged 6 years and older. After the surveys are submitted, a weighting technique is used to calculate the total number of sport participants aged 6 years and older. The SFIA reports participation statistics as 1 athlete per sport per year, which we describe in this study as an athlete-year. An *athlete-year* was defined as 1 youth athlete participating in 1 sport in a calendar year.<sup>16</sup> Athletes may have participated in more than 1 sport in a calendar year and were counted separately for each sport.

### *Statistical Analyses*

Data were analyzed using SAS (version 9.4; SAS Institute Inc, Cary, NC), Excel 2013 (Microsoft Corp, Redmond, WA), and VRP Injury Statistics Software (University of North Carolina at Chapel Hill) for analysis.<sup>17</sup> Descriptive analyses included the frequency and proportion of sudden deaths and the mean, range, and standard deviation of continuous measures. Distributions of characteristics related to the athlete (age, sex), event (sport, level of play, event type), and death (year, location, official cause, and speculated cause of death) were computed. Sudden death incidence rates were presented as the sum of the number of sudden death cases divided by the sum of the number of athlete-years. Sudden death incidence rates were expressed per 10 million athlete-years, and 95% confidence intervals (CIs) were calculated. Trends in incidence rates across time were examined via linear regression. All statistics yielding *P* values <.05 were considered statistically significant.

## **RESULTS**

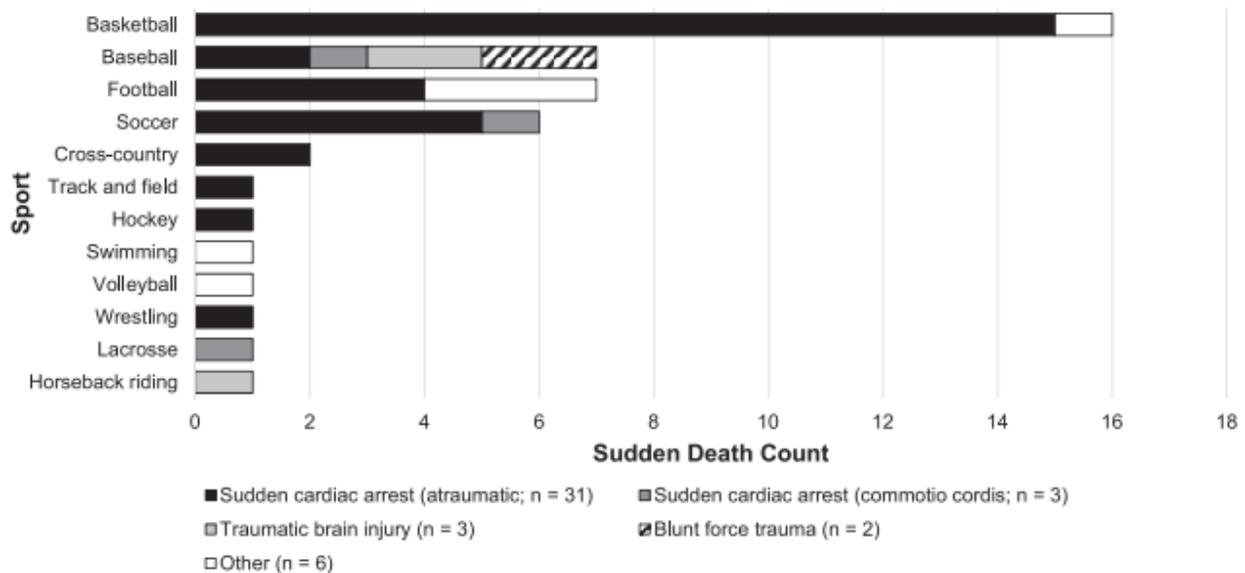
### *Sudden Death: Athlete, Setting, and Injury Characteristics*

From 2007 through 2015, a total of 45 deaths resulting from participation in organized youth sports in the United States were reported in publicly available online media sources (Tables 1 through 3). The average number of sudden deaths in youth sports per year during this 9-year period was 5. The average age at the time of death was  $13 \pm 2$  (range, 9–17) years. Overall, 73% ( $n = 33/45$ ) of sudden deaths occurred among individuals aged 12 to 14 years. Four in 5 sudden deaths affected males (80%,  $n = 36/45$ ). Of all cases of sudden death in our population, basketball accounted for the largest proportion (36%,  $n = 16/45$ ), followed by baseball (16%,  $n = 7/45$ ), American football (16%,  $n = 7/45$ ), and soccer (13%,  $n = 6/45$ ; Figure 1). More than half of all sudden deaths occurred during organized middle school sports (58%,  $n = 26/45$ ), followed by youth sport leagues (40%,  $n = 18/45$ ); 1 sudden death was reported in recreational race training (2%). More than two-thirds of sudden deaths occurred during practices (71%,  $n = 32/45$ ), and nearly one-third occurred during competitions (29%,  $n = 13/45$ ). The 45 sudden deaths were distributed across 27 states. New York reported the largest number of sudden deaths ( $n = 5$ ), followed by Illinois ( $n = 4$ ) and California, Georgia, and New Jersey ( $n = 3$  each). Of the 45 deaths, the official cause was provided in the media source via the coroner's or medical

examiner's report for 35 (78%) cases. For the remaining 10 (22%) cases, speculated causes were assigned by a member of the research team (B.D.E.) based on the information in the media report. The most frequent causes of sudden death were cardiac related (76%, n = 34/45; Figure 1). Of the 34 SCDs, 31 were nontraumatic and 3 were due to commotio cordis. Interestingly, 15 of the 16 sudden deaths (94%) in youth basketball were the result of SCD. Of these 15 cases of SCD in basketball, 12 occurred in males and 3 in females. Traumatic brain injury was the second most frequent cause of sudden death (7%, n = 3/45), followed by blunt force trauma to the body (4%, n = 2/45). Other causes of sudden death were anaphylactic shock, lightning, drowning, and exertional heat stroke (each 2% and n = 1). Two deaths (4%) were considered inconclusive due to a lack of publicly available information.

**Table 1.** Characteristics of Athletes Who Experienced Sudden Death in Youth Sports: 2007-2015

Sport	Count, No. (%)	Age, y or Mean $\pm$ SD	Sex, No. (%)	
			Male	Female
Basketball	16 (35.6)	13 $\pm$ 1	13 (81)	3 (19)
Baseball	7 (15.6)	12 $\pm$ 2	7 (100)	0 (0)
Football	7 (15.6)	11 $\pm$ 2	7 (100)	0 (0)
Soccer	6 (13.4)	13 $\pm$ 3	3 (50)	3 (50)
Cross-country	2 (4.4)	14 $\pm$ 1	1 (50)	1 (50)
Hockey	1 (2.2)	14	1 (100)	0 (0)
Horseback riding	1 (2.2)	13	0 (0)	1 (100)
Lacrosse	1 (2.2)	12	1 (100)	0 (0)
Swimming	1 (2.2)	14	1 (100)	0 (0)
Track and field	1 (2.2)	14	1 (100)	0 (0)
Volleyball	1 (2.2)	14	0 (0)	1 (100)
Wrestling	1 (2.2)	14	1 (100)	0 (0)
Total	45	13 $\pm$ 2	36 (80)	9 (20)



**Figure 1.** Frequency of sudden death in youth sport by sport and cause of death: 2007–2015. *Other* includes anaphylactic shock, lightning, drowning, exertional heat stroke, and inconclusive.

**Table 2.** Descriptive Results of Cases of Sudden Death in Youth Sports by Sport Setting, 2007-2015, No. (%)

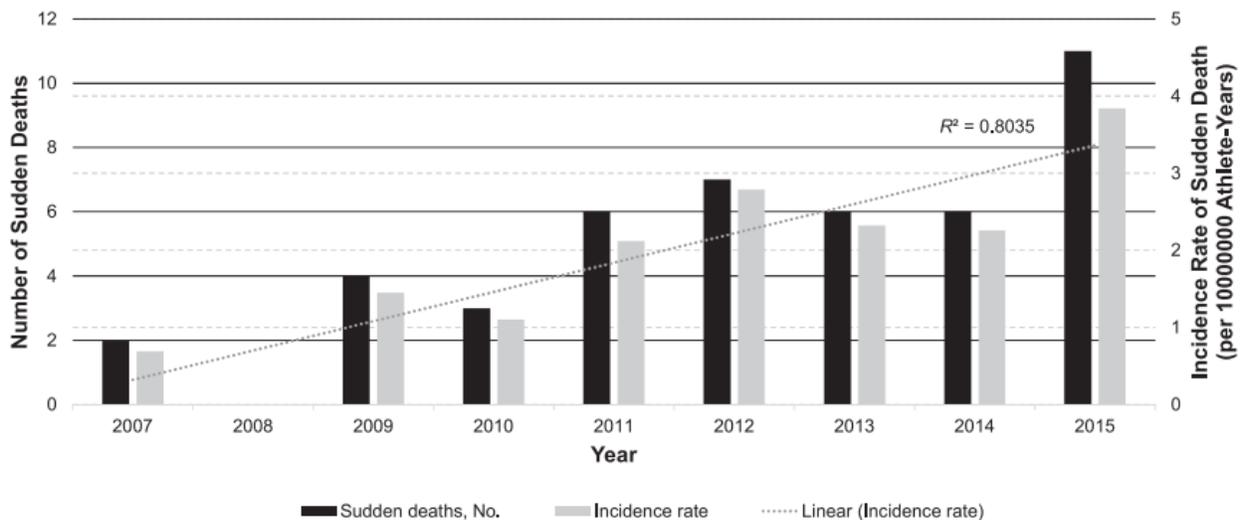
Sport	Count	Setting			Event Type				
		Middle School	Youth Sport League	Recreation	School-Sanctioned Practice	School-Sanctioned Game	Youth Sport League Practice	Youth Sport League Game	Race Training
Basketball	16 (35.6)	12 (75)	4 (25)	0 (0)	3 (37)	6 (37)	2 (13)	2 (13)	0 (0)
Baseball	7 (15.6)	3 (43)	4 (57)	0 (0)	3 (43)	0 (0)	4 (57)	0 (0)	0 (0)
Football	7 (15.6)	4 (57)	3 (43)	0 (0)	3 (43)	1 (14)	3 (43)	0 (0)	0 (0)
Soccer	6 (13.4)	1 (17)	5 (83)	0 (0)	1 (17)	0 (0)	5 (83)	0 (0)	0 (0)
Cross-country	2 (4.4)	2 (100)	0 (0)	0 (0)	0 (0)	2 (100)	0 (0)	0 (0)	0 (0)
Hockey	1 (2.2)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)
Horseback riding	1 (2.2)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)
Lacrosse	1 (2.2)	1 (100)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)
Swimming	1 (2.2)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)
Track and field	1 (2.2)	1 (100)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Volleyball	1 (2.2)	1 (100)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Wrestling	1 (2.2)	1 (100)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Total	45	26 (58)	18 (40)	1 (2)	16 (36)	10 (22)	15 (33)	3 (7)	1 (2)

**Table 3.** Speculated Causes of Sudden Death in Youth Sport, 2007-2015, No. (%)

Sport	Count	Speculated Cause of Sudden Death						
		Cardiac (Non-Traumatic)	Cardiac (Commotio Cordis)	Traumatic Brain Injury	Trauma to Body	Other	Inconclusive	
Basketball	16 (35.6)	15 (94)	0 (0)	0 (0)	0 (0)	0 (0)	1 (6)	
Baseball	7 (15.6)	2 (29)	1 (14)	2 (29)	2 (29)	0 (0)	0 (0)	
Football	7 (15.6)	4 (57)	0 (0)	0 (0)	0 (0)	2 (29)	1 (14)	
Soccer	6 (13.4)	5 (83)	1 (17)	0 (0)	0 (0)	0 (0)	0 (0)	
Cross-country	2 (4.4)	2 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Hockey	1 (2.2)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Horseback riding	1 (2.2)	0 (0)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	
Lacrosse	1 (2.2)	0 (0)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	
Swimming	1 (2.2)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)	
Track and field	1 (2.2)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Volleyball	1 (2.2)	0 (0)	0 (0)	0 (0)	0 (0)	1 (100)	0 (0)	
Wrestling	1 (2.2)	1 (100)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Total	45	36 (69)	3 (7)	3 (7)	2 (4)	4 (9)	2 (4)	

## Sudden Death Incidence Rate

The overall incidence rate of sudden death from 2007 through 2015 was 1.83 per 10 million athlete-years (95% CI = 1.30, 2.37). The number of sudden deaths and incidence rate in youth sports per year are shown in Figure 2. By year, 2015 had the highest number ( $n = 11$ ) and rate of sudden death in youth sport, with an incidence rate of 3.84 per 10 million athlete-years. A linear trend was found in the annual sudden death incidence rates during the study period ( $P < .001$ ), suggesting an increased incidence of reported sudden deaths across years. This finding was retained when we excluded 2015, which had a larger incidence rate than all other years ( $P < .001$ ).



**Figure 2.** Frequency and incidence rate of sudden death in youth sports by year: 2007–2015. Total youth sport participation rates of athletes aged 6 to 17 years taking part in 111 team and individual sports from 2007–2015 were provided by the Sport & Fitness Industry Association. Total youth sport participation from 2007–2015 was 245 567 000 athlete-years. *Athlete-year* was defined as 1 youth athlete participating in 1 sport in a calendar year. Athletes who participated in more than 1 sport were counted multiple times. Excluded were deaths that were characterized by the following: (1) affected athletes over the age of 18 years, (2) occurred outside of organized sport, (3) occurred during sanctioned high school or collegiate athletic events.

## DISCUSSION

The purpose of our study was to describe the epidemiology of sudden death in organized middle school, youth, and recreational sports in the United States from 2007 through 2015. Youth sports were categorized into (1) middle school athletics, (2) organized youth sport leagues, and (3) youth athlete participation in organized recreational athletic events or training for said events. The overall incidence rate of sudden death in organized youth sport in America from 2007 through 2015 was 1.83 per 10 million athlete-years (95% CI = 1.30, 2.37). We found that the highest number of organized youth sport-related sudden deaths from 2007 through 2015 affected males (80%), were cardiac related (76%), occurred during practice (67%), and happened while playing basketball (36%). Furthermore, the frequency and incidence rate of sudden death in youth sports increased from 2007 through 2015 (Figure 2), highlighting the need for continued

surveillance to inform our current and future prevention efforts among youth athletes. Although the exact cause of the increased incidence of sudden death in youth sports remains unknown, we may speculate as to why this trend is occurring.

One cause may be that sudden deaths in youth sports are actually occurring at a greater rate and frequency in recent years. With a larger number of youth athletes participating in sports, we might expect to see increases in the numbers of injuries and sudden deaths. However, if the increases in sudden deaths and athlete-years were equivalent, the incidence rate would stay constant rather than rise. Therefore, our findings suggest that the frequency of sudden death in youth sport may indeed be increasing at a faster rate than the rate of participation. Yet it is important to note that the total number of participants represents all sports. Therefore, multisport athletes were counted more than once.

An agenda-setting effect may also contribute to the increase in the sudden death incidence rate over the past few years. *Agenda setting* is a concept of communication theory<sup>18,19</sup> that was defined by Scheufele and Tewksbury as “the idea that there is a strong correlation between the emphasis that mass media place on certain issues (eg, based on relative placement or amount of coverage) and the importance attributed to these issues by mass audiences.”<sup>19(p11)</sup> In other words, increased media attention to cases of sudden death leads to increased interest in the subject from media consumers such as parents, athletes, coaches, and sport governing body officials. Eventually, this increased interest by the public leads to increased attention from medical providers and researchers. Certainly national interest and corresponding research in sport-related injury and death over the past few years have risen considerably.<sup>20-23</sup> With additional interest and research, sport-related injuries and sudden deaths become more apparent to a hyperaware public, and thus, the media reporting continues to increase in response. Therefore, increased reporting of sudden death cases in recent years may also explain the increased incidence rates.

Finally, searches conducted retrospectively may have resulted in an undercapture of deaths that occurred from 2007 through 2012, which may have contributed to the increase in death rates observed over the study period. Other currently unknown causes could also underlie the increases in the frequency and incidence rate of sudden deaths in youth sports. Ultimately, the increased rate of sudden death in youth sports in recent years is an important and interesting finding that warrants further research.

We also noted that most reported sudden deaths in youth sport were among males during practices, were cardiac related, and occurred while playing basketball. These findings are similar to those of other investigators<sup>10,12</sup> who demonstrated sudden death epidemiology in athletic populations participating in high school and collegiate sports. Furthermore, our data suggested that the incidence of SCD was higher than any other cause of death in youth sports. We observed that SCD accounted for 76% of the total deaths in youth sports from 2007 through 2015. These results are also consistent with findings in older athletic populations,<sup>8,9,24</sup> which is concerning because SCD often occurs with no warning signs or symptoms.<sup>25</sup> The incidence of SCD has been previously shown<sup>7,8,11</sup> to be higher among African-American males than among males of other races and ethnicities. Therefore, not only should future researchers address the epidemiology of SCD in youth sports as a whole but also among youth sport participants belonging to populations known to have a higher risk of SCD. Special consideration for the sport of basketball may also

be warranted to investigate the unique factors leading to the high frequency of basketball-related SCD.

Sudden deaths occurred in various youth sport settings from 2007 through 2015. Although all such settings operate under the umbrella of youth sport, each setting is unique. Middle schools operate under the guidance of the superintendent of a school district and may be the most likely youth sport settings to adopt policies and procedures that have been implemented at the high school level. For example, the Alabama High School Athletic Association governs both high school and middle school athletics.<sup>26</sup> On the other hand, organized youth sport leagues in the United States are part of a \$5 billion industry that is largely organized and maintained by nonprofit groups with highly variable sport safety policies and procedures in place to promote the wellbeing of the youth athletes who participate.<sup>27</sup> Many recreational youth sporting events have even less oversight<sup>27,28</sup> and are often made up of participants wanting to take part in an individual event or sport of interest as a hobby or purely for leisure. Fifty-eight percent (n = 26) of sudden deaths occurred in organized middle school sports, whereas 40% (n = 18) affected athletes participating in youth sport leagues. Furthermore, 71% of the sudden deaths occurred during practices. This is an important finding because these settings (practices and organized youth sport leagues) have been described as having poor medical coverage.<sup>28</sup> Our findings support current and future efforts to implement the best practices as outlined in recent consensus statements on the prevention of sudden death in sport.<sup>25,29</sup>

### *Limitations*

This study was not without limitations. First, we were unable to obtain yearly practice and competition exposure data for youth athletes. Therefore, the incidence rates reported in this study were derived from estimates of yearly youth-level sport participation. Though these estimates were made using previously established methods,<sup>1</sup> the incidence rates in this study may not reflect the true incidence in the organized youth sport population. Without question, further research is needed to measure the participation of athletes in youth and recreational sports and determine more accurate sudden death incidence rates.

Second, information on sudden death was obtained via online and print media, which was derived from medical records and health professionals through families, police, and schools. This process may hamper the collection and recall of details about the event and ultimately limit the quality of the data. Using media sources to find cases of sudden death could also result in an undercapture of cases. This reality is a definite area for improvement in future studies of sudden death epidemiology in youth sports.

Third, some media reports did not differentiate between catastrophic injuries that occurred during nonorganized recreation and those that occurred during organized competitions. One of the inclusion criteria in this study was that the sudden death must have occurred during an organized youth sport competition. These cases were ultimately excluded, and as a result, some sudden deaths may have been missed due to a lack of information in the media reports.

Fourth, 10 media reports did not include an official cause of death as assigned by the coroner or medical examiner or listed the official cause of death as *unknown or inconclusive*. The certified

athletic trainer involved in reviewing the sudden death cases therefore had to use the information provided in the media report to assign a speculated cause of death.

Fifth, as mentioned previously, our period of data collection included only 9 years, from 2007 through 2015, and our data collection from 2007 through 2012 was performed retrospectively. These retrospective searches may have resulted in an undercapture of sudden deaths in the earlier years of this study and contributed to the increase in incidence rates observed over the entire study period. Although this is a limitation, it also supports the need for ongoing surveillance of sudden death among youth sports and ongoing discussions about how to best capture youth sudden deaths.

Sixth, we were not able to report the the race and ethnicity of patients who experienced sudden death. Previous authors<sup>12,30</sup> have reported race and ethnicity based on death reports in the public domain (eg, media reports) or autopsy reports. However, we did not have access to these death reports, and the media reports we used in our surveillance did not explicitly report race or ethnicity. In addition to our previous discussion of race and ethnicity, this limitation further emphasizes the need for better surveillance methods that include collecting details of race and ethnicity in cases of sudden death, especially SCD among youth athletes. Future epidemiologic efforts specific to sudden death in organized youth sport should include obtaining death information via interviews, medical records, autopsy reports, and state vital records.

Finally, our study focused only on organized youth sports below the high school level. We recognize the many other settings for organized sports outside of the youth, high school, collegiate, and professional levels. These settings include adult sporting events, such as adventure racing and adult recreational leagues, and organized recreational events, such as triathlons and marathons. To promote safety at all levels of sport, surveillance of sudden death at these levels is also encouraged.

In conclusion, 45 youth athletes died while playing in sanctioned middle school sporting events, organized youth sport leagues, or organized recreational athletic events or training for said events in the United States between 2007 and 2015. The overall incidence rate of sudden death was 1.83 deaths per 10 million athlete-years. The majority of deaths occurred at the middle school and youth league levels during practices, were experienced by males, were cardiac related, and happened while playing basketball. Our results support the need for continued surveillance of sudden deaths at all levels of youth sport. This surveillance is critical for the development and assessment of evidence-based policies aimed at preventing sudden death and promoting overall athlete health and safety.

## **ACKNOWLEDGMENTS**

We thank SFIA for their gracious assistance in obtaining data on youth sport participation. We also thank Jack Murphy for his help with figure and table creation throughout the data-collection process and Greg Hite for assistance in searching for cases of sudden death.

## **REFERENCES**

1. Sport & Fitness Industry Association. 2015 Sports, Fitness and Leisure Activities Topline Participation Report. Silver Spring, MD; 2015: 26.
2. Bayt DR, Bell TM. Trends in paediatric sports-related injuries presenting to US emergency departments, 2001–2013. *Inj Prev*. 2016; 22 (5): 361– 364.
3. Centers for Disease Control and Prevention (CDC). Nonfatal sports- and recreation-related injuries treated in emergency departments: United States, July 2000–June 2001. *MMWR Morb Mortal Wkly Rep*. 2002; 51 (33): 736– 740.
4. Meehan WP 3rd, Mannix R. A substantial proportion of life-threatening injuries are sport-related. *Pediatr Emerg Care*. 2013; 29 (5): 624– 627.
5. Nalliah RP, Anderson IM, Lee MK, Rampa S, Allareddy V, Allareddy V. Epidemiology of hospital-based emergency department visits due to sports injuries. *Pediatr Emerg Care*. 2014; 30 (8): 511– 515.
6. Boden BP, Breit I, Beachler JA, Williams A, Mueller FO. Fatalities in high school and college football players. *Am J Sports Med*. 2013; 41 (5): 1108– 1116.
7. Harmon KG, Asif IM, Maleszewski JJ, et al. Incidence and etiology of sudden cardiac arrest and death in high school athletes in the United States. *Mayo Clin Proc*. 2016; 91 (11): 1493– 1502.
8. Harmon KG, Asif IM, Maleszewski JJ, et al. Incidence, cause, and comparative frequency of sudden cardiac death in National Collegiate Athletic Association athletes: a decade in review. *Circulation*. 2015; 132 (1): 10– 19.
9. Kucera KL, Cox LM, Cantu RC. National Center for Catastrophic Sport Injury Research: Thirty-Fourth Annual Report Fall 1982–Spring 2016. National Center for Catastrophic Sport Injury Research Web site. <http://nccsir.unc.edu/reports>. Accessed March 14, 2018.
10. Maron BJ, Haas TS, Ahluwalia A, Murphy CJ, Garberich RF. Demographics and epidemiology of sudden deaths in young competitive athletes: from the United States National Registry. *Am J Med*. 2016; 129 (11): 1170– 1177.
11. Harmon KG, Drezner JA, Wilson MG, Sharma S. Incidence of sudden cardiac death in athletes: a state-of-the-art review. *Br J Sports Med*. 2014; 48 (15): 1185– 1192.
12. Maron BJ, Doerer JJ, Haas TS, Tierney DM, Mueller FO. Sudden deaths in young competitive athletes: analysis of 1866 deaths in the United States, 1980–2006. *Circulation*. 2009; 119 (8): 1085– 1092.
13. Thomas M, Haas TS, Doerer JJ, et al. Epidemiology of sudden death in young, competitive athletes due to blunt trauma. *Pediatrics*. 2011; 128 (1): e1– e8.

14. Centers for Disease Control and Prevention (CDC). Sports-related injuries among high school athletes: United States, 2005–06 school year. *MMWR Morb Mortal Wkly Rep.* 2006; 55 (38): 1037– 1040.
15. Comstock RD, Currie DW, Pierpoint LA. 2015–2016 National High School Sports-Related Injury Surveillance Study Summary Report. Denver, CO: Colorado School of Public Health; 2016.
16. Dompier TP, Kerr ZY, Marshall SW, et al. Incidence of concussion during practice and games in youth, high school, and collegiate American football players. *JAMA Pediatr.* 2015; 169 (7): 659– 665.
17. VRP Injury Software. University of North Carolina Injury Prevention Research Center Web site. <http://iprc.unc.edu/sportsinjurystatistics.shtml>. Accessed July 18, 2017.
18. McCombs ME, Shaw DL. The agenda-setting function of mass media. *Public Opin Q.* 1972; 36 (2): 176– 187.
19. Scheufele DA, Tewksbury D. Framing, agenda setting, and priming: the evolution of three media effects models. *J Communication.* 2007; 57 (1): 9– 20.
20. Ford BD. Triathlon death study: screen middle-aged men. ESPN.com Web site. [http://www.espn.com/sports/endurance/story/\\_/id/15139696](http://www.espn.com/sports/endurance/story/_/id/15139696). Accessed March 5, 2017.
21. Brown J. New film tackles dangers of concussions in the NFL. PBS NewsHour Web site. December 2015. <http://www.pbs.org/newshour/bb/new-film-tackles-dangers-of-concussions-in-the-nfl/>. Accessed April 3, 2017.
22. McEvers K, Silverman L, Sullivan B. Deaths persist in youth and student football despite safety efforts. NPR.org Web site. <http://www.npr.org/sections/health-shots/2015/11/25/457374128/deaths-persist-in-youth-and-student-football-despite-safety-efforts>. Accessed March 5, 2017.
23. Fainaru S, Fainaru-Wada M. OTL: New science suggests CTE widespread. ESPN.com Web site. [http://www.espn.com/espn/otl/story/\\_/id/14982032](http://www.espn.com/espn/otl/story/_/id/14982032). Accessed March 5, 2017.
24. Adams WM, Casa DJ, Drezner JA. Sport safety policy changes: saving lives and protecting athletes. *J Athl Train.* 2016; 51 (4): 358– 360.
25. Casa DJ, Guskiewicz KM, Anderson SA, et al. National Athletic Trainers' Association position statement: preventing sudden death in sports. *J Athl Train.* 2012; 47 (1): 96– 118.
26. AHSAA history and mission statement. Alabama High School Athletic Association Web site. <http://www.ahsaa.com/AHSAA/About-Us/AHSAA-History-and-Mission-Statement>. Accessed September 6, 2017.

27. Kelley B, Carchia C. Hidden demographics of youth sports. ESPN.com Web site. [http://www.espn.com/espn/story/\\_/id/9469252](http://www.espn.com/espn/story/_/id/9469252). Accessed March 4, 2017.
28. Huggins RA, Scarneo SE, Casa DJ, et al. The Inter-Association Task Force Document on Emergency Health and Safety: best-practice recommendations for youth sports leagues. *J Athl Train*. 2017; 52 (4): 384– 400.
29. Casa DJ, Almquist J, Anderson SA, et al. The Inter-Association Task Force for Preventing Sudden Death in Secondary School Athletics Programs: best-practices recommendations. *J Athl Train*. 2013; 48 (4): 546– 553.
30. Maron BJ, Carney KP, Lever HM, et al. Relationship of race to sudden cardiac death in competitive athletes with hypertrophic cardiomyopathy. *J Am Coll Cardiol*. 2003; 41 (6): 974– 980.