Epidemiology of Sudden Death in Young, Competitive Athletes Due to Blunt Trauma

WHAT’S KNOWN ON THIS SUBJECT: Fatalities caused by blunt trauma are known to occur in children and adolescents in a variety of circumstances, including while engaged in competitive sports.

WHAT THIS STUDY ADDS: This unique national database provides a prevalence for trauma-related catastrophes in children, adolescents, and young adults aged 21 or younger; establishes the epidemiology of events for which football conveys highest risk; and provides visibility to underrecognized mortality risks associated with “second-impact syndrome.”

BACKGROUND: Sudden deaths of young competitive athletes are highly visible events that have a substantial effect on families and communities. Recent attention has focused predominantly on cardiovascular causes, and less on traumatic organ damage.

OBJECTIVE: To define the clinical profile, epidemiology, and frequency of trauma-related deaths in young US athletes.

METHODS: We analyzed the 30-year US National Registry of Sudden Death in Young Athletes (1980–2009) by using systematic identification and tracking strategies.

RESULTS: Of 1827 deaths of athletes aged 21 years or younger, 261 (14%) were caused by trauma-related injuries, usually involving the head and/or neck (mean: 16 ± 2 years; 90% male) in 22 sports. The highest number of events in a single year was 16 (1986), with an average of 9 per year throughout 30 years. The mortality rate was 0.11 in 100 000 participations (95% confidence interval: 0.08–0.15). The largest number of deaths was in football (148 [57%]), including 17 high school athletes who sustained concussions shortly before fatal head trauma (“second-impact syndrome”). Football deaths were more frequent in defensive players, although the single most common position involved was running back (61% of offensive players).

CONCLUSIONS: In a large community-based national registry, sudden deaths caused by blunt trauma in young athletes aged 21 years or younger were relatively uncommon with 16 or fewer per year, about fourfold less than cardiovascular deaths. These fatalities were most frequent in football, and an important proportion of deaths after head blows in high school football were associated with a recent history of symptomatic concussion. Pediatrics 2011;128:e1–e8
Although participation in competitive athletics is usually regarded as healthy and safe, athletes are nevertheless subject to an unpredictable risk for sudden death while engaging in a variety of sports.1 Although most data regarding these tragic events has focused on cardiovascular causes,2–4 other risks of the athletic field involve trauma-related injuries5 or commotio cordis.6 Most previous reports of blunt trauma that cause structural organ damage have been tabulated during relatively short time periods, often including early eras of risk or largely confined to nonfatal events in small cohorts, and in single sports.5,7–12 In addition, the risks associated with previous head blows and concussions have been the subject of substantial recent attention in the media and medical literature.13–27 For these reasons, we believe it is timely to interrogate our large US national registry, assembled throughout 30 years, to assess the epidemiology and frequency of trauma-related sudden deaths in children, adolescents, and young adults aged 21 years and younger engaged in competitive athletics, compared with the incidence of those events caused by cardiovascular disease over the same period.

METHODS

Study Population

The US National Registry of Sudden Death in Young Athletes was instituted at the Minneapolis Heart Institute Foundation for the purpose of prospectively and retrospectively assembling data on the deaths of young athletes who participate in organized competitive sports.24,28 The registry includes a 30-year period (1980–2009) during which 1827 cases of athletes 21 and younger at the time of their death have been enrolled, and who represent the present study group.

Strategies for Identification

The study population was identified by previously reported methods2,24,28 with targeted searches using a variety of sources: (1) LexisNexis archival informational database with searchable access to authoritative news, legal, and public records (n = 5 billion from thousands of sources); (2) news media accounts systematically assembled through Burrelle’s Information Services (Livingston, NJ), with access to 18 000 US newspapers and international media sources daily; (3) Internet searches; access to online information via Web-based search engines (eg, Google, Yahoo); (4) reports from the US Consumer Product Safety Commission (Washington, DC); (5) accumulated records of the National Center for Catastrophic Sports Injury Research (University of North Carolina, Chapel Hill, NC); and (6) reports directly to the registry and the Minneapolis Heart Institute Foundation Web site (US National Registry of Sudden Death in Athletes), (www.suddendeathathletes.org), or reports from high schools, colleges, medical examiners, and parents.

Individual athletes were included in this registry when identified through the aforementioned sources and if 2 criteria were met: (1) participation in organized team or individual sports that required regular competition against others as a central component, placed a high premium on achievement, and required systematic and usually vigorous training (excluding those participating in college-sponsored intramural sports); and (2) experienced sudden death at age 21 or younger. A trauma-related death was defined as one caused by blunt-force impact to a vital organ, sustained during participation in an organized athletic event. Deaths from commotio cordis were excluded from this analysis.5,20

As reported previously,2,24,28 systematic identification and tracking strategies were established to assemble detailed information on each case, including a request for the autopsy report (with gross anatomic and toxicologic findings) and pertinent clinical and demographic information. Selected data, related to the event and demographics, were often derived from media accounts or telephone interviews with family members, witnesses, or officials/coaches. When necessary, autopsy findings were verified or obtained by direct communication with medical examiners.

Definition

Concussion is defined as a trauma-induced alteration in mental status, usually characterized by confusion and amnesia that may or may not involve a loss of consciousness.26–27 This project was reviewed by the Allina Institutional Review Board.

Statistical Methods

Numeric data are expressed as mean ± SD. Proportions were compared with Pearson’s $\chi^2$ or Fisher’s exact tests. Ages were compared using a 2-sample $t$ test. All tests were performed by using Stata 11.0 (Stata Corp, College Station, TX).

By search of online Web sites, direct e-mail, or telephone contact, we assembled the number of participations in organized competitive sports. To calculate the rate of sudden deaths, the total number of these events that occurred during the 5 years from the 2003–2004 to 2007–2008 seasons was divided by the estimated number of participations in all competitive sports for athletes aged 21 years or younger in the United States during the same period.30–32 The number of participations was assembled from the records of several sports organizations, including the National Federation of State High School Associations (35 854 456), the National Collegiate Athletic Association.
The National Junior College Athletic Association (245 732), and the National Association of Intercollegiate Athletics (250 009) for high school and college athletes. Finally, the number of participants in major and minor US professional sports (including baseball, football, and hockey) were tabulated.33 The confidence interval for rate per 100,000 participations assumes a Poisson distribution.

RESULTS
Trauma-Related Deaths
Of the 1827 youths registered who were 21 or younger, 261 (14%) died as a result of bodily trauma and vital organ damage. At least 4 such deaths were reported in each of the 30 years. The proportion of deaths in the most recent 15-year period from 1995–2009 (129 [49%]) was similar to the previous 15 years from 1980 to 1994 (132 [51%]). Deaths were reported from 46 states and Washington, DC, most commonly in those with the largest populations: California (n = 37); Texas (n = 26); Florida (n = 14); and Colorado (n = 12), but none from Alaska, Maryland, Rhode Island, South Dakota, or Wyoming. The highest number of trauma-related deaths recorded in any single year was 16, in 1986, followed by 14 in 1985; 12 occurred in 1982, 1984, 1997, and 2001 (Figs 1 and 2). The average number of trauma-related deaths has remained relatively constant (P = .21) and was 9 per year (range: 4–16) throughout 30 years, and also 9 per year for the most recent 10-year period of reporting (2000–2009).

Mortality rate in young athletes because of blunt trauma was calculated for the recent 5-year period (2003–2004 to 2007–2008) using an estimated 7,670,000 million participations per year of youths aged 21 and younger in organized high school and college sports. The rate of trauma death was 0.11 per 100,000 participations (95% confidence interval: 0.08–0.15). The comparable rate for 1139 cardiovascular deaths was 0.83 per 100,000 participations (95% confidence interval: 0.74–0.93 (P < .0001) (Fig 1).

Demographics
The 261 athletes ranged in age from 8 to 21 years at the time of death (mean: 16 ± 2 years); 235 were male (90%), and 26 were female (10%) (Table 1). Deaths reported in white athletes (174 [67%]) substantially exceeded those in blacks (39 [15%]), Hispanics (34 [13%]), Asians including Pacific Islanders (5 [2%]), and others (9 [3%]) (Table 1). In football, most deaths oc-
curred in white athletes (85 [57%]), and males (147 [99%]). Overall, white and nonwhite athletes did not differ significantly with respect to age (16.1 ± 2v s 17 ± 2 years; \( P = .14 \)), although white athletes were more likely to be female (14% of deaths in whites were female versus 2.5% in nonwhites; \( P = .006 \)).

Throughout the 30-year time period, there were significantly fewer trauma-related deaths (261) than cardiovascular deaths (1 130) (\( P < .0001 \)) in athletes 21 and younger. The fraction of trauma deaths decreased from 56% in 1980 (10 of 18 deaths) to 9% by 2009 (only 7 of 75 deaths). The proportion of trauma-related deaths decreased from 56% in 1980 (10 of 18 deaths) to 9% by 2009 (only 7 of 75 deaths). The proportion of trauma-related deaths in the most recent 15-year period (1995–2009) was 13%, whereas the analogous proportion was 30% in the initial 15-year period (\( P < .0001 \)).

Black athletes accounted for a much smaller fraction of trauma-related fatalities (15%) than of cardiovascular deaths (37%; \( P < .0001 \)).

Sports and Level of Participation

Athletes participated in 22 organized competitive sports at the time of their deaths, most commonly in football (148 [57%]), but also track and field (27% of black athletes accounted for a much smaller fraction of trauma-related fatalities (15%) than of cardiovascular deaths (37%; \( P < .0001 \)).

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Athletes participated in 22 organized competitive sports at the time of their deaths, most commonly in football (148 [57%]), but also track and field (27% of athletes were engaged in either competitive events (161, 61%) or practice sessions (100, 39%). Trauma-related deaths occurred when athletes were engaged in either competitive events (161, 61%) or practice sessions (100, 39%).

Context

Trauma-related deaths occurred when athletes were engaged in either competitive events (161, 61%) or practice sessions (100, 39%). Trauma that caused death was most frequently

TABLE 1 Clinical Profile of Trauma-Related Deaths in 261 Competitive Athletes Aged 21 Years and Younger

<table>
<thead>
<tr>
<th>Gender</th>
<th>Race</th>
<th>Circumstance</th>
<th>Type of Traumatic Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male, n (%)</td>
<td>Female, n (%)</td>
<td>White, n (%)</td>
<td>Black, n (%)</td>
</tr>
<tr>
<td>Football</td>
<td>148 (56.7)</td>
<td>147 (99)</td>
<td>85 (57)</td>
</tr>
<tr>
<td>Track and field</td>
<td>27 (10.3)</td>
<td>17 (18)</td>
<td>18 (100)</td>
</tr>
<tr>
<td>Baseball</td>
<td>18 (8.9)</td>
<td>152 (2.2)</td>
<td>18 (100)</td>
</tr>
<tr>
<td>Boxing</td>
<td>12 (4.6)</td>
<td>189 (1.9)</td>
<td>12 (100)</td>
</tr>
<tr>
<td>Soccer</td>
<td>11 (4.2)</td>
<td>141 (2.1)</td>
<td>8 (73)</td>
</tr>
<tr>
<td>Horseback-riding</td>
<td>8 (3.1)</td>
<td>17.5 (2.5)</td>
<td>2 (25)</td>
</tr>
<tr>
<td>Skiing</td>
<td>8 (3.1)</td>
<td>16.1 (2.7)</td>
<td>3 (38)</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>4 (1.1)</td>
<td>16.5 (1.3)</td>
<td>3 (75)</td>
</tr>
<tr>
<td>Softball</td>
<td>4 (1.1)</td>
<td>14.8 (4.3)</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Basketball</td>
<td>3 (1.1)</td>
<td>14.7 (2.9)</td>
<td>3 (100)</td>
</tr>
<tr>
<td>Cheerleading</td>
<td>3 (1.1)</td>
<td>16.4 (4.4)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Hockey</td>
<td>3 (1.1)</td>
<td>15.7 (3.5)</td>
<td>3 (100)</td>
</tr>
<tr>
<td>Wrestling</td>
<td>3 (1.1)</td>
<td>16.3 (3.2)</td>
<td>3 (100)</td>
</tr>
<tr>
<td>Cycling</td>
<td>2 (0.8)</td>
<td>16.5 (4.9)</td>
<td>2 (100)</td>
</tr>
<tr>
<td>Lacrosse</td>
<td>2 (0.8)</td>
<td>16.5 (5.5)</td>
<td>2 (100)</td>
</tr>
<tr>
<td>Running</td>
<td>2 (0.8)</td>
<td>15.6 (2.1)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Rugby</td>
<td>1 (0.4)</td>
<td>16.6 (1.0)</td>
<td>1 (100)</td>
</tr>
<tr>
<td>Surfing</td>
<td>1 (0.4)</td>
<td>13.0 (0)</td>
<td>1 (100)</td>
</tr>
<tr>
<td>Weightlifting</td>
<td>1 (0.4)</td>
<td>14.6 (0)</td>
<td>1 (100)</td>
</tr>
<tr>
<td>Total</td>
<td>261</td>
<td>16.3 (2.4)</td>
<td>255 (90)</td>
</tr>
</tbody>
</table>

* Includes Hispanic (n = 34), Asian (n = 3), American Indian (n = 2), Pacific Islander (n = 2), and unknown (n = 17).

** Includes equestrian (n = 6) and jockey (n = 2).

† Includes skiing (n = 7) and snowboarding (n = 1).

‡ Includes triathlon (n = 1) and cross-country running (n = 1).
confined to the head and/or neck (or spine-related) (231 [89%]), including all 12 boxing deaths and 10 helmet-to-helmet blows in football. In baseball, there were 18 deaths, including 16 because of head trauma, which resulted from hard-hit line-drives or other batted balls (n = 18), bodily collisions (n = 2), or errantly thrown or pitched balls (n = 6).

Other deaths resulted from multiple organ damage (7 [3%]), abdominal blows that produced splenic rupture or laceration of liver or intestine (12 [4%]), or chest blows that caused laceration of the aorta or left ventricle (4 [1.5%]); 7 (3%) were unspecified.

Consequences of Concussions

Of the 138 football players who died as a result of head/neck blows with subdural hematoma, 17 (12%) had a reported history of concussion a few days to 4 weeks prior, which was followed by persistent symptoms that included recurring headache, dizziness, disorientation, memory loss, visual disturbances, seizures, and vomiting. This sequence of events is consistent with “second-impact syndrome.”34–38 These athletes were 14 to 18 years of age, and all competed at the high school level; 9 were white, 5 black, and 3 Hispanic.

Player Position and Risk of Death (Football)

The relationship between football position and trauma-related death risk was analyzed in 123 of 148 players (Fig 3). Overall, defensive positions were associated with greater numbers of deaths (n = 69) than were offensive positions (n = 54). Among the 69 deaths in defensive players, 24 (35%) were in backs, 24 (35%) were linebackers, 12 (17%) were linemen, and 9 (13%) were special-teams players. However, the player position in which fatal trauma-related injury was sustained most commonly was offensive running back, accounting for 33 (61%) of deaths among offensive players, whereas the positions of quarterback (6 [11%]), lineman (5 [9%]), receiver (4 [7%]), and special teams (6 [11%]) were associated with distinctly lower event rates (Fig 3).

DISCUSSION

Sudden deaths in young trained athletes have become a highly visible public health issue that has attracted considerable media attention, with great importance to the physician and lay communities, particularly given the youthful age and apparent good health of the victims.1 Substantial emphasis has been directed toward recognition and detection of unsuspected cardiovascular diseases, including various strategies for preparticipation screening.1–4 However, there has been increasing attention (including in the news media) on the risks in children and young adults of blunt trauma associated with certain competitive sports (e.g., particularly football) leading to nonfatal concussion injury, permanent disability, or even death.*

The national registry at the Minneapolis Heart Institute Foundation assembles deaths occurring nationwide in young competitive athletes and is a unique resource for events related to participation in competitive sports disciplines at all levels. In acquiring these data, we were largely dependent on information from the public domain and record that was assembled systematically by using a variety of resources that most importantly include the powerful LexisNexis database, informational services, and Internet search engines.1,2,4,28 The primary impetus of this report was to establish an estimate of the demographic profile, epidemiology, and absolute number of trauma-related athlete deaths among athletes aged 21 or younger that occur annually in the United States (exclusive of commotio cordis). Although several reports have addressed sudden death caused by blunt trauma on the athletic field,5–9,21,38–40 such data have not been assembled previously throughout long periods of time (compared with the 3 decades in this study),

FIGURE 3
Trauma-related football deaths, according to player position (n = 148). Analysis includes 123 deaths; exclusive of the 16 players who died during practice drills, which inherently do not have designated positions, and 9 players who died during games for which the available information did not document their position. DB indicates defensive back; DL, defensive lineman; LB, linebacker; OL, offensive lineman; QB, quarterback; RB, running back; ST, special teams; WR, wide receiver. a Kick returner (n = 4), punter (n = 1), field goal holder (n = 1). b Players tackling during kick-off or punt return (n = 9).
nor in a large informative registry format such as presented here (including >1800 deaths).

By accessing this database, we found that trauma deaths (predominantly involving the head and neck) occurred in children, adolescents, and young adults during participation in a wide variety of 22 sports. Notably, the frequency of such deaths in athletes because of bodily trauma proved to be relatively low. The highest number tabulated for 1 year was 16, and the average over the last decade was 9 events per year. In absolute numbers, that rate does not seem to have changed significantly over the 3 decades of study. Overall, this annual mortality proved to be far less (by about fourfold) than for cardiovascular-related deaths in the same young registry population (Fig 2), although the ratio of cardiovascular to trauma deaths has increased over time.

Football, played on amateur levels from middle school through college (and also professionally), is widely recognized as a highly physical sport with inherent risks for bodily collision and injury, but not necessarily associated with the possibility of death. Indeed, football was the single most common sport involved in these catastrophes, with almost 60% occurring in children and adolescents, the vast majority of which were in high school and middle school athletic competition. Nonfatal concussions in preadolescent (<14 years) athletes also have been linked disproportionately to competitive football.

In addition, in football, we found a predilection for fatal events at particular player positions. For example, deaths were more common in defensive positions (eg, linebacker and defensive backfield), presumably because such players commonly initiate and deliver high-velocity blows while moving toward the point of contact. However, offensive running backs, who are exposed to severe bodily contact inflicted by defensive players, were commonly involved in fatal collisions.

Considerable attention has recently focused specifically on the risks associated with concussions in football at all ages including children, and importantly the consequence of repeated head blows (“second-impact syndrome”).

In this regard, our data included a subset of 17 high school football players with death because of cerebral edema and brain herniation or subdural hematoma, in whom there was a recent history of concussion, after which symptoms such as headache, dizziness, or memory loss persisted (comprising 12% of all football-related deaths due to head injury). In some cases, these athletes were cleared for competition despite residual symptoms from their previous head injury. These are potentially preventable deaths, and increasing recognition of this syndrome has led to recommendations or regulations to remove athletes from additional practice or game participation after a suspected concussion or head injury until their symptoms have abated. Taken together, these observations underscore the importance of continued attention by coaches, athletes, and families to the potential consequences of violent collisions to further reduce fatalities on the football field.

Certain sports with relatively low participation rates also seem to be associated with considerable risk. For example, the registry has tabulated 22 trauma-associated deaths with pole vaulting in this young age group, predominantly from head injuries when athletes fall outside the padded landing pit. Although the precise number of at-risk competitors in this sport is unknown, the mortality risk associated with pole vaulting would nevertheless seem to be particularly high. Similarly, competitive cheerleading was associated with 3 trauma-related deaths.

Without a systematic and mandatory reporting system for sudden cardiac deaths in young competitive athletes, the true absolute number of these events that occur in the United States cannot be known. Indeed, given that improved surveillance systems during the most recent 15 years accounted for a greater proportion of sudden deaths detected during the study period, it is likely that the number of events identified overall would have been higher if a mandatory reporting system had been implemented throughout the 30-year period.

The low risk of trauma death reported here during competitive sports (~9 per year) is substantially less than that observed among other risks applicable to this age group, eg, cancer (2500 per year), leukemia (700 per year), cystic fibrosis (175 per year), automobile accidents (12 000 per year), homicides (6000 per year), meningococcemia (250 per year), or even lightning-related fatalities (50 per year). However, it was impractical to provide a reliable calculation for the incidence of death in our registry over the substantial 30-year period because denominators accurately reporting the overall at-risk athlete population for each of 22 individual sporting disciplines were not available. Nevertheless, using available data from the recent 5-year period, we were able to estimate the overall frequency of these trauma deaths to be ~0.11 per 100 000 participations.

CONCLUSIONS

Trauma-related deaths in young competitive athletes are relatively uncommon events relative to the vast numbers of athletes participating safely in a wide variety of organized sports, and...
they occurred at a lower event rate in this population than cardiovascular deaths. Nevertheless, these catastrophic events remain an important public health issue with a devastating effect on families, communities, and physicians, and of particular relevance to the practicing pediatric community. Notably, in football the preventable “second-impact syndrome” has emerged as a recognized risk. Most of the fatal events reported here are potentially preventable, and our observations underscore the importance of developing more effective equipment design, return-to-play decision strategies, modified blocking/tackling rules, and greater attention to the education of coaches, trainers, parents, and athletes regarding the consequences of repeated head blows and concussions. The ultimate aspiration of reporting these data is the creation of a safer environment for young people on the athletic field.

ACKNOWLEDGMENT
This work was supported by the Hearst Foundations (New York, NY).

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Pediatrics 2011;128:e1
DOI: 10.1542/peds.2010-2743 originally published online June 20, 2011;
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