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Catastrophic Cervical Spine Injuries in High School and College Football Players

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

Purpose: To update the incidence of catastrophic cervical injuries in scholastic football players and identify new injury patterns.

Study Design: Descriptive epidemiology study.

Methods: The authors retrospectively reviewed 196 incidents of catastrophic high school and collegiate football injuries reported to the National Center for Catastrophic Sports Injury Research during 13 academic years (September 1989 through June 2002).

Results: There were 15.08 direct catastrophic cervical spine injuries in scholastic football participants per year, an incidence of 1.10 and 4.72 injuries per 100 000 high school and 100 000 college participants, respectively. Seventy-six athletes had quadriplegia (5.85 per year), 0.50 per 100 000 high school players and 0.82 per 100 000 college players. Spear tackling by players on defense continued to be the predominant mechanism of injury causing quadriplegia. Five athletes had a Brown-Séquard–like syndrome; only 1 made a full recovery. One athlete with Brown-Séquard–like syndrome and permanent neurologic symptoms reported a cervical cord neurapraxia event before the study period. Forty-three athletes (3.31 per year) had diagnosed cervical cord neurapraxia. In addition to hyperflexion and hyperextension injuries, axial forces were found to cause cervical cord neurapraxia. Sixteen of the 43 athletes returned to football after a cervical cord neurapraxia episode, and none of the 16 suffered a permanent quadriplegic event. Nine athletes sustained an isolated injury at the C1 or C2 level, and 7 sustained a combined injury at the C1, or C2 level and at a subaxial level.

Conclusion: The total number of quadriplegic events for high school and college football players is approximately 6 per year, with a higher incidence at the college level. Cervical cord neurapraxia can be caused by hyperflexion, hyperextension, and axial compression forces. Upper level cervical injuries involving the atlas and axis can occur in football players and may be associated with noncontiguous subaxial injuries.

Keywords: football; quadriplegia; cervical cord neurapraxia

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.[9] 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").[8] Therefore, it is critically important to monitor catastrophic cervical spine injuries and preventive strategies.

Torg et al[22,23] showed that axial loading of the cervical spine is the primary mechanism responsible for injuries in football resulting in quadriplegia. After spear tackling was banned from football, the incidence of these injuries dropped dramatically in the late 1970s and 1980s.[18]

To our knowledge, there has been no published study of catastrophic cervical spine injuries in football at the high school and college levels during the past decade. Therefore, we reviewed the Center data for 13 academic years (September 1989 through June 2002) to determine the current incidence of catastrophic cervical spine injury secondary to scholastic football injuries and to identify any new injury patterns.

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. Health Insurance Portability and Accountability Act regulations were observed throughout.

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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)[7] 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 (a severe injury, but the athlete has no permanent functional disability, for example, a fractured cervical vertebra that does not cause paralysis).[7] This study reviews all 3 categories of direct catastrophic cervical spine 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, athlete's age, diagnosis, school, and a brief description of the mechanism of injury).

This study includes catastrophic injuries only to the cervical spine region in high school and college football participants. Inclusion criteria were any athlete with spinal column disruption (fracture, subluxation, or dislocation), cervical nerve root avulsion, or a cervical injury resulting in any permanent neurologic deficits or transient neurologic symptoms in at least 2 extremities. Athletes with cervical strains and isolated nerve root brachial plexus injuries were excluded from this 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 cervical 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 was the head and neck position at the time of injury. The interview investigated whether the injury could have been prevented. Information also was obtained concerning the medical diagnosis, symptoms, treatment, and outcome of the player. Athletes also were queried about any previous or subsequent neck 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 were employed in the final analysis of this article.

A total of 234 direct catastrophic football injuries involving the cervical spine were reported to the Center during the study period. Thirty-eight injuries were excluded from the study because the injured athlete was not participating at the high school or college level, or the athlete did not meet the injury criteria for this study. Of the 38 excluded injuries, 6 occurred at the junior high school level with 3 resulting in quadriplegia. Of the 196 remaining injuries in the study, medical information was obtained from a treating physician or the hospital on 80 (41%) athletes. One hundred twenty-two contacts were located in 2004 for extensive phone interviews. In 74 circumstances, a contact person could not be located, and only the original information reported to the Center with or without the medical records was analyzed. Of the 122 contacts who were located, information was obtained via a personal telephone interview with the athlete (40 cases), an athletic trainer (37 cases), a coach (32 cases), an athletic director (7 cases), a family member (5 cases), or a team physician (1 case). The interviewees rated their memory of the event as a mean of 4.2 ± 1.10 on a scale from 1 to 5 (1, not at all; 2, vaguely; 3, somewhat; 4, well; 5, very well). Ninety-nine of the 122 interviewees experienced or directly witnessed the injury; in 23 cases, the information was received indirectly from a contact who spoke with an eyewitness. The time from injury to the follow-up interview averaged 103 months (range, 22-183 months).

All injured athletes in this study were male. The level of participation was high school in 150 (76.5%) and college in 46 (23.5%). The mean age, weight, and height at the time of injury were 17 years (range, 14-28 years), 184 lb (range, 120-324 lb), and 71 in (range, 59-78 in), respectively. The position played at the time of injury was determined in 186 cases: 107 (57.5%) players on defense, 48 (25.8%) on offense, and 31 (16.6%) on special teams. The positions most frequently associated with a catastrophic cervical spine injury were defensive backs or secondary (cornerback or safety) in 54, linebacker in 32, special teams player in 30, quarterback in 15, running back in 15, defensive lineman in 14, offensive lineman in 8, wide receiver in 8, tight end in 3, and unknown in 17 cases.

During the study period, there were 13 675 832 high school and 975 000 college football players[9,10] (personal communication, Amy Tagliareni, National Junior College Athletic Association, September 2005; Renee Wiebe, National Association of Intercollegiate Athletics, September 2005). Participation numbers for high school were based on National Federation of State High School Associations data plus an additional 100 000 players each year for the schools that do not participate with the federation.[10] 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 the Christian colleges[9] (personal communication, National Junior College Athletic Association, National Association of Intercollegiate Athletics, September 2005).

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 incidence, respectively, the number of injuries and number of athletes were restricted to the appropriate high school or college playing level. For specific types of injuries (quadriplegia, cervical cord neurapraxia), the incidence was calculated as the total number of the 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. Risk ratios were calculated to compare the risk of injury among college athletes to the risk of injury among high school athletes (referent category). Confidence intervals (CIs) were estimated at the .05 α level as a marker of imprecision in the incidence estimate.

RESULTS

Epidemiologic and Demographics Patterns

There was a combined mean of 15.08 ± 4.70 direct catastrophic football cervical spine injuries per year for the high school and collegiate groups and individual means of 11.54 ± 4.24 and 3.54 ± 1.61 per year, respectively. The annual incidences of direct catastrophic football injuries were 1.10 per 100 000 high school players (95% CI, 0.92-1.27), 4.72 per 100 000 college players (95% CI, 3.35-6.08), and 1.34 per 100 000 high school and college players (95% CI, 1.15-1.53).

Timing of Injury

According to the interviewees, all of the injuries occurred during supervised participation with the school team. The injuries were slightly more than 3 times more common in a game (146, 75.6%) than in practice sessions (47, 24.4%), with the setting unknown in 3 cases. Most injuries occurred during the regular season (101); the remainder occurred during the preseason (12), the off-season (5), the postseason (4), or an unknown period (74).

Injury Profile

The Center injury classification was not known for 3 injuries. Of the remaining 193 injuries, 93 (48.2%) were classified as nonfatal (permanent neurologic deficit), and 100 (51.8%) were classified as serious (no residual neurologic deficits). There were no acute fatalities as a result of an injury. The events resulted in fracture, dislocation, or major ligamentous injury at a subaxial cervical level in 95 athletes, at the C1 or C2 level (or both) in 9 athletes, at combined upper and lower levels in 7 athletes, and at an unknown level in 41 athletes. In addition, 43 athletes were diagnosed with cervical cord neurapraxia, and 1 athlete had a cervical nerve root avulsion.

Quadriplegia

Seventy-six athletes (68 high school and 8 collegiate players) suffered an injury resulting in quadriplegia during the study period (Figure 1A). There were 5.85 ± 3.13 injuries per year in the combined group: 5.23 ± 2.83 at the high school level and 0.62 ± 0.65 at the college level. After a peak of 13 injuries during the 1989-1990 academic year, the number of events started to diminish. The mean annual incidence of quadriplegia was 0.52 per 100 000 participants (95% CI, 0.40-0.64), with a peak in the 1989-1990 school year of 1.18 per 100 000 participants (95% CI, 0.54-1.82) (Figure 1B). Although the majority of injuries occurred at the high school level, the incidence at the college level, 0.82 per 100 000 (95% CI, 0.25-1.39), was 1.65 times higher (95% CI, 0.79-3.43) than the high school incidence, 0.50 per 100 000 (95% CI, 0.38-0.62).

The level of injury was known in 63 of the 76 athletes: 58 injuries occurred at a subaxial level, 3 at the upper cervical levels, and 2 at combined upper and lower levels. Most of the quadriplegia injuries occurred to players on defense (45/71, 63.4%), as shown in Figure 2A. There were 13 (18.3%) injuries to special teams players, 13 (18.3%) to offense players, and 5 unknown. The position played at the time of injury was determined in 70 cases, with the highest percentage of injuries occurring to defensive backs (31, 44.3%), followed by special teams players (13, 18.6%), and linebackers (12, 17.1%) (Figure 3A). The activity at the time of injury was determined in 69 players, with the vast majority of players making a tackle (55, 79.7%) (Figure 4A). Twenty-three (88%) of the 26 contacts were able to recall the details of the mechanism of injury and reported a likely spear tackle event. Videotapes of 4 events were reviewed, and all revealed an axial loading injury to the cervical spine. Fifty-seven contacts reported that at least 1 cervical spine surgical procedure was performed to treat the injury. Thirty-eight of the quadriplegic athletes reported no previous cervical injuries, and 8 reported a previous stinger.

Incomplete Injuries

Seventeen (8.7%) athletes suffered an incomplete neurologic cervical spine injury. Fifteen sustained a cervical fracture at a subaxial cervical level with varying degrees of permanent motor or sensory deficits. One athlete sustained a nerve root avulsion from making a tackle and has limited use of his right hand. Another athlete had a cervical cord neurapraxia–like injury from an axial compression tackle verified by videotape review. The athlete developed transient quadriplegia and was unable to walk normally for 8 weeks after the injury. Magnetic resonance imaging, computed tomography, and radiography reports of the cervical spine within 4 days of the injury revealed no abnormalities. At the 15.5-year follow-up, the patient had

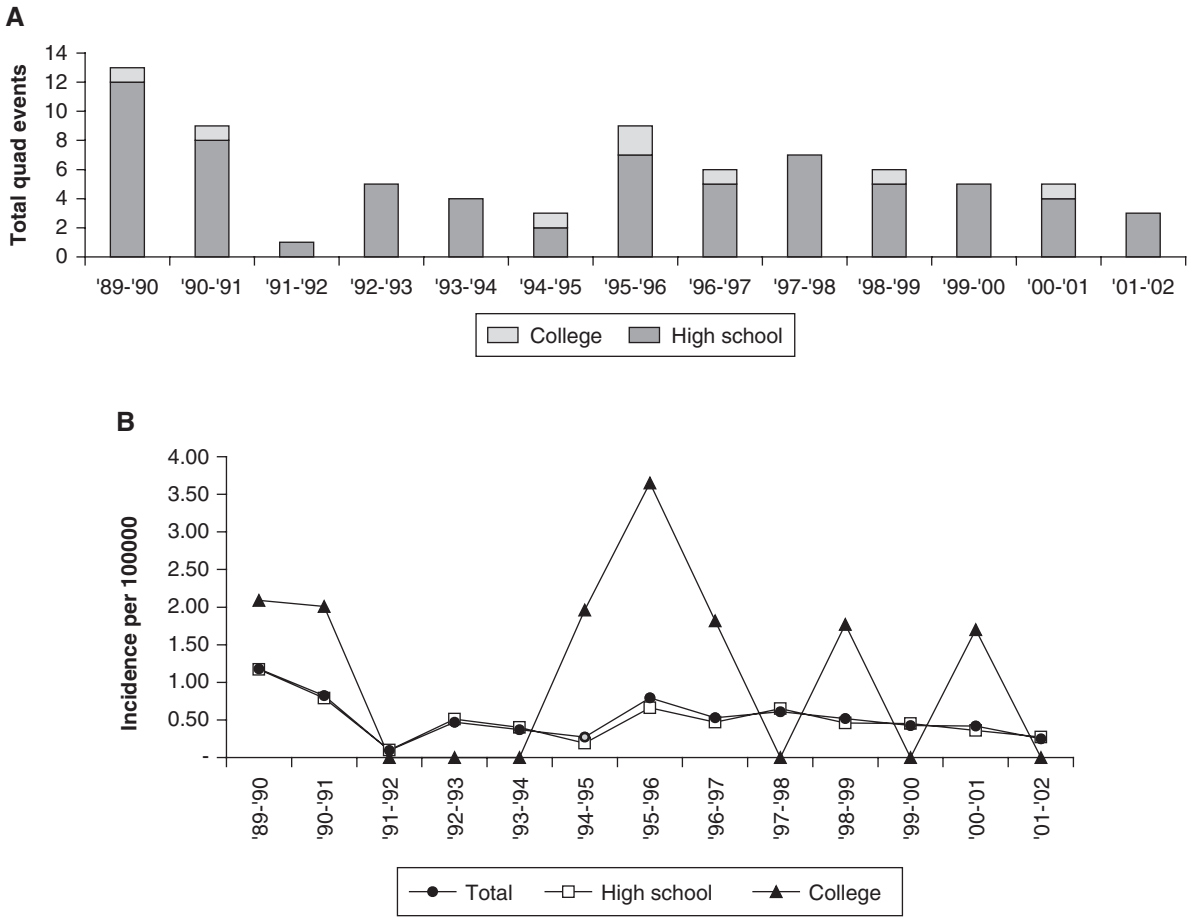

Figure 1. A, number of football injuries resulting in quadriplegia at the high school and college levels reported to the National Center for Catastrophic Sports Injury Research per school year from 1989-1990 to 2001-2002. B, annual incidence of high school, college, and total football injuries resulting in quadriplegia per 100 000 participants from 1989 to 2002.

residual paresthesias in all 5 digits of the left hand and the first and second left toe, as well as a sense of clumsiness or poor coordination in the left arm and leg.

Brown-Séquard–like Syndrome

Five (2.6%) injuries were classified as Brown-Séquard–like syndrome with ipsilateral motor loss and contralateral loss of pain and temperature. A detailed questionnaire was completed on all 5 athletes, and medical records were obtained in 3 cases. Four of the 5 athletes were making a tackle at the time of injury, and 1 was being tackled. Three players were on defense, 1 on offense, and 1 on special teams when the injury occurred. There was no uniform mechanism of injury. Four of the injuries were classified as permanent with incomplete neurologic recovery, and 1 was classified as a serious injury with complete recovery. All 5 athletes recovered ambulation, with only 1 requiring an assistive device. Four of the 5 injuries required a surgical procedure. None of the athletes returned to football after the injury. One patient with a permanent Brown-Séquard–like injury reported a previous cervical cord neurapraxia event.[3]

Cervical Cord Neurapraxia

Forty-three athletes sustained a cervical cord neurapraxia injury during the study period (23 high school and 20 collegiate players) (Figure 5A). There were 3.31 ± 1.84 cervical cord neurapraxia injuries per year or 1.77 ± 1.09 at the high school level and 1.54 ± 1.51 at the college level. There was a peak of 8 injuries during the 1994-1995 academic year. The mean annual incidence of cervical cord neurapraxia for the study period was 0.29 per 100 000 participants (95% CI, 0.21-0.38), with a spike during the 1994-1995 school year of 0.72 per 100 000 participants (95% CI, 0.22-1.22) (Figure 5B). The mean incidence during the study period was 0.17 per 100 000 high school participants (95% CI, 0.10-0.24) and 2.05 per 100 000 college participants (95% CI, 1.15-2.95), resulting in a risk ratio of 12.20 for college compared to high school participants (95% CI, 6.70-22.21).

The mechanism of cervical cord neurapraxia injury varied widely according to the 23 contacts who could accurately recall the event. The major component was reported to be axial compression (5), hyperextension (5), hyperflexion (4), or a combination of forces (9).

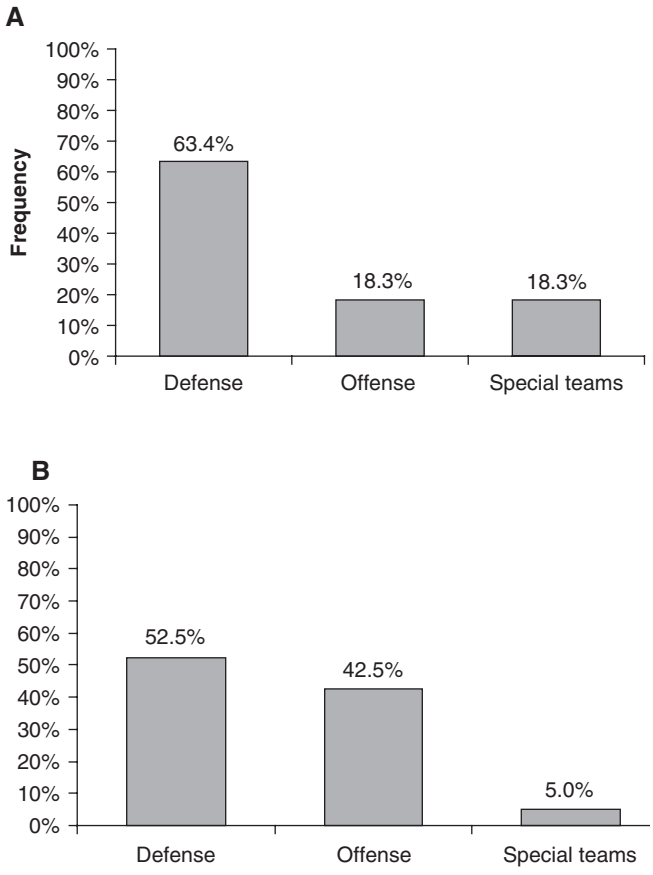

Figure 2. Percentage of quadriplegia (A) and cervical cord neurapraxia (B) injuries based on position.

The level of the spinal cord concussion was unknown in most patients. The injuries were fairly evenly distributed between defensive (21/40, 52.5%) and offensive players (17/40, 42.5%); 2 of 40 (5%) occurred on special teams, and the player position for 3 injuries was unknown (Figure 2B). The position played at the time of injury was determined in 39 players and varied widely: 7 defensive lineman, 6 defensive backs, 6 linebackers, 5 quarterbacks, 5 running backs, 4 offensive linemen, 4 wide receivers, and 2 on special teams (Figure 3B). The activity at the time of injury was determined in 38 athletes and was fairly evenly split between making a tackle (17, 44.7%) and being tackled (14, 36.8%) (Figure 4B). There were also 3 (7.9%) players who were being blocked, 3 (7.9%) who were blocking, and 1 (2.6%) who collided with a teammate.

Two athletes reported a previous cervical cord neurapraxia episode, and 2 reported a stinger before the documented event. Although none of the athletes reported a congenital neck anomaly, 3 were subsequently given a diagnosis of congenital spinal stenosis. Of the 43 cervical cord neurapraxia injuries, limited neurologic data were obtained on 40 patients. Patients whose medical information was obtained were classified according to the length of symptoms and extremities involved. Duration of neurologic symptoms was obtained in 12 players: 5 players had symptoms for less than 15 minutes, 5 players' symptoms lasted more than 15 minutes but less than 24 hours, and 2 players had symptoms that lasted for more than 24 hours. The duration of symptoms was unknown in the remaining athletes. Twenty-eight patients had neurologic involvement of both upper and lower extremities, and 1 had involvement of both lower extremities and the right upper extremity. Twenty-five athletes had involvement of motor and sensory in the affected extremities, 3 had sensory involvement only, and 2 had only motor involvement.

All of the athletes with cervical cord neurapraxia were classified as a serious injury with a full recovery. Seven athletes sustained a concomitant concussion at the time of the cervical cord neurapraxia injury. Most patients were treated with observation after imaging studies revealed no evidence of spinal fracture or instability. Only 1 athlete, who sustained 2 cervical cord neurapraxia episodes, required surgery secondary to a C3-C4 disc herniation, which contributed to the cord neurapraxia and compression.

Seventeen of the 26 patients contacted stated that they returned to football after the injury. One athlete who returned to football after the reportable injury sustained a second cervical cord neurapraxia episode. No athletes sustained an injury causing quadriplegia after the cervical cord neurapraxia event.

C1-C2 Injuries

Sixteen (8.2%) of the 196 injuries involved the upper cervical levels (C1 or C2, or C1 and C2). Nine athletes sustained an isolated injury at the C1 or C2 level, and 7 sustained a combined injury at an upper and lower cervical level. Three of the isolated upper level injuries and 2 of the combined upper and lower level injuries resulted in quadriplegia. Most players were on defense at the time of injury (12, 75%) followed by offense (3, 19%) and special teams (1, 6%).

Prevention and Legal Ramifications

None of the interviewees attributed the injury to preexisting medications or illegal substance use. Several athletes with a cervical cord neurapraxia injury reported that they would not have participated in football had they known before the cervical cord neurapraxia injury that they had cervical spine stenosis. In addition to the devastating health and emotional impact, at least 18 accidents resulted in a lawsuit or insurance settlement, with many interviewees refusing to discuss this matter.

DISCUSSION

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. Therefore, continued surveillance and preventive strategies are crucial for the sport.

Although the number of quadriplegia injuries was higher at the high school than college level, the overall incidence

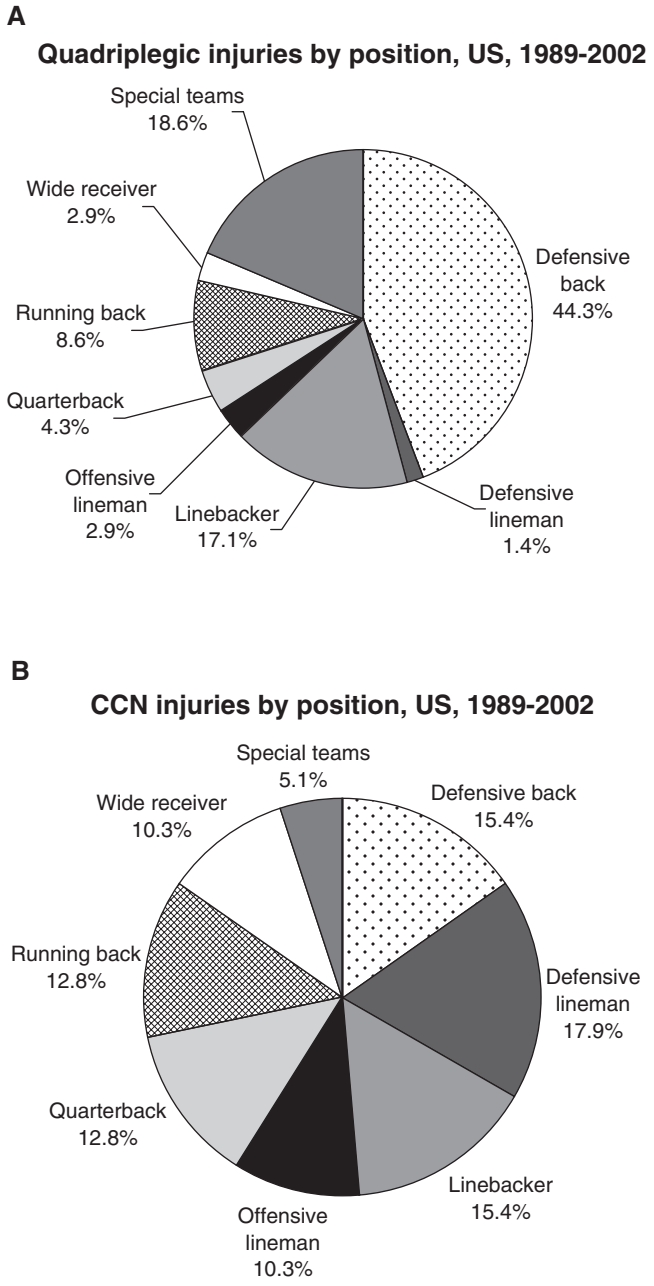

Figure 3. Percentage of quadriplegia (A) and cervical cord neurapraxia (B) injuries by position played at time of injury. CCN, cervical cord neurapraxia.

of quadriplegia per 100 000 football players was more than 1.5-fold higher in college athletes in our study. For cervical cord neurapraxia injuries, the incidence of injuries was more than 12-fold higher at the college level. We believe the higher rate of injuries to college athletes may be explained by faster, bigger, and stronger athletes, resulting in higher collision forces. There were no acute fatalities identified in our study period of upper cervical spine injuries, likely the result of advancement in on-field medical management.

Quadriplegia

Our quadriplegic data concur with the findings of Torg et al[18,21-23] that the predominant mechanism of injury reported, and the only mechanism of injury captured on videotape in 4 cases, was spear tackling. When the neck is in a neutral position, the cervical vertebrae are in a lordotic alignment. It has been documented that during spear tackling, the neck is flexed to 30°, placing the cervical spine into a straight column. When an axial force is applied to the vertex, the paravertebral muscles are no longer effective at dissipating the forces, and the vertebral column fails in a flexion mode, often leading to fracture, subluxation, or facet dislocation.[17]

Similar to other studies on football injuries resulting in quadriplegia, we also found that most of these injuries occurred at a subaxial level,[22] likely due to the relative narrowing of the spinal canal at these levels.[13] Our study also concurs with previous studies that most injuries occur to defensive players (63%) who are making a tackle (80%).[2,23] In addition, we showed that a disproportionate number of injuries occurred to players on special teams (18%), likely owing to the high speed of collisions during special team plays.[14]

In 1976, the National Collegiate Athletic Association banned spear tackling or the intentional striking of an opponent with the crown of the helmet. Shortly thereafter, spear tackling was made illegal at the high school level. These rule changes resulted in a dramatic reduction of quadriplegia injuries in football. In 1976, there were 34 reported cases of quadriplegia at the high school and college levels, with high school and college rates of 2.24 and 10.66 per 100 000 players, respectively.[18] In 1977, the high school and college rates decreased to 1.3 and 2.66 per 100 000 players, respectively.[18] The mean number of quadriplegia injuries at the high school and college levels in the 1980s (1980-1981 to 1989-1990 academic years) was 10 incidents per year, compared with 6 incidents per year in the 1990s (1990-1991 to 1999-2000 academic years).[2,18] Because the participation numbers have steadily increased at the high school level but have remained constant at the college level, the incidence of quadriplegia has decreased more than that shown by the absolute numbers of these injuries.[10] The rate of injuries resulting in quadriplegia has remained fairly steady in the 1990s and early 2000s at 5.19 per 1 million participants, or 1 injury per 192 000 participants.

In an effort to reduce the number of quadriplegia injuries, the National Collegiate Athletic Association strengthened its spearing rule, effective for the 2005-2006 academic year. The revision removes the word *intentional* from the rule, which makes it easier for referees to call spearing penalties. Under the previous rule, intent was difficult for referees to assess on the field, and the penalty was rarely called. As part of that organization's efforts to publicize its spearing rule change, it has produced a poster for locker rooms, a PowerPoint presentation, and a video on the risks, mechanism of injury, the concept of axial loading, and injury prevention through the adoption of safe techniques.[9] Future epidemiologic data will reveal if this new rule can further reduce the incidence of quadriplegia in football.

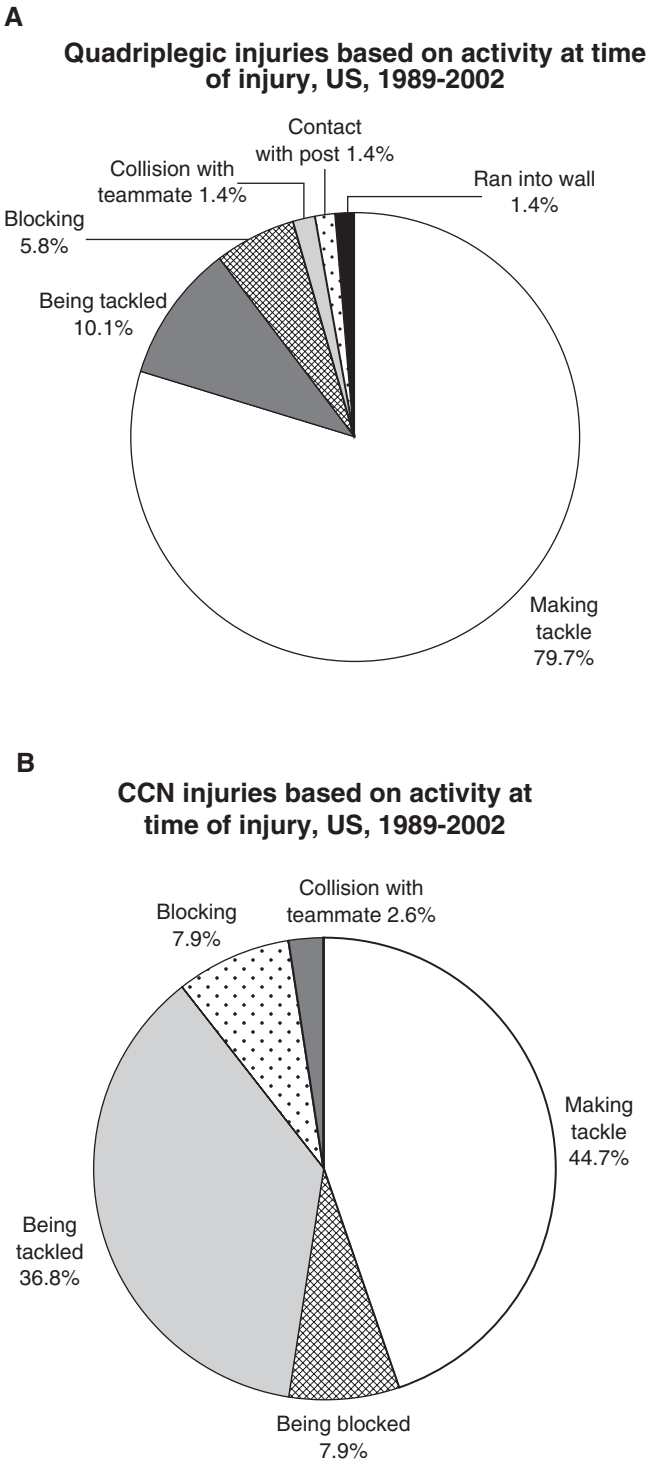

Figure 4. Percentage of quadriplegia (A) and cervical cord neurapraxia (B) injuries based on activity at time of injury. CCN, cervical cord neurapraxia.

Identification of spear tackling as the primary culprit leading to quadriplegia has had a profound effect on reducing this catastrophic injury. Coaches need to continually reinforce the proper tackling techniques with the head up. Players should never be allowed to tackle with the head down as a battering ram.

Brown-Séquard Syndrome

We identified 5 football players with Brown-Séquard–like syndrome. Brown-Séquard syndrome has been reported to account for 2% to 4% of all traumatic spinal cord injuries.[12] Nonetheless, we are aware of only 1 case report of Brown-Séquard syndrome in a football player[3] (also included in our study). The players in our study did not have pure Brown-Séquard syndrome but, rather, many features of the condition, including ipsilateral motor loss and contralateral loss of pain and temperature. Despite the reported favorable prognosis with Brown-Séquard syndrome,[12] 4 of the 5 players with the condition in this study had permanent neurologic deficits. One patient with a permanent injury reported a previous cervical cord neurapraxia episode, indicating that cervical cord neurapraxia has the potential to lead to more devastating sequelae. The player's radiographs after the cervical cord neurapraxia event revealed spinal stenosis with a canal width of 12 mm[2].

Cervical Cord Neurapraxia

Cervical cord neurapraxia, or spinal cord concussion, is defined as an acute, transient neurologic episode associated with sensory changes in more than 1 extremity with or without motor changes of weakness or complete paralysis. The cervical area is usually pain free at the time of injury with full painless range of motion. The mean annual incidence of cervical cord neurapraxia in our study (0.29 per 100 000 players) was much lower than that in previous reports.[20] There are several plausible explanations for this finding. It is possible that not all cervical cord neurapraxia injuries were reported to the Center because the neurologic symptoms often resolve within 15 minutes. In fact, our limited medical data on 12 players revealed that 7 had symptoms lasting longer than 15 minutes.[16] Alternatively, the incidence of cervical cord neurapraxia episodes may be decreasing with time.

The proposed mechanism of injury of cervical cord neurapraxia is hyperextension or hyperflexion of the cervical spine, which causes compression of the spinal cord between the anterior and posterior structures of the spinal canal.[15] In our study, the mechanism of injury varied, with hyperextension, hyperflexion, axial forces, and a combination of these forces being reported. In an animal study evaluating the effect of a compression injury to the vertex of the head, Gosch et al[5] found central hemorrhagic necrosis at the cervical spinal level. The authors postulated that the transmission of shear strain along the axis of acceleration produces central cord hemorrhages when the elastic deformation of the cervical spinal cord is exceeded.[4] Our clinical data provide further support that axial forces without spinal column disruption can result in central cord injury. Injury to the spinal cord is likely secondary to shear forces from continued momentum of the body on the fixed head segment. Both of our players with a cervical cord neurapraxia episode with symptoms lasting longer than 48 hours reported an axial force to the top of the head.

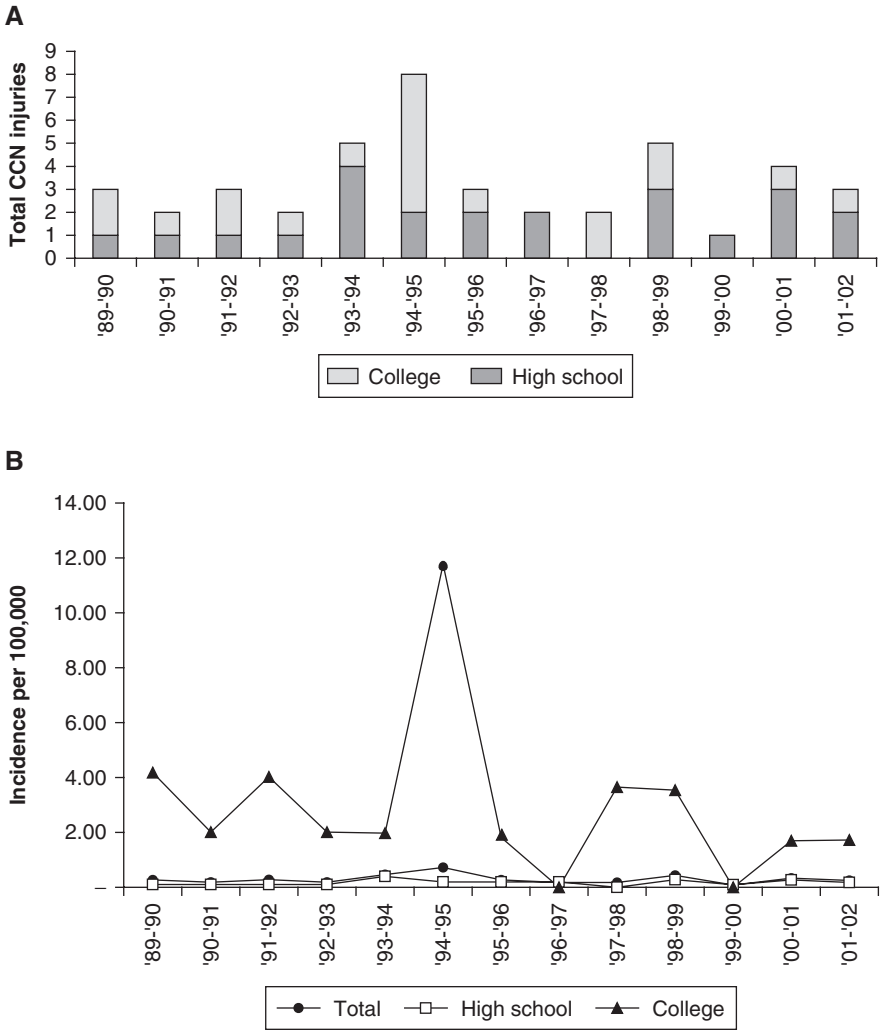

Figure 5. A, number of cervical cord neurapraxia football injuries at the high school and college levels reported to the National Center for Catastrophic Sports Injury Research per school year from 1989-1990 to 2001-2002. B, annual incidence of high school, college, and total football cervical cord neurapraxia injuries per 100 000 participants from 1989 to 2002. CCN, cervical cord neurapraxia.

The cervical cord neurapraxia injuries were fairly evenly distributed between defensive (52.5%) and offensive players (42.5%), as well as in the position played at the time of injury. The activity at the time of injury was fairly evenly split between making a tackle (44.7%) and being tackled (36.8%). Based on this information, it appears that there is no one position or activity that is particularly vulnerable in sustaining a cervical cord neurapraxia episode.

Torg et al[19] previously reported that the occurrence of cervical cord neurapraxia and an injury resulting in quadriplegia are unrelated. They documented that an athlete's risk of recurrent cervical cord neurapraxia is proportional to the degree of cervical stenosis and that cervical cord neurapraxia does not predispose an athlete to a quadriplegia event. The overall risk of a recurrent episode of cervical cord neurapraxia with return to football has been reported to be 56%.[16] In our study, 16 players returned to football after a cervical cord neurapraxia episode, and none sustained a permanent quadriplegia event. Because the overall incidence of quadriplegia is extremely low (approximately 1 in 192 000 participants), it would require a much higher number of cervical cord neurapraxia episodes without a quadriplegia event to make a definitive statement. To our knowledge, there have been no reported cases of quadriplegia after cervical cord neurapraxia. However, because of the low number of players who returned to play after a cervical cord neurapraxia episode and the extremely small risk of quadriplegia, we cannot make a definitive statement. We are aware of 2 athletes with a cervical cord neurapraxia episode who developed permanent neurologic deficits after returning to play.[1] One athlete (in our report) sustained a Brown-Séquard–like lesion, and the second experienced permanent upper extremity dysesthesias and mild weakness.[1,3] Athletes need to be counseled on an individual basis on the known and potential risks of injury with return to football after a cervical cord neurapraxia episode.

C1-C2 Injuries

Considering the wider diameter of the spinal canal at the C1 and C2 levels,[13] we were surprised to discover that 3 of the 9 isolated upper cervical spine injuries resulted in permanent cord damage. Clinical and experimental studies have shown that upper-level injuries can be associated with concomitant lower cervical spine injuries, especially with vertical impacts.[6,11] Two of the 7 combined injuries in our study involved noncontiguous subaxial levels. It has been hypothesized that combined injuries are the result of the most severe types of vertical impacts.[11] As players continue to be larger and play with greater collision speeds, the threshold for a combined injury may be exceeded. In 1 study, collision speeds causing concussions at the professional level often were found to exceed 20 mph.[14] Continued surveillance of these injuries to elucidate the mechanisms of injury and develop preventive strategies is currently under way.

Limitations

There are several limitations to our study. It is probable that not all catastrophic cervical spine 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 75 incidents in which an interviewee could not be located for the detailed questionnaire. We attribute this low contact rate to the mean 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 that may lead to inaccurate information and faulty conclusions. In addition, we were able to confirm medical information by a review of medical records in only 80 patients. Finally, new Health Insurance Portability and Accountability Act regulations have made obtaining medical records and imaging studies extremely difficult. Nonetheless, the problem of catastrophic football injuries is real and needs to be addressed. We believe that continued analysis of injuries and rule changes may help further reduce the incidence and severity of such catastrophic events.

CONCLUSION

Direct catastrophic cervical spine injuries in football are uncommon but tragic events. Spear tackling continues to be the predominant mechanism of injury responsible for quadriplegia. In addition to defensive players, especially those in the secondary, special teams players are considered an at-risk position. The incidence of quadriplegia in football has dramatically decreased since the rule banning spear tackling. For the 13-year study period, the overall high school and college incidence of quadriplegia was approximately 5.19 per 1 million participants or 1 per 192 000 participants. The incidence of quadriplegia was more than 1.65 times higher (95% CI, 0.79-3.43) at the college level (0.82/100 000) than at the high school level (0.50/100 000). Coaches need to continue educating players to avoid the potentially devastating spear tackling technique.

Although somewhat controversial, athletes with a cervical cord neurapraxia injury are at risk for permanent neurologic injuries with return to football. Axial compression forces may cause cervical cord neurapraxia injuries in addition to hyperflexion and hyperextension mechanisms. Brown-Séquard–like syndrome can occur in football players and may have a less favorable prognosis than that in the general population. C1 or C2 injuries constitute 8% of direct catastrophic injuries and may be associated with noncontiguous injuries and quadriplegia.

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