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Am J Sports Med 2013 41: 1108 originally published online March 11, 2013
DOI: 10.1177/0363546513478572

Fatalities in High School and College Football Players

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Background: Fatalities in football are rare but tragic events.

Purpose: The purpose was to describe the causes of fatalities in high school and college football players and potentially provide preventive strategies.

Study Design: Descriptive epidemiology study.

Methods: We reviewed the 243 football fatalities reported to the National Center for Catastrophic Sports Injury Research from July 1990 through June 2010.

Results: Football fatalities averaged 12.2 per year, or 1 per 100,000 participants. There were 164 indirect (systemic) fatalities (average, 8.2 annually [or 0.7 per 100,000 participants]) and 79 direct (traumatic) fatalities (average, 4.0 annually [or 0.3 per 100,000 participants]). Indirect fatalities were 2.1 times more common than direct fatalities. The risk of a fatality in college compared with high school football players was 2.8 (95% CI, 0.7-8.2) times higher for all fatalities, 3.6 (95% CI, 2.5-5.3) times higher for indirect events, 1.4 (95% CI, 0.6-3.0) times higher for direct injuries, 3.8 (95% CI, 1.8-8.3) times higher for heat illness, and 66 (95% CI, 14.4-308) times higher for sickle cell trait (SCT) fatalities. Most indirect events occurred in practice sessions; preseason practices and intense conditioning sessions were vulnerable periods for athletes to develop heat illness or SCT fatalities, respectively. In contrast, most brain fatalities occurred during games. The odds of a fatality during the second decade, compared with the first decade of the study, were 9.7 (95% CI, 1.2-75.9) for SCT, 1.5 (95% CI, 0.8-2.9) for heat illness, 1.1 (95% CI, 0.8-1.7) for cardiac fatalities, and 0.7 (95% CI, 0.4-1.2) for brain fatalities. The most common causes of fatalities were cardiac failure (n = 100, 41.2%), brain injury (n = 62, 25.5%), heat illness (n = 38, 15.6%), SCT (n = 11, 4.5%), asthma and commotio cordis (n = 7 each, 2.9% each), embolism/blood clot (n = 5, 2.1%), cervical fracture (n = 4, 1.7%), and intra-abdominal injury, infection, and lightning (n = 3, 1.2% each).

Conclusion: High school and college football have approximately 12 fatalities annually with indirect systemic causes being twice as common as direct blunt trauma. The most common causes are cardiac failure, brain injury, and heat illness. The incidence of fatalities is much higher at the college level for most injuries other than brain injuries, which were only slightly more common at the college level. The risk of SCT, heat-related, and cardiac deaths increased during the second decade of the study, indicating these conditions require a greater emphasis on diagnosis, treatment, and prevention.

Keywords: football; fatalities; cardiac; brain

Football is one of the most popular team sports in the United States, with more than 1 million high school participants annually since the 1998-1999 academic year.[20] Football also is associated with the highest number of fatalities for any sport reported to the National Center for Catastrophic Sports Injury Research (hereinafter termed the "Center").[17] In one report on sudden death secondary to blunt trauma in young competitive athletes in all sports over a 30-year span, football was associated with almost 60% of the fatalities.[24] Another review of all football fatalities at the professional, college, high school, and sandlot levels over a 55-year period (1945-1999) identified 718 fatalities, or an average of 13 annually.[5] Football was also associated with the highest number of nontraumatic sports deaths in high school and college athletes identified by the Center (n = 67, 42%) over a 10-year period (1983-1993).[28]

However, to our knowledge, there have been no comprehensive published studies focusing solely on football fatalities at the high school and college levels during the past 2 decades. Our goal was to review the Center data for 20 years (July 1990 through June 2010) to determine the incidence and causes of high school and college football fatalities and potentially provide preventive strategies.

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The authors declared that they have no conflicts of interest in the authorship and publication of this contribution.

The American Journal of Sports Medicine, Vol. 41, No. 5
DOI: 10.1177/0363546513478572

MATERIALS AND METHODS

Injury Definitions

This study was exempt from institutional review board approval (all information was public domain). The Center classifies fatalities as direct (trauma from participation in a sport resulting in a brain injury, cervical fracture, or intra-abdominal injury) or indirect (from systemic compromise such as cardiac failure, heat illness, sickle cell trait [SCT], asthma, or pulmonary embolism secondary to exertion while participating in a sport).[18]

Injury Reports

From July 1990 through June 2010, the Center collected data on high school and college football fatalities in the United States. It annually contacted and requested reports of any catastrophic events in organized school-sponsored sports from high school and college coaches, athletic directors, and athletic trainers; executive offices of state and national athletic organizations; and a national newspaper clipping service. Once information was received concerning a possible catastrophic football injury, the Center contacted the college athletic trainers and the National Federation of State High School Associations (NFSHSA) contacted the high school coaches or athletic trainers to obtain preliminary data (eg, the athlete's name, date of injury, age, diagnosis, school, circumstances such as practice session versus game, and mechanism of injury).

Injury Surveillance

In 2011 and 2012, we performed extensive Internet searches to acquire additional information about any football fatalities reported to the Center. A detailed questionnaire was used to collect data on player characteristics (weight, height, position played), timing of injury, and participation level. Information was recorded regarding the mechanism of injury, previous head injury and equipment worn, medical diagnosis, and treatment. Weather conditions on the day of the heat and SCT fatalities were also obtained via Internet searches.[30] The odds ratio (95% confidence interval [CI]) was assessed for college versus high school athletes, and the common causes of fatalities were compared for the first and second decades. The locations for the heat-related and SCT deaths were divided into 4 regions using the United States Census Bureau classification (Table 1).[27]

Participation Numbers

During the study period, there were 22,530,754 high school (average, 1,126,537.7 annually) and 1,570,000 college (average, 78,500 annually) football players (personal communication, Dee Dubois, National Junior College Athletic Association [NJCAA], August 2011).[20,21] Participation numbers for high schools were based on the NFSHSA[21] data plus an additional 100,000 players (estimate based on the NFSHSA[21] recommendation) each year for non-NFSHSA schools. There were approximately 78,500 college participants annually based on data provided by the National Collegiate Athletic Association (NCAA) and the NJCAA.[20]

TABLE 1
Geographic Regions in the United States

Region	States
South	Maryland, Delaware, Florida, Georgia, North Carolina, South Carolina, Virginia, West Virginia, District of Columbia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, and Texas
Midwest	Ohio, Indiana, Michigan, Illinois, Wisconsin, Iowa, Minnesota, Kansas, Missouri, Nebraska, North Dakota, and South Dakota
West	Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington, and Wyoming
Northeast	Connecticut, Maine, Massachusetts, New Jersey, New Hampshire, New York, Pennsylvania, Rhode Island, and Vermont

RESULTS

Epidemiological and Demographic Patterns

During the study period, there were 243 football fatalities (1.0 per 100,000 participants), all in male athletes (average, 12.2 annually): 203 (average, 10.2 annually; 0.9 per 100,000 participants) in high school players and 40 (average, 2.0 annually; 2.5 per 100,000 participants) in college players (Table 2 and Figure 1). There were 164 indirect fatalities (average, 8.2 annually; 0.7 per 100,000 participants): 131 (average, 6.6 annually; 0.6 per 100,000 participants) in high school players and 33 (average, 1.65 annually; 2.1 per 100,000 participants) in college players (Figure 2). There were 79 (average, 4.0 annually; 0.3 per 100,000 participants) direct fatalities: 72 (average, 3.6 annually; 0.32 per 100,000 participants) in high school players and 7 (average, 0.4 annually; 0.5 per 100,000 participants) in college players (Figure 3). The most common causes were cardiac (n = 100, 41.2%) and brain (n = 62, 25.5%) injuries (Figure 4). In 146 cases, the diagnosis was confirmed via autopsy. The odds ratio for a fatality was higher at the college level than at the high school level for all categories, especially SCT (66.6), heat illness (3.8), indirect (3.6), and cardiac (2.3) fatalities (Table 2).

Timing of Injury

The fatalities occurred when athletes were engaged in practices (n = 143, 62.2%) or games (n = 87, 37.8%); the timing was unknown for 13 fatalities. Most cardiac deaths occurred during practices (n = 71, 74%) rather than games (n = 25, 26%); in 4 cases, the timing was unknown. All 11 SCT deaths and all but 1 of the heat deaths (n = 37, 97%) (in 1 case, the timing was unknown) occurred during practices. In contrast, most brain fatalities occurred during

TABLE 2
Number, Annual Average, and Incidence of Fatalities for Total, Indirect, Direct, and Specific Diagnoses at the High School and College Levels

		No. of Injuries					Incidence			
Category	Total No.	Total Annual Average	Total High School	Annual High School Average	Total College	Annual College Average	Total Annual	High School Annual	College Annual	Odds Ratio of College to High School (95% CI)
All	243	12.1	203	10.1	40	2.0	1.0	0.9	2.5	2.8 (0.7-8.2)
Indirect	164	8.2	131	6.6	33	1.65	0.7	0.6	2.1	3.6 (2.5-5.3)
Direct	79	4.0	72	3.6	7	0.4	0.4	0.32	0.5	1.4 (0.6-3.0)
Cardiac	100	5	86	4.3	14	0.7	0.41	0.38	0.89	2.3 (0.4-13.9)
Brain	62	3.1	57	2.85	5	0.25	0.26	0.25	0.32	1.3 (0.5-3.2)
Heat	38	1.9	30	1.5	8	0.4	0.16	0.13	0.51	3.8 (1.8-8.3)
Sickle cell trait	11	0.55	2	0.1	9	0.45	0.05	0.01	0.57	66.6 (14.4-308)
Asthma	7	0.35	6	0.3	1	0.05	0.03	0.03	0.06	2.4 (0.3-19.8)
Commotio cordis	7	0.35	5	0.25	2	0.1	0.03	0.02	0.13	5.8 (1.1-29.7)
Embolism/clot	5	0.25	4	0.2	1	0.05	0.02	0.02	0.06	3.6 (0.4-31.8)
Cervical fracture	4	0.2	4	0.2	0	0.05	0.02	0.02	0	
Intra-abdominal	3	0.15	3	0.15	0	0	0.01	0.01	0	
Lightning	3	0.15	3	0.15	0	0	0.01	0.01	0	
Infection	3	0.15	3	0.15	0	0	0.01	0.01	0	

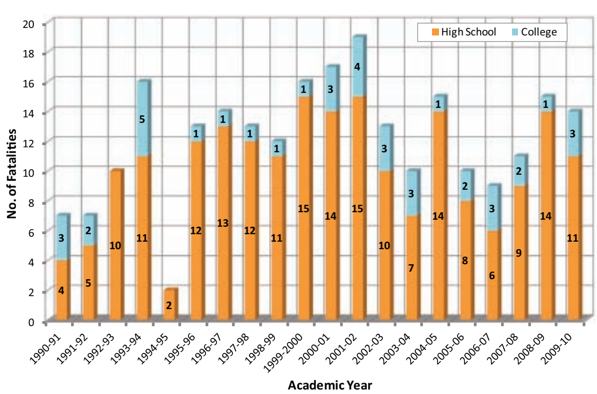

Figure 1. Football fatalities annually at the high school and college levels, 1990-1991 through 2009-2010.

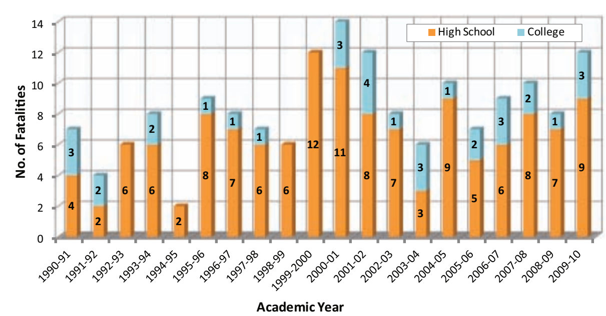

Figure 2. Indirect football fatalities annually at the high school and college levels, 1990-1991 through 2009-2010.

games (n = 48, 83%) rather than practices (n = 10, 17%); in 4 cases, the timing was unknown.

Causes

Cardiac Causes. There were 100 deaths (average, 5 annually; peak, 9 annually from 1999-2002; 0.41 per 100,000 participants) from cardiac causes: 86 in high school players and 14 in college players (Table 2 and Figure 5). The risk of a cardiac death in the second decade of the study was 1.1 (95% CI, 0.8-1.7) times greater than a cardiac fatality in the first decade, which may be caused by a spike of fatalities during the 2000-2001 and 2001-2002 academic years. A precise diagnosis could not be determined in 63 cases. For the remaining 37 cases, the diagnosis was hypertrophic cardiomyopathy (n = 22), coronary artery anomaly (n = 11), mitral valve abnormality (n = 2), or myocarditis (n = 2).

Brain Injuries. There were 62 deaths (average, 3.1 annually; peak, 7 in 1993-1994; 0.26 per 100,000 participants) from brain-related injuries: 57 in high school players and 5 in college players (Table 2 and Figure 5). The risk of a brain death in the second decade of the study was 0.7 (95% CI, 0.4-1.2) compared with the first decade. The average age at death was 16.6 years (range, 14-22 years). The fatalities resulted from complications secondary to subdural hematoma (n = 49), arteriovenous malformation or aneurysm (n = 5), diffuse brain edema (n = 3), and unknown diagnosis (n = 5). At least 15 (24.2%) athletes, all at the high school level, had a history of concussion, with 10 (16.1%) within 1 month of the fatality. In these cases, the diagnosis provided was subdural hematoma in 11 and unknown in 4.

The position played was determined for 49 athletes (13 unknown). The most common positions were linebacker

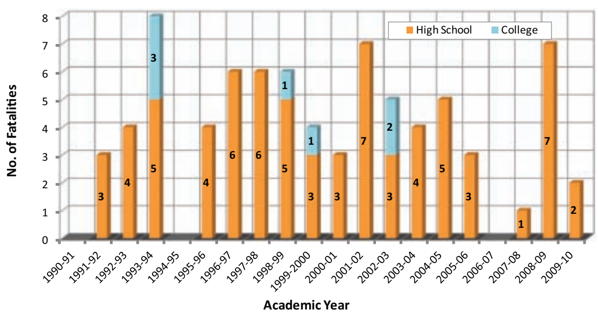

Figure 3. Direct football fatalities annually at the high school and college levels, 1990-1991 through 2009-2010.

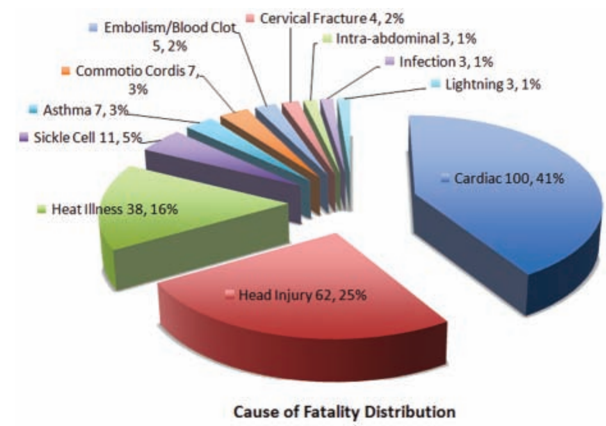

Figure 4. Number and percentage of football fatalities by diagnosis.

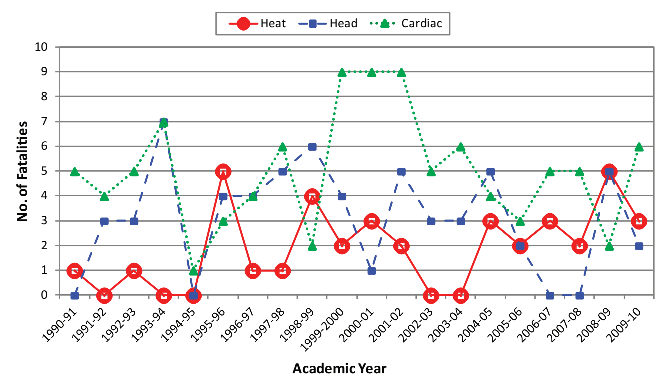

Figure 5. Incidence trends of heat, head, and cardiac fatalities in football.

(n = 11), running back (n = 10), and defensive back (n = 9), followed by special teams player and defensive lineman (n = 3 each) and quarterback and offensive lineman (n = 2 each). In addition, 9 high school athletes played 2 positions: 4 played running back/linebacker, and 1 each played running back/defensive back, special teams/defensive back, special teams/defensive lineman, defensive back/wide receiver, and offensive lineman/linebacker.

Heat. There were 38 heat-related deaths (average, 1.9 annually; peak, 5 annually during the 1995-1996 and 2008-2009 academic years; 0.16 per 100,000 participants): 30 in high school players and 8 in college players (Table 2 and Figure 5). The risk of a heat death in the second decade of the study was 1.5 (95% CI, 0.8-2.9) times greater than a heat fatality in the first decade. The average temperature and average maximum temperature on the fatal day were 79.8°F (range, 67°F-88°F) and 89.6°F (range, 70°F-100°F), respectively. The core body temperature, identified in 10 cases, averaged 107.8°F (range, 104°F-111°F). The average humidity and average maximum humidity on the fatal day were 67.1% (range, 45%-91%) and 87.7% (range, 38%-100%), respectively. The average weight and body mass index (BMI), identified in 26 cases, were 265 lb (range, 185-360 lb) and 33.9 (range, 25-47), respectively.

All deaths occurred during the preseason or the early part of the regular season: July (n = 7, 18%), August (n = 28, 74%), and September (n = 3, 8%). Most (97%) occurred during practices; 1 occurred during a game, and the timing of 1 was unknown. The exact timing of the injury was determined in 18 cases: 15 (83%) occurred during 2-a-day practices, and 8 (44%) occurred on the first day of practice. The equipment worn was noted in 17 of those practice sessions: 10 (60%) occurred in players wearing helmets, and 4 (25%) occurred in athletes wearing full equipment. Most heat-related deaths occurred in the South (n = 24, 63%), followed by the Midwest (n = 7, 18%), the West (n = 5, 13%), and the Northeast (n = 1, 3%); the location was unknown in 1 (3%). One athlete was reported to have been taking an ephedra product, and 1 had a history of gastrointestinal symptoms the night before suffering the heat stroke.

Sickle Cell Trait. There were 11 deaths (0.05 per 100,000 participants), secondary to complications from SCT, all occurring from 1999-2000 through 2009-2010 (0.08 per 100,000 participants during this 11-year span) (Table 2). The risk of a SCT death in the second decade of the study was 9.7 (95% CI, 1.2-75.9) times greater than a SCT fatality in the first decade. The 11 deaths occurred in 2 high school and 9 college athletes, with a 66.6 (95% CI, 14.4-308.0) times greater risk in college athletes compared with high school athletes. All 11 were African American; their average weight and BMI were 198.7 lb (range, 181-260 lb) and 27.7 (range, 26.0-32.5), respectively. The average temperature and average maximum temperature on the fatal day were 71.5°F (range, 44°F-83°F) and 79.6°F (range, 57°F-93°F), respectively. The average humidity and average maximum humidity on the fatal day was 66.4% (range, 50%-94%) and 84.6% (range, 60%-100%), respectively. The average altitude at the fatal site was 712 ft (range, 48-2116 ft). Four deaths occurred during the organized football season (2 in August and 2 in September), and 7 occurred during off-season conditioning (3 in July, 2 in February, 1 in March, and 1 in May). Eight deaths occurred in the South, and 2 occurred in the Midwest; the location of 1 was unknown. It was not known that 4 athletes had SCT until postmortem testing, and in 1 case, the diagnosis was known by the athlete but was not reported to the team. The timing of the SCT diagnosis and whether the coach and medical staff were aware of the diagnosis were not known in 6 cases. All deaths occurred during sprinting or agility drills in practice sessions. In 2 cases, death occurred during sprinting drills in the season's first practice session.

Asthma. Seven deaths resulted from asthma complications: 6 in high school players and 1 in a college player. The average age at death was 17 years (range, 15-22 years).

Commotio Cordis. Seven deaths resulted from commotio cordis (arrhythmia or sudden death from low-impact blunt trauma to the chest in patients with no pre-existing cardiovascular disease[13]). The average age at death was 17 years (range, 16-19 years); 5 were high school players, and 2 were college players. The risk of commotio cordis was 5.8 (95% CI, 1.1-29.7) times higher in college than in high school athletes. In all 7 cases, injury was caused by a direct impact to the chest region that occurred while making a tackle or being tackled in a game (4 cases) or practice (3 cases). Detailed information concerning equipment was obtained in 6 cases: all 6 were wearing full equipment. The time to death was less than 1 hour in 3 cases, 70 minutes in 1 case, and unknown in 3 cases.

Pulmonary Embolism/Blood Clot. Five deaths resulted from a pulmonary embolism. The average age at death was 17 years (range, 16-18 years); 4 were high school players, and 1 was a college player. Four cases were precipitated by a traumatic injury (blunt trauma to the leg in 1, and tibia and fibula fracture in 1) or surgery (knee surgery in 1, and ankle surgery in 1), and 1 case was idiopathic and occurred during a game.

Cervical Fracture. Four deaths resulted from cervical fractures, all in high school players; the average age at death was 16 years (range, 15-17 years). One case occurred from a cervical fracture causing a vascular injury with subsequent stroke; 2 occurred when a player was tackled (n = 1) or was blocking (n = 1); the mechanism was unknown for 1.

Intra-abdominal Injury. There were 3 fatalities from intra-abdominal injuries secondary to direct trauma during a game. All fatalities occurred in high school players: 1 from complications of a splenic rupture and intestinal tear from being tackled, 1 from a delayed diagnosis of a splenic rupture, and 1 from a liver laceration secondary to a collision. The average age at death was 16.7 years (range, 15-18 years).

Infection. There were 3 deaths from infection complications, all in high school players; the average age at death was 17.7 years (range, 17-18 years). There were 2 direct injuries (1 from a severe thigh contusion, which led to necrotizing fasciitis, and 1 from a severe ankle injury complicated by septicemia) and 1 indirect injury (from a methicillin-resistant *Staphylococcus aureus* [MRSA] infection).

Lightning. There were 3 lightning fatalities, all in high school players. The average age at death was 15.7 years (range, 15-17 years). The deaths occurred in September, October, and May; 2 occurred during practices, and 1 occurred in a game. Two athletes were wearing full football equipment, and 1 was wearing at least a helmet. Two fatalities occurred in Texas, and 1 occurred in Florida.

DISCUSSION

Of all high school and college sports followed by the Center, football was associated with the highest number of total, indirect, and direct fatalities over the 20-year study period and accounted for nearly half (46%) of all fatalities recorded by the Center for male athletes (Table 3).[17] Similar to other reports,[11,12,28] we found that the number and incidence of indirect events were higher than those of direct traumatic fatalities. We also found that football had a higher percentage (30%) of deaths secondary to blunt trauma (excluding commotio cordis) than the average (22%[12]) of all sports combined.

TABLE 3
Fatalities by Sport Type During the 20-Year Study Period

Sport	Indirect, n (%)	Direct, n (%)	Total, n (%)
Football	164 (40)	79 (64.2)	243 (45.6)
Other	246 (60)	44 (35.8)	290 (54.4)
Basketball	120 (29.3)	3 (2.4)	123 (23.1)
Soccer	28 (6.8)	0 (0)	28 (5.3)
Track and field/ pole vaulting	25 (6.1)	19 (15.4)	44 (8.3)
Cross-country (running)	16 (3.9)	0 (0)	16 (3)
Wrestling	16 (3.9)	1 (0.8)	17 (3.2)
Baseball	14 (3.4)	13 (10.6)	27 (5.1)
Lacrosse	7 (1.7)	0 (0)	7 (1.3)
Swimming	6 (1.5)	0 (0)	6 (1.1)
Ice hockey	4 (1.0)	2 (1.6)	6 (1.1)
Rowing	3 (0.7)	0 (0)	3 (0.6)
Tennis	3 (0.7)	0 (0)	3 (0.6)
Water polo	3 (0.7)	0 (0)	3 (0.6)
Skiing	1 (0.2)	0 (0)	1 (0.2)
Lacrosse	0 (0)	5 (4.1)	5 (0.9)
Softball	0 (0)	1 (0.8)	1 (0.2)

Direct and indirect fatalities were more numerous at the high school than at the college level because of participation numbers; however, the overall risk of a fatality was 2.8 times higher at the college level. The risk of fatalities was 3.6 times higher for indirect events and 1.4 times higher for direct injuries in college than in high school athletes. The risk of fatalities from head injuries (1.3) was only slightly higher in college than in high school athletes, but the risk of SCT (66.6), heat illness (3.8), and cardiac conditions (2.3) was much higher in college than in high school athletes.

Cardiac Causes

Our data are in agreement with those of other reports that sudden cardiac death is the leading cause of mortality in young athletes.[11,12] Despite limited numbers, our findings also are similar to those of other reports that identify the most common causes of atraumatic cardiovascular deaths in young athletes as hypertrophic cardiomyopathy followed by coronary artery anomalies.[11,12] It has been estimated that approximately 33% of all cardiovascular deaths are caused by hypertrophic cardiomyopathy and 15% by coronary artery anomalies in young athletes.[11,12] Despite a recent focus on detecting unsuspected cardiovascular diseases in the preparticipation history and physical examination, the risk of cardiac deaths increased during the second decade of the study.[11,12] Improved, cost-effective screening tests are necessary to better identify these at-risk athletes.

Brain Injuries

In contrast to a study of all catastrophic brain injuries (fatal and nonfatal) that reported a 3-fold higher incidence of injury at the high school level compared with college,[4] our current findings showed a slightly higher risk of brain fatalities in college players. The explanation for this discrepancy is difficult to determine, but younger athletes may be more predisposed to nonfatal, catastrophic brain injuries, although the incidences for fatalities are similar.

From 1945 to 1975, there was an average of 9.5 brain fatalities annually at the high school and college levels, with a peak of 17.2 annually from 1965 to 1969.[5] In the 1980s, the average number of brain fatalities in high school and college football dropped to 5 annually, which is a dramatic decline, considering that the number of participants increased during this time period.[5] One possible factor responsible for this mortality reduction is the improved football helmet and safety standards established by the National Operating Committee on Standards for Athletic Equipment, which have significantly reduced the number of skull fractures.[5] The safety standard for football helmets was adopted by the NCAA in 1978 and by the NFSHSA in 1980. During this study, the average number of brain fatalities annually for high school and college players has continued to decline from the first decade (3.6) to the second decade (2.6). This decline may be secondary to improved medical coverage at games and treatment for major brain injuries. Further reduction of brain fatalities will need to focus on preventing return to play after incomplete recovery from a concussion, identification of risk factors that predispose athletes to catastrophic head injuries, additional assessment and improvement of the football helmet, and/or determination of an athlete's career end point after repetitive concussions.

It is not surprising that we found most brain fatalities occurred during games, which are associated with high-intensity competitive situations. The most common positions for the occurrence of these injuries were linebacker, running back, defensive back, and playing multiple teams (offense and defense, or defense and special teams). Our results are in accordance with those of other reports indicating that running backs, linebackers, and defensive backs are the most vulnerable positions for head-related catastrophic injuries and fatalities.[4,24]

A worrisome finding in our study is that 25% of athletes with a brain fatality had a history of concussion, with 16% within 1 month of the fatality. All athletes with a history of concussion were at the high school level. Although we were unable to obtain a complete head injury history on all cases, this finding indicates that younger players may be more predisposed to a fatal brain injury if incompletely recovered from a prior concussion. In one study that reviewed both fatal and nonfatal catastrophic head injuries in football, 60% of the contacted athletes had a previous mild head injury, with 71% occurring during the same season.[4] Because it is more difficult to obtain previous head injury status on fatalities than on survivors of catastrophic brain injuries, it is possible that improved surveillance and diagnostic tests may have shown a much higher incidence of previous concussions in this study. It has been reported that collegiate football players with a history of concussions are more likely to have subsequent concussive injuries than those with no history.[8] Similarly, a history of mild traumatic brain injury may also predispose an athlete to a more severe head injury. The exact role of previous head injuries in the development of a subsequent severe head injury is unknown and requires further study. Nonetheless, it is prudent that any player with symptoms or signs of a concussion not be allowed to return to play on the day of injury and also not be allowed to return to play until all symptoms have resolved and do not recur with sport-specific exercise.[14]

Heat

Although most (30 of 38) of the heat illness deaths in our study occurred among high school football players, the risk of a heat fatality was 3.8 times greater in college participants compared with high school participants. The reason for this higher incidence is unclear but may be related to the more intense training at this level. The average BMI of the athletes in our study was 33.9, which confirms that obesity (BMI >30 in adults) is a risk factor for heat-related fatalities.[9] Obese patients have increased heat production and a relatively low surface area necessary for heat dissipation via evaporation. Overweight or obese athletes, especially linemen, should be monitored closely for signs of heat illness.

In our study, the average maximum temperature (89.6°F) and humidity (87.7%) on days with heat-related fatalities equate to an approximate wet bulb globe temperature of 104°F.[1] If the athletes were exercising during the hottest portion of the day, this temperature would place the athletes in the hazardous risk category, well above the level where sporting events should be cancelled.[1] Most (63%) heat-related deaths occurred in the South, which is known to have the highest average temperatures and humidity in the month of August.[19]

For the 18 fatalities on which we had event information, 83% occurred during 2-a-day practices, 44% occurred on practice day 1, 60% occurred in players wearing helmets, and 25% occurred in athletes wearing full equipment. Preseason practices are often associated with the most intense conditioning during the hottest weather. Uniform wear lowers the heat tolerance for an athlete by decreasing the amount of skin surface available for evaporation.[9] Acclimatization to the weather conditions is a key component of heat illness prevention and often takes 7 to 10 days, with gradual increases in exertion, environmental exposure time, and equipment wear.[9]

The importance of maintaining adequate hydration when exercising is paramount. One athlete in our study had a gastrointestinal virus just before the heat-related fatality, which may have caused dehydration and increased the risk. In addition to the guidelines indicated above, players should be offered frequent sports drinks with electrolytes or water breaks during practice sessions and encouraged to seek shade and remove equipment to facilitate body cooling during rest periods. One athlete in our study population was taking ephedra, a sympathomimetic that causes increased heat production and impedes the body's ability to regulate temperature; in 2004, after the death of this athlete and several other high-profile athletes, ephedra was banned.

Despite the development of these prevention guidelines, the incidence of heat-related deaths was 1.5 times greater during the second decade of this study. The reason is unclear, but it indicates that additional education, rule compliance, and guideline validation are required as well as improved medical supervision during the early part of the football season.

Sickle Cell Trait

The rate of sudden death in athletes with SCT has been reported to be 10 to 30 times higher than in athletes without SCT.[15] It has been estimated that, for every fatality, there may be 3 to 5 nonfatal episodes with limited organ damage.[7]

It is unclear why the risk of deaths from SCT complications in our study was 66.6 times higher in college than in high school athletes. One possibility is that many fatalities at the high school level are misdiagnosed as cardiac or heat-related illnesses because of nonrecognition of SCT.[7] The low incidence of SCT-related deaths during the first decade of the study also may be partially the result of nonrecognition during this time period. It is also possible that the percentage of African American athletes is higher at the college level. Alternatively, college athletes may be more predisposed to complications because of more intense training or other unknown reasons.

In our study, all 11 SCT-related fatalities occurred during intense conditioning drills, often sprinting. In 2 cases, death occurred during conditioning drills on the first day of practice, indicating that this day may be a particularly vulnerable time. The SCT-related deaths typically occur in practice sessions after 2 to 30 minutes of high-level running with limited rest periods as opposed to game situations in which the plays usually last only a few seconds and rest periods of 30 to 45 seconds are provided between plays.[7] The average maximum temperature and humidity on the day of the SCT event were 10°F cooler and 3% less humid, respectively, than those for the heat-related deaths, indicating that temperature and humidity do not play as critical a role in the pathogenesis of SCT-related fatalities. The athletes with SCT on average were not considered obese (average BMI, 28 vs 34 for the athletes who died from heat-related causes). Other clinical features that distinguish SCT from heat illness are core body temperatures of less than 105°F, buttock and low back pain during the crisis, and faster onset of crisis symptoms without warning signs.[7]

Our findings revealed that the SCT status of 4 athletes was not known until postmortem testing and that 1 athlete did not report his SCT condition to the team. It is possible that in all 5 cases, death could have been prevented with proper screening for and knowledge of the condition. In August 2010, the NCAA instituted a universal screening program to test for SCT in all Division I athletes; future research will determine whether this policy will reduce the SCT fatality incidence. Currently, at the high school level, testing is not required, but it is recommended that the athlete be queried about SCT status during the preseason physical examination. Once a player is identified as having SCT, the National Athletic Trainers' Association (NATA)[7] recommends that the athletes should be allowed to perform conditioning drills at their own pace and should stop exercising immediately if unusual shortness of breath, undue fatigue or muscle pain, weakness, or cramping develop. Intense performance tests that last more than 2 minutes without a break should be avoided.

Asthma

Fatalities due to exercise-induced asthma in the older adolescent and adult are extremely uncommon.[6,28] Our results concur with a similar report of 160 nontraumatic deaths in high school and college athletes over a 10-year period in which only 4 were the result of asthma.[28] In another report, 61 asthma-related deaths were reported from 1993 to 2000 in all athletes.[2] However, the most frequent sports played, basketball and track, and the most prevalent age group, between 10 and 14 years, were different from our study. Patients with asthma should be properly medicated and understand that rescue medication should be immediately available during exercise activity.

Commotio Cordis

Fifty percent of reported cases of commotio cordis occur in amateur athletes participating in organized sports, and medical personnel should be prepared to treat this often fatal injury.[13] Although commotio cordis is more commonly reported in baseball, softball, and hockey, our study has shown that it can occur in football players. The average age at death (17 years) in our study was higher than that reported in the literature.[13] The reason for this difference is unclear, but it may be associated with the large diffuse forces that occur with collisions in football (vs focal impacts from projectiles such as baseballs or hockey pucks). Our fatalities occurred despite the football pads worn by 6 of the players, reinforcing the concept that current chest protectors are not preventive against this condition.[10] Although commotio cordis traditionally has a high fatality rate, recent data show that public education to avoid impact to the chest region, prompt initiation of cardiopulmonary resuscitation, and the increased availability of automatic external defibrillators may reduce the fatality rate.[13]

Pulmonary Embolism/Blood Clot

Pulmonary embolism in young athletes is an extremely rare condition, limited to case reports in the literature.[16,23] The condition is more common postoperatively, as seen in our 2 patients, but it can also occur after blunt trauma or fracture to the leg, leading to deep venous thrombosis and propagation of the clot to the lungs. Pulmonary embolism should be included in the differential diagnosis of any athlete with dyspnea, especially if there has been a previous major lower leg trauma or surgery.

Cervical Fracture

From 1990 to 2010, fatalities from a cervical spine injury in high school and college football players were extremely rare. One study reported 116 cervical spine fatalities from 1945 to 1999, but the timing of the fatalities was not specified.[5] Our findings indicate that the number of cervical spine fatalities has dramatically decreased over the past 20 years, likely from the identification of spear tackling[25,26] as a cause of severe cervical spine injuries and the resultant rule changes that have lowered the incidence of spear-tackling injuries.[3,25]

Intra-abdominal Injury

All 3 fatalities from intra-abdominal injuries resulted from a collision in a game situation. Our findings indicate that game-day football equipment and padding could be improved to prevent these injuries. Although the incidence of these intra-abdominal fatalities is rare,[24] it is also likely that for every fatality, there are numerous injuries that do not result in a fatality.

Infection

Two of the 3 infections were the result of direct trauma to the leg complicated by systemic infection. The third infection-related death occurred in 2008 and was caused by MRSA, which has become more common in recent years. Prevention is best accomplished with proper hygiene, including showering after every practice or game, avoiding the sharing of towels and other personal care items, regular cleaning of communal bathing areas, and cleaning or laundering of equipment and clothing after every use. Athletes with draining lesions that cannot be adequately covered should not share athletic equipment that is in contact with the skin, should not participate in contact sports, and should be excluded from common whirlpools or saunas until the wound has healed or drainage can be contained.[22]

Lightning

Lightning, one of the top 3 causes of weather-related deaths in the United States, is responsible for approximately 100 deaths annually[29]; 75% have occurred between May and September. In our study, 2 deaths occurred within this time frame, and 1 occurred in October. The NATA position statement[29] recommends no outdoor athletic activity during active lightning storms and has specific time rules for stopping and restarting games.

Study Limitations and Future Focus

Our study has some limitations. First, it is possible that not all fatalities in organized high school and college football were reported to the Center; therefore, any flaw in the collection of data would have been one of underreporting. Second, we relied on information from the public domain, which may have some inaccuracies. However, these deaths are highly visible events with extensive reporting by the news media. In addition, the diagnosis was confirmed in 146 deaths with an autopsy report. Third, we were unable to locate detailed information on some of the fatalities (eg, cardiac and asthma-related deaths).

Although our data may not have been complete, the problem of football fatalities is real and needs to be addressed by continued surveillance and rule changes when applicable to further reduce the incidence. Knowledge of the causes of football fatalities may allow team physicians to be better prepared to treat these conditions expeditiously and prevent fatalities. Potential preventive strategies that require further research include identifying athletes with potentially fatal cardiac conditions, avoidance of return to play before full recovery from a head injury, and strict adherence to guidelines to prevent heat illness and SCT crises. A greater emphasis needs to be placed on the recognition, treatment, and prevention of heat illness and SCT during practice sessions. Focused data collection templates are being developed to more accurately record information in the future.

ACKNOWLEDGMENT

The authors are grateful to the National Catastrophic Center for Sports Injury Research for sharing its data and making this article possible. The authors also thank Stephen Belkoff for his assistance on the statistics as well as Matthew Boden, Sean Meredith, Dan Wilcoxson, Greg Dammann, and Bob Colgate for their help on this study.

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