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Catastrophic Head Injuries in High School and College Football Players

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Background: Catastrophic head injuries in football are rare but tragic events.

Purpose: To update the profile of catastrophic head injuries in high school and college football players and to describe relevant risk factors.

Study Design: Case series; Level of evidence, 4.

Methods: We reviewed 94 incidents of severe football head injuries reported to the National Center for Catastrophic Sports Injury Research during 13 academic years (September 1989 through June 2002).

Results: In the study period there were an average of 7.23 (standard deviation = 2.05) direct high school and college catastrophic head injuries in scholastic football participants per year. There were 0.67 injuries per 100 000 (95% confidence interval: 0.54, 0.81 per 100 000) high school and 0.21 injuries per 100 000 (95% confidence interval: 0.0, 0.49 per 100 000) college participants for a risk ratio of 3.28 (95% confidence interval: 0.81, 13.3). The injuries resulted in subdural hematoma in 75 athletes, subdural hematoma with diffuse brain edema in 10 athletes, diffuse brain edema in 5 athletes, and arteriovenous malformation or aneurysm in 4 athletes. Fifty-nine percent of the contacts reported that the athlete had a history of a previous head injury, of which 71% occurred within the same season as the catastrophic event. Thirty-nine percent of the athletes (21 of 54) were playing with residual neurologic symptoms from the prior head injury. There were 8 (9%) deaths as a result of the injury, 46 (51%) permanent neurologic injuries, and 36 (40%) serious injuries with full recovery. Most players sustained a major impact to the head either from tackling or being tackled.

Conclusion: The incidence of catastrophic head injuries in football has remained low since the advent of the modern day football helmet in the early 1970s. The incidence of catastrophic head injuries in football is dramatically higher at the high school level than at the college level. Although the reason for this discrepancy is unclear, an unacceptably high percentage of high school players were playing with residual symptoms from a prior head injury. Coaches, athletes, athletic trainers, and medical personnel need to adhere to the guideline that an athlete with any neurologic symptoms from a head injury should be strongly discouraged from returning to play.

Keywords: football; subdural hematoma; severe head injury

Football is one of the most popular team sports in the United States, with more than 1.2 million high school participants during the 2001-2002 academic year.^{16,17} Football also is associated with the highest number of direct catastrophic injuries for any sport reported to the National

Center for Catastrophic Sports Injury Research (hereinafter called the "Center").¹⁵ Therefore, it is critically important to monitor catastrophic head injuries and preventive strategies.

Cantu and Mueller² reported on 497 fatalities among American football players during the period from 1945 through 1999. Sixty-nine percent of the deaths were caused by brain injuries, with the majority (86%) being associated with subdural hematomas. The greatest number of brain-injured fatalities occurred during the 5-year span from 1965 through 1969. Although concussions have received abundant attention in recent literature, there is a paucity of literature on catastrophic head injuries in American football.^{10,11,18,20}

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To the authors' knowledge, there have been no comprehensive published studies of catastrophic head injuries at the high school and college levels of football during the past decade. Therefore, we reviewed the Center data for 13 academic years (September 1989-June 2002) to determine the current incidence of catastrophic head injuries secondary to scholastic football injuries, identify any new injury patterns, and potentially provide preventive strategies.

MATERIALS AND METHODS

The study was approved by the University of North Carolina Academic Affairs Institutional Review Board. All interviewees consented to participate in the study after review of risks and benefits. All medical records were handled in a Health Insurance Portability and Accountability Act (HIPAA) compliant fashion.

Injury Definitions

The Center classifies catastrophic injuries as direct (resulting from participation in the skills of a sport) or indirect (resulting from systemic failure secondary to exertion while participating in a sport),¹⁴ and subdivides each classification into 3 categories: fatal (the injury causes the death of the athlete), nonfatal (the injury causes a permanent neurologic functional disability), and serious (while severely injured, the athlete has no permanent functional disability; eg, a subdural hematoma that is immediately relieved resulting in complete neurologic recovery).¹⁴ This study reviews all 3 categories of direct catastrophic head injuries.

Injury Reports

From September 1989 to June 2002 (13 academic years), the Center collected data on catastrophic football injuries in the United States. High school and college coaches, athletic directors, and athletic trainers; executive offices of state and national athletic organizations; and a national newspaper clipping service were contacted annually by the Center and requested to report any catastrophic events in organized school-sponsored sports. 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 contacted the high school coaches or athletic trainers to obtain preliminary data (ie, the athlete's name, date of injury, age, diagnosis, school, and a brief description of the mechanism of injury).

This study includes catastrophic injuries only to the head in high school and college football participants. Catastrophic head injuries are defined as injuries with macroscopic brain lesions such as subdural hematomas, epidural hematomas, diffuse brain edema, arteriovenous malformation, or aneurysm. Athletes with microscopic brain injury, such as concussions, were excluded from the study.

Injury Surveillance

Within 6 months of notification of the injury, the Center sent treating physicians a questionnaire for medical information

on the injured athletes. In 2004, we contacted the injured football players, coaches, athletic trainers, athletic directors, and/or family members by telephone to acquire additional information about any direct head injuries reported to the Center. A detailed questionnaire was employed to collect data on player characteristics and participation level. Information was recorded regarding the circumstances of the injury, such as the player's position and whether the injury occurred during practice or competition. Specific questions were posed to determine the mechanism of injury, including whether the player was making a tackle or being tackled and what the head and neck position was at the time of injury. The interview investigated whether the interviewee was aware of any actions that could have been taken to prevent the injury. Information also was obtained concerning the medical diagnosis, symptoms, treatment, and outcome of the player. Athletes also were queried about any previous or subsequent head injuries. If the athlete or a family member was contacted, authorization for the medical records was requested. Available videotape footage of the injury also was requested. If there was a discrepancy between the original data and the follow-up data, the more recent follow-up data was employed in the final analysis of this paper.

A total of 100 direct catastrophic head football injuries were reported to the Center during the study period. Six injuries were excluded from the study because they were not participating at the high school or college level or they did not meet the injury criteria. Of the 94 remaining injuries in the study, medical information was obtained from a treating physician or medical records in 49 (52.1%) athletes. Fifty-four (57.4%) contacts were located in 2004 for extensive phone interviews. In 40 circumstances, a contact person could not be located and only the original information reported to the Center with or without medical records was analyzed. Of the 54 contacts who were located, information was obtained via a personal telephone interview with a family member (16 cases), the athlete (14 cases), a coach (12 cases), an athletic trainer (7 cases), or an athletic director (5 cases). The interviewees rated their memory of the event as an average of 4.0 (standard deviation [SD] = 1.3) on a scale from 1 to 5 (1 = not at all, 2 = vaguely, 3 = somewhat, 4 = well, 5 = very well). Forty-eight of the 54 interviewees experienced or directly witnessed the injury; in 6 cases, the information was received indirectly from a contact who spoke with an eyewitness. The time from injury to the follow-up interview averaged 113 months (range, 37-182 months).

Statistical Analysis

The overall incidence for the 13-year study period was calculated as the total number of injuries divided by the total number of high school and college football players during the study period. Annual injury incidence was calculated as the number of injuries during that year divided by the number of high school and/or college football players participating during the specified time period. For high school and college incidences, respectively, the number of injuries and athletes were restricted to the appropriate high school or college playing level. For specific types of injuries (ie, subdural hematoma, diffuse edema, epidural hematoma),

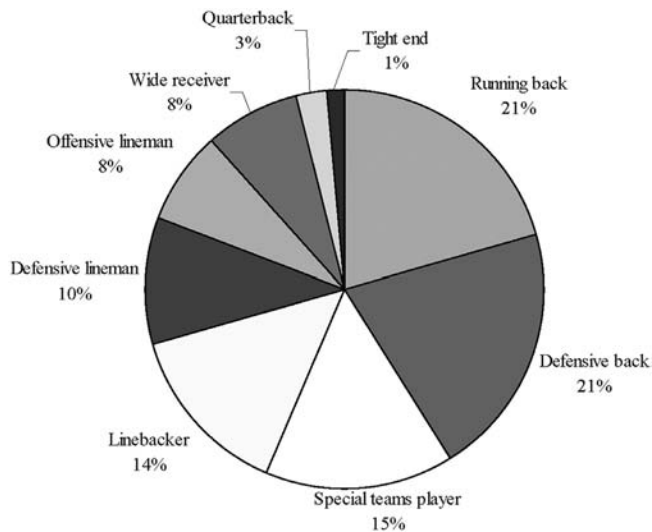


Figure 1. Number of catastrophic football head injuries by position played at the time of injury. Numbers are rounded off to the nearest whole number.

the incidence was calculated as the total number of specific injuries divided by the total number of high school and/or college football players participating during the specified time period. Incidence proportions were calculated per 100 000 athletes.

RESULTS

Epidemiologic and Demographics Patterns

All injured athletes in this study were male. Ninety-two incidents occurred at the high school level (97.9%), and 2 incidents occurred at the college level (2.1%). The mean age, weight, and height at the time of injury was 17 years (range, 14-21), 178 pounds (range, 120-260), and 71 inches (range, 66-75), respectively. The position played at the time of injury was determined in 81 cases: 39 (48.1%) players on defense, 30 (37.0%) on offense, and 12 (14.8%) on special teams. Positions most frequently associated with a catastrophic head injury were running back and defensive back or secondary (cornerback or safety) in 16 each, a special teams player in 12, a linebacker in 11, a defensive lineman in 8, an offensive lineman and wide receiver in 6 each, a quarterback in 2, a tight end in 1, and unknown in 16 cases (Figure 1).

During the study period, there were 13 675 832 high school and 975 000 college football players^{16,17} (personal communication, Amy Tagliareni, NJCAA, Sept 2005; Renee Wiebe, NAIA, Sept 2005). Participation numbers for high school were based on National Federation of State High School Associations (NFHS) data plus an additional 100 000 players each year for the schools that don't participate with the NFHS.¹⁷ There were approximately 75 000 college participants per year based on data provided by the National Collegiate Athletic Association, the National Junior College Athletic Association, the National Association of Intercollegiate Athletics, and

Christian colleges¹⁶ (personal communication NJCAA, NAIA). There was a combined average of 7.23 (SD = 2.05) direct catastrophic football head injuries per year for the high school and collegiate groups and individual averages of 7.08 (SD = 2.10) and 0.15 (SD = 0.38) per year, respectively (Figure 2). The annual incidences of direct, catastrophic football injuries were 0.67 injuries per 100 000 (95% CI: 0.54, 0.81 per 100 000) high school and 0.21 injuries per 100 000 (95% CI: 0.0, 0.49 per 100 000) college participants for a risk ratio of 3.28 (95% CI: 0.81, 13.3) (Figure 3). The combined incidence of injuries at the high school and college levels was 0.64 per 100 000 participants (95% CI: 0.51, 0.77 per 100 000 athletes).

Timing of Injury

According to the interviewees, all injuries occurred while being supervised during participation with the school team. The injuries were slightly more than 3.5 times more common in a game ($n = 71$, 78.0%) than a practice session ($n = 20$, 22.0%), with the setting unknown in 3 cases. Most injuries occurred during the regular season ($n = 46$); the remainder occurred during the preseason ($n = 6$), the off-season ($n = 2$), or an unknown period ($n = 40$).

Injury Profile

The injury classification was not known for 4 injuries. Of the remaining 90 injuries, 46 (51.1%) were classified as nonfatal (permanent neurologic deficit), 36 (40.0%) as serious (no residual neurologic deficits), and 8 (8.9%) as fatalities. The events resulted in subdural hematoma in 75 athletes, subdural hematoma with diffuse brain edema in 10 athletes, and diffuse brain edema in 5 athletes. Four athletes were diagnosed with arteriovenous malformation or an aneurysm. Two athletes also sustained a cervical fracture in addition to the head injury. There were no reported skull fractures.

Prior Head Injuries

Fifty-nine contacts and/or medical records revealed information on prior head injury status. Thirty-five (59.3%) athletes had a previous head injury prior to the day of the catastrophic event, and 24 (40.7%) reported no known history of a head injury. In 25 (71.4%) of the 35 cases with a prior head injury, the injury occurred earlier in the season with the time of the prior head injury unknown in 6 cases. In 21 (38.9%) of 54 cases, the athlete was playing with residual neurologic symptoms from the prior head injury. Five contacts reported a minimum of 2 concussions before the major episode.

Mechanism of Injury

The mechanism of injury was identified in 70 cases. Twenty-four (34.3%) athletes were making a tackle, 24 (34.3%) were being tackled, 6 (8.6%) were blocking, and 2 (2.9%) were being blocked. Fourteen (20.0%) interviewees reported no major collision; 7 (10.0%) of these cases felt that the injury

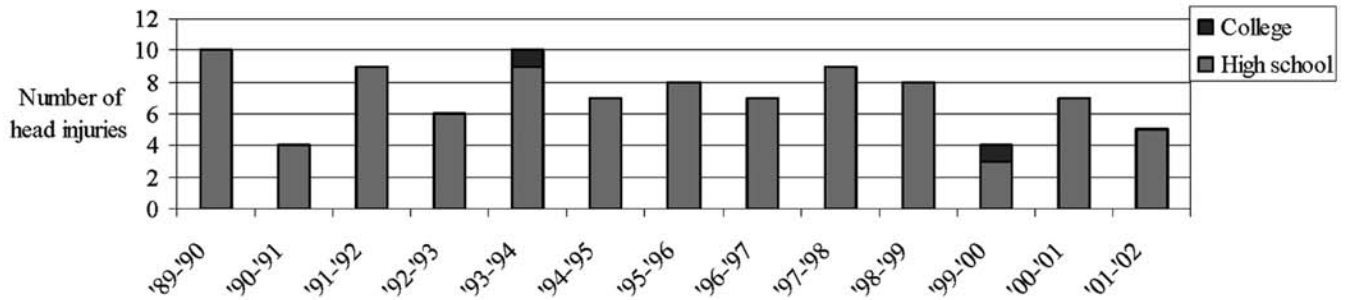


Figure 2. Number of catastrophic football head injuries at the high school and college levels reported to the National Center for Catastrophic Sports Injury Research per school year from 1989-1990 to 2001-2002.

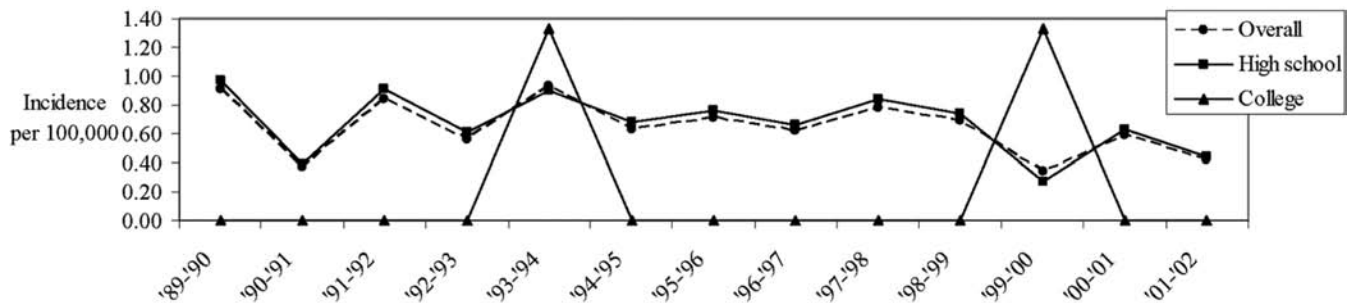


Figure 3. Annual incidence of high school and college catastrophic football head injuries per 100 000 participants from 1989 to 2002.

was a result of multiple cumulative minor injuries. All 14 athletes suffered an isolated subdural hematoma.

In 37 cases the point of impact resulting in injury was reported: 16 (43.2%) helmet-to-helmet collisions, 14 (37.8%) helmet-to-opponent's body part other than the helmet, and 7 (18.9%) helmet-to-ground impacts. Five of the 14 helmet-to-helmet collisions were reported to involve a spear-tackling mechanism. For the 7 impacts with the ground, 5 were playing on natural grass, 1 on AstroTurf (Textile Management Associates Inc, Dalton, Georgia), and 1 on an unknown surface. Two injuries occurred out of bounds. The helmet being worn at the time of injury was determined in 34 cases and varied widely between manufacturers. The material on the inside of the helmet was determined in 30 cases: air in 22 (73.3%), foam in 4 (13.3%), and an air/foam combination in 4 (13.3%).

Symptoms and Treatment

Loss of consciousness was a common symptom occurring in 41 (80.3%) of 51 cases. Other common symptoms included headaches, visual disturbances, paresis, and seizures. Eight patients progressed to coma with fixed dilated pupils and decerebrate posturing. Fifty-three (75.7%) of 70 contacts or medical records reported that surgery was performed, with 24 cases unknown. The surgical procedures all involved a variety of craniotomy with, in most instances, subdural hematoma removal, decompression, and intracranial pressure monitoring.

Outcome

There were 8 fatalities as a result of injury: 5 athletes with an isolated subdural hematoma, 1 athlete with a subdural hematoma and diffuse brain edema, 1 athlete with atriovenous malformation, and 1 athlete with diffuse brain edema. All patients died within 28 days of the injury except 1 athlete who remained in a coma with a feeding tube for 5 years.

The forty-six athletes with a nonfatal (permanent neurologic deficit) injury were determined to have a variety of residual deficits such as memory loss, slurred speech, paralysis, blindness, seizures, personality changes, hearing loss, spasticity, and medical complications. None of the athletes with a nonfatal injury returned to playing competitive football after the reported catastrophic head injury.

Thirty-six athletes were classified with a serious injury with no residual neurologic deficits. Two athletes returned to football without any known recurrences.

Prevention and Legal Ramifications

None of the interviewees attributed the injury to illegal substance use. Twenty interviewees thought that the injury was potentially preventable. Eight athletes reported that they never informed anyone about preexisting neurologic symptoms before the catastrophic injury. Seven interviewees blamed the injury on either a poorly fitting helmet, a defective helmet, or an old refurbished helmet. Three interviewees blamed the injury on a questionable

clearance to play by medical personnel evaluating a prior head injury. Two athletes reported using the head to tackle an opponent. In addition to the health and emotional impact, at least 10 accidents resulted in a lawsuit or insurance settlement, with many interviewees refusing to discuss this matter.

DISCUSSION

Most athletic head injuries in football are noncatastrophic concussions. Severe head injuries in football are much less common but can be life-threatening.³ Because of the physical nature of football and the tremendous level of participation at the high school and college levels, football has the highest overall number of direct catastrophic injuries reported to the Center.¹⁵ We identified an average of 7.23 direct catastrophic football head injuries per year for high school and collegiate football players during the 13 academic years from 1989 through 2002. Therefore, continued surveillance and preventive strategies are crucial for the sport of football.

The number (92 high school, 2 college) and incidence (0.67 high school and 0.21 college injuries per 100 000) of catastrophic head injuries at the high school level far exceeded that at the college level in this study. This is in contrast to rates of catastrophic injuries for other sports, as well as cervical injuries in football.¹ Most catastrophic injuries are more common at the college level, which may be explained by faster, bigger, and stronger athletes resulting in higher collision forces. There are several possible explanations for the higher catastrophic head injury rates in high school football players: the brain is not fully developed so the injury threshold is lower, blood vessels tear more easily, the skull is thinner providing less protection to the brain, less medical coverage at high school games, and/or younger players have not fully developed proper strategies to avoid brain injury.¹² Field et al⁶ demonstrated that high school athletes tend to have a protracted recovery from concussion compared with college athletes. It is therefore possible that high school athletes are more susceptible to a brain injury, and returning to play before complete recovery from a prior minor head injury may predispose them to a catastrophic event. Alternatively, high school athletes with a history of concussions may be less likely to play college football. Why the younger brain may be more susceptible to catastrophic head injuries requires further research.

It is not surprising that the majority of injuries occurred during game situations, which are associated with high-intensity competitive situations. Most players were on defense (48.1%), followed by offense (37.0%), and special teams (14.8%). Specific positions played at the time of injury revealed defensive backs (20.5%), running backs (20.5%), special teams players (15.4%), and linebackers (14.1%) to be the most susceptible to injury. Special teams players are likely vulnerable because of the high speed of collisions during special teams plays.¹⁸

The reported mechanism of injury in most cases was a single major blow to the player's head while making a

tackle (34.3%) or being tackled (34.3%). The point of impact on the injured player's head was usually with an opponent's head (43.2%), followed by an opponent's body part other than the helmet (37.8%) and the ground (18.9%). Since the 1970s, the NCAA and the NFHS have banned tackling with the helmet. Both spear tackling (tackling with the top of the helmet), face tackling (tackling with the face), and butt blocking (driving the face mask or frontal area of the helmet into an opponent while blocking) are banned and carry a 15-yard penalty or disqualification. Starting with the 2005-2006 academic year, the NCAA strengthened its spearing rule by penalizing athletes who spear tackle with or without the intent to hurt the opposing player. Our data reveal that head tackling and sustaining contact to the head while being tackled can lead to severe head injury. Although some contact with the head is accidental and will never be completely eliminated, we believe that coaches need to continue encouraging athletes not to tackle with the head. In addition, stricter rules against making contact with the opponent's head during tackling, as implemented by the NCAA in 2005, need to be considered by the NFHS rules committee. Since most high school fields have a grass surface, we were unable to determine if the type of playing surface had any effect on the injuries attributed to contact with the ground. We also were unable to determine if one particular type of helmet may be less protective. Since 7 interviewees subjectively blamed the injury on either a poorly fitting helmet, a defective helmet, or a refurbished helmet, we believe that helmet manufacturing, fitting, and the refurbishing process require continued surveillance.

In addition to a major blow to the head, 14 contacts reported that the injury resulted from multiple minor collisions or no known precipitating head trauma. This finding agrees with other case reports that acute subdural hematoma does not always result from a single traumatic event,^{10,11,20} but rather some subdural hematomas may develop after repeated minor head trauma. Alternatively, some athletes may have been suffering from a small, undiagnosed subdural hematoma, which did not manifest clinically until more minor blows to the head.

Perhaps the most worrisome finding in this study is that 59% of those contacted stated that the athlete had a prior mild head injury, with 71% occurring during the same season. This incidence may be an underestimation since athletes often underreport the true incidences of concussion.⁵ This is especially true for questionnaires that are not anonymous since players may be reluctant to provide truthful information that may jeopardize playing time.⁵ The reported annual incidences of concussion at the high school and college level is between 3.6% and 20% of all players in a season.^{7,9,19,21} Guskiewicz et al⁸ reported that collegiate football players with a history of previous concussions are more likely to have future concussive injuries than those with no history. Similarly, a history of mild traumatic brain injury may also predispose an athlete to a more severe head injury. The exact role of prior head injuries in the development of a subsequent severe head injury and second impact syndrome is unknown and requires further study. Alternatively, the interviewees may

have maximized previous symptoms in this study to make sense of why such a serious injury happened or to support litigation. Prior head injury may be indicative of athletes who hit more frequently with their helmets when playing football, making them more susceptible to future injury.

Another worrisome finding in this study was that 39% of athletes with a prior head injury were still playing with neurologic symptoms at the time of the catastrophic event. As the medical community gains more insight into concussions, the return-to-play criteria have become more conservative. The 2nd International Conference on Concussion in Sport recommended that any player with symptoms or signs of a concussion not be allowed to return to play on the day of injury.¹³ The consensus also recommended return to play only after the player's symptoms of concussion disappear and do not recur with sport-specific exercise. Adherence to these guidelines may have prevented some of the severe head injuries reported in this study. Coaches, athletes, parents, athletic trainers, and all medical personnel need to be educated to never allow an athlete to continue playing football with ongoing neurologic symptoms. All athletes with symptoms consistent with a concussion should be referred for medical evaluation. Some states require football players with a concussion to obtain medical clearance before returning to play.²⁰ Another preventive strategy would be to institute a rule where the coach or parent informs all players the day before a game that no athletes with any head symptoms are permitted to participate in the upcoming game without medical consultation. Although some players may continue to minimize or lie about their symptoms, awareness of the potential sequelae when players return to football before complete neurologic recovery may reduce the incidence of severe head injuries.

There were 8 fatalities identified during the 13 academic years (0.62 per year). This is a significant reduction compared with the 5-year span from 1965 through 1969 when there were more than 80 brain injury-related fatalities reported at the high school and college levels.² The most likely factor responsible for the reduction in deaths during this time period is the improved football helmet and the establishment of safety standards for the helmet by the National Operating Committee on Standards for Athletic Equipment (NOCSAE). Other likely factors include improved medical care of athletes, such as more on-field medical personnel, the advent of computed tomography, and surgical advances. In addition, surveillance of sport injury data has reinforced the need for coaches to teach proper tackling techniques avoiding head-first contact.

There are several limitations to our study. It is probable that not all catastrophic head injuries 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. In addition, limited information was available for the 40 incidents in which an interviewee could not be located for the detailed questionnaire. Interpreting information with a high rate of missing data can lead to faulty conclusions. The authors attribute this low contact rate to the average length of time since the injury, multiple moves during the years making tracking difficult, or information withheld because of pending

litigation. Another limitation of the study is the ability of individuals to recall a sudden, brief event that occurred on average 8.6 years before the interview. Participants and witnesses often have different interpretations of the situation, which may lead to inaccurate information and faulty conclusions. In addition, the authors were able to confirm medical information by a review of medical records or discussion with a treating physician in only 49 patients. Finally, new HIPAA regulations have made obtaining medical records and imaging studies extremely difficult.

Nonetheless, the problem of catastrophic football injuries still exists. While the incidence of these injuries will never be completely eliminated in a collision sport, the authors believe that continued analysis of injuries and rule changes may help further reduce the incidence and severity of such catastrophic events.

CONCLUSION

Direct catastrophic head injuries in football are uncommon but tragic events. There are approximately 7 direct catastrophic football head injuries per year in scholastic athletes, with the incidence being higher at the high school level. The higher incidence of catastrophic head injuries in younger athletes is quite dramatic and demands more attention at the high school level. The majority of severe head injuries are subdural hematomas that result from tackling or making a tackle with contact to the head. Athletes with prior head injuries, especially within the same season, are likely at increased risk for a severe head injury. Players should be strongly discouraged from returning to play with any neurologic symptoms. Coaches need to continue educating players to avoid hitting with the head.

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