Epidemiology of Spinal Injuries in Sports

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Supraphysiological stresses placed on the spine during sporting activity can lead to various spinal injuries, ranging from a simple sprain or strain of the musculoligamentous structures surrounding the spine to a cervical fracture dislocation with complete spinal cord injury. Collision sports, such as football, are responsible for the vast majority of catastrophic spinal injuries. Gymnastics and other sports that require repetitive hyperextension at the waist have been associated with isthmic spondylolysis. This article reviews the epidemiology of spinal injuries associated with various sports, with a specific focus on spinal cord injury.

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Injuries to the vertebral column and spinal cord can be devastating as those severe enough may prevent a patient from regaining full neurologic function. Structurally, the spine's encases and protects the spinal cord while bearing load and still permitting the vertebral arrangement a remarkable degree of motility. Unfortunately, when loads exceed the normal physiological stresses that the spine is accustomed to handle, bony, ligamentous and potentially even neurologic injury can result.

Although sports activity in particular can serve as an excellent medium for exercise and developing skills in teamwork and discipline, involvement in athletic activity may predispose individuals to these very same supraphysiological stresses that ultimately result in spinal injury. Although, sports-related injury accounts for only 8.7% of all spinal cord injuries, they represent the second most frequent cause of spinal cord injury in those younger than 30 years (the mean age of injury being 24 years).1-3 Not surprisingly, it is collision sports, most notably football, which account for most such injuries.4

Although spinal cord injury in the setting of sporting activity is relatively rare, a wide range of more common spinal injuries may result from sports, including strain or sprain of the cervical, thoracic, or lumbar region, intervertebral disc herniation, a variety of spinal fractures (eg, spinous process, transverse process, vertebral body, facet joint, and pedicle), and isthmic spondylolysis, which is thought to be more prevalent in athletes that participate in sports that require repetitive hyperextension at the waist (eg, gymnastics and football lineman).5 Overall, strains or sprains are most common.3 When compression fractures occur in the cervical spine, they are usually between C4 and C7 as a result of a flexion, compression mechanism.3 Although more rare in incidence, a catastrophic spinal injury refers to one that leads to permanent neurologic injury or even death.6 Relative to thoracic or lumbar regions, it is trauma to the cervical spine, which is more likely to result in such a disability.1 Catastrophic injuries are most commonly attributed to football, hockey, and gymnastics.7 This review focuses on the epidemiology of the most devastating spinal injuries encountered in various sporting activities, including football, hockey, and gymnastics.

Football

Approximately, 600,000-1.2 million football-related injuries occur in the United States annually; of these, between 10% and 25% involve the spine or axial skeleton.8 Early on, in 1964, Schneider9 studied the relationship between football and spinal injuries. At the time, he recognized 56 cases of football-related cervical fractures or dislocations over a 5-year interval (1959-1963).9 Of the 56, 30 ended in quadriplegia.9 Subsequently, in 1979, Torg et al.10 analyzed data collected retrospectively by the National Football Head and Neck Injury Registry from 1971-1975. They noted 259 cases of cervical fracture or dislocation, 99 of such cases were complicated with persistent quadriplegia.10 The authors recognized the increase in permanent football-related neurologic injury as alarming, especially given recent trends involving the increased use of protective equipment, most notably helmets and face masks. Although counterintuitive, the authors...
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paradoxically attributed the increased rate of quadriplegia to the increase in the use of protective gear. Although the advent of such protective equipment was geared toward player safety, players were more likely to employ their heads as the initial point of contact—ultimately increasing the incidence of cervical spine injuries. The term “spearing” was used to describe a tactic in which the head is used as the initial point of contact with which to initiate a tackle.

Six years later, in 1985, Torg et al performed an analysis involving a more extended time frame (1971-1984) using the same 14-year registry and determined that most cervical fractures and dislocations could be attributed to axial loading. It is noteworthy that during a preliminary analysis done in 1975, the same suggestion had been made. The report in 1975 served as an impetus for the National Collegiate Athletic Association and the National Federation of High School Athletic Associations to modify game rules. In 1976, players were no longer permitted to initiate contact with helmets and “spearing” was banned. Consequently, from 1976-1984, a decrease from 34 instances of football-related permanent cervical quadriplegia to 5 was observed.

Similarly, Cantu and Mueller noted a decrease in cervical spinal injury during a 25-year interval (1977-2001) in comparison with when the issue was explored early on by Schneider. The authors analyzed data obtained via personal contact and questionnaires on a national level with respect to catastrophic football injuries. Although they attributed the change in cervical spinal injury in part to the 1976 rule change, the value of a more complete physical examination, changes in conditioning programs and more effective treatment or management options are thought to contribute. A more complete physical examination is thought to prevent those more prone to injury from competing, thus, preventing injury.

Although not necessarily apparent on a physical examination, there is evidence that spinal stenosis places subjects at increased risk of quadriplegia. Eismont et al measured the diameters of 98 patients with spinal fracture dislocations and determined that smaller sagittal diameters were associated with increased risk of neurologic injury.

Of the 223 football players with residual neurologic deficits following injury to the cervical spine in the Cantu and Mueller study, most competed at a high school level; however, the greatest risk of quadriplegia was at the professional level.

Mall et al examined the incidence of spinal and axial skeletal injuries at the professional level in the National Football League over an 11-year period (2000-2010) via its injury surveillance system. In their study, of the 31,338 injuries observed, the spine or axial skeleton was involved in 7%. Cervical injuries (44.7%) comprised the largest proportion of such injuries; the most common causes were identified as tackling (32.5%) followed by blocks (24%). Following cervical injuries were those to the lumbar (30.9%) and pelvic (10.1%) regions. In contrast to the cervical region, the most common cause of injury, here, involved noncontact mechanisms (20.8% for lumbar and 22.5% for pelvis). Injuries from blocking were also high in these regions (18.6% and 19.4% for lumbar and pelvis, respectively). The thoracic spine and ribs comprised only 3.9% of injuries. Here, the distribution of tackling (19.8%), blocking (18.6%), and being tackled (18.6%) was similar. Although the sample size was small, spinal cord injuries accounted for only 0.6% of injuries and occurred most often following tackling (28.6%) and being tackled (21.4%).

Although nerve injuries were most common in the cervical region, muscle spasms and sprains were most common in the thoracic, lumbar, and pelvic regions.

Although the prevalence of injuries was similar between offensive and defensive players, offensive linemen were the most likely to experience a spinal or axial skeletal injury. The authors concluded that tackling produces more cervical spine injuries, whereas blocking produces more thoracic and lumbar injuries.

This explains why linebackers, defensive ends, and linemen are more prone to cervical injury when compared with their offensive counterparts. The authors also noted that per game exposure, the number of injuries was similar regardless of whether games are played during the preseason or regular season; hence, it does not appear that increases in competition and aggressiveness during the regular season affect rate of injury.

Hockey

Although the incidences of nonfatal catastrophic neck injuries each year in American football are greater than those in Canadian hockey, the annual incidence of spinal cord injury with paralysis in hockey is more than 3 times as high. Nonetheless, spinal injury was initially quite rare in Canada; it was only after 1980 that the incidence of spinal injury in hockey became noteworthy—a dramatic increase that remained high until 2001.

Similar to in football, Reynen and Clancy suggested that the act of wearing helmets and face masks may have altered the way players played hockey, paradoxically increasing the risk of cervical spinal injury in particular. To assess this, LaPrade et al conducted a 4-year prospective review in which they compared the effect of having players on a varsity intercollegiate ice hockey team wear mandatory face masks with previous studies in which such a requirement was optional. The authors failed to observe an increase in head and neck injury; rather, they observed a decrease in facial lacerations.

Tator et al conjectured that the sudden rise in spinal injury could simply be attributed to the increased popularity of the sport, leading to an increased overall participation; unfortunately, the lack of data available prior to 1980 made it difficult to confirm this rationale.

Nonetheless, this new onset increase in spinal injury needed an effective means of documentation. For this purpose, in 1981, the Committee on Prevention of Spinal Cord Injuries Due to Hockey, eventually succeeded by ThinkFirst-SportSmart was established. National surveys were sent out, and the incidences and factors associated with spinal injury from hockey were documented every 2-3 years. By 1993, a total of 241 cases had been recognized.

Tator et al reporting on this registry, noted that of the 211 cases in which the vertebral level affected was documented,
Gymnastics

As with football and hockey, gymnastics is not without spinal injury from acute trauma. In 1986, Silver et al. studied 38 subjects between 1954 and 1984, who had sustained gymnastic-related injuries. Of these, 31 had spinal cord damage with 24 cases of complete paralysis and 7 cases of incomplete paralysis. Two of the 38 had no neurologic deficit, and there was incomplete information for 5 of the injured athletes. Similar to in football and hockey, most of the injuries involved cervical vertebrae (Fig. 1). The authors attributed many of these injuries to inadequate supervision and noted that gymnasts were injured independent of the gymnast’s skill level and experience. The authors reasoned that, technically speaking, any level of gymnast attempting a new skill was a beginner, and beginners, who often trust and yield to pressure from their coaches, may attempt maneuvers beyond their current level of training, ultimately predisposing them to injury.

Although injuries from gymnastics leading to scoliosis are a fairly rare phenomenon, falls and injuries in gymnastics may lead to diagnosis of a previously asymptomatic scoliosis. Furthermore, the incidence of scoliosis may be higher in female gymnasts. Tanchev et al. studied 100 female rhythmic gymnasts between the ages of 10 and 16 years who had been training in rhythmic gymnastics for more than 5 years and noted a 12% incidence of scoliosis in this demographic. This is 10 times the incidence in adolescent girls of similar age. The authors attribute the observation to asymmetric spinal loading, joint laxity, and delayed maturity.

Furthermore, repeated hyperextension and rotation in the lumbar spine of gymnasts likely predisposes these and other athletes involved in similar repetitive activities to isthmic spondylolysis, a defect in the pars interarticularis. Jackson et al. in 1976 did an analysis in which they looked at the lumbar radiographs of 100 female gymnasts and found an 11% incidence of spondylolysis. The authors noted that the incidence was 4 times higher than that of the general female Caucasian population and 2 times higher than that of the general young male population. A complication of spondylolysis is that when it occurs bilaterally the pathology may transition to isthmic spondylolisthesis. In the study by Jackson et al, 6% of the affected athletes were already noted to have spondylolisthesis. Given the increased incidence of spondylolysis in the gymnast demographic, it should not be surprising that the overall the prevalence of isthmic spondylolisthesis is higher in gymnasts as well. Muschik et al. reported on the effects of intensive sports training on 86 young athletes with spondylolysis or spondylolisthesis (mean listhesis of 10.1%) over a 4.8-year period and concluded that adolescents and children with spondylolisthesis should not be advised against participation in sports as long as there is lordosis in the displaced segment, the patient is asymptomatic, there is regular medical follow-up, and the spondylolisthesis is limited.

Generally speaking, attention in the literature with respect to spinal injuries in gymnasts has been more skewed toward posterior column injuries, such as spondylolysis and isthmic...
spondylolisthesis; however, Katz and Scerpella performed a literature review and examined a series of cases in which multiple anterior and middle column spinal injuries including disc herniation, compression fractures, disc degeneration, and Schmorl nodes were recognized in female gymnasts. The aim was to illustrate that injuries to the anterior and middle column in gymnastics were also relatively common.

Radiographically, Goldstein et al examined the spines of female gymnasts at the pre-elite, elite, and national or Olympic level using MRI and found abnormalities in 9% of the pre-elite, 43% of the elite, and 63% of the Olympic group. Abnormalities were associated with age and hours of training per week.

Other Sports
Skiing or Snowboarding
The incidence of spinal injury from alpine skiing and snowboarding ranges from 1%-17%. Gertzbein et al retrospectively reviewed subjects sustaining thoracic or lumbar spinal fractures while skiing or snowboarding between 2005 and 2010 at a hospital servicing 4 local mountains. In all, the authors reviewed 119 patients from these locations: 63 snowboarders, 54 skiers, and 2 for which the status of snowboarder versus skier could not be determined. The authors determined that the chance of sustaining a spinal fracture was low at only 0.009% per ski or snowboard day with no difference of whether it was a skier or a snowboarder. A total of 146 fractures were identified, of which, 114 (46 thoracic, 68 lumbar) were classified according to the AO comprehensive classification, with the remainder representing isolated spinous or transverse process fractures. Of those classified, 94.7% were due to compression injuries, 4.4% were due to distraction injuries, and 0.9% were due to rotation injuries. The lack of neurologic injuries in the study was attributed to the exclusion of cervical fractures, which are typically associated with an increased incidence of neurologic injury. In all, the authors concluded that skiing or snowboarding injuries to the thoracic and lumbar spine are mostly stable.

Figure 1 (A) Sagittal T2-weighted cervical MRI of a 17-year-old gymnast who suffered a flexion-distraction injury resulting in bilateral C5-6 jumped facets and an incomplete spinal cord injury. (B) Prereduction lateral cervical spine radiograph showing the C5-6 subluxation and jumped facets. (C) Postreduction lateral cervical spine radiograph following reduction in the emergency department. (D) Postoperative lateral cervical radiograph following anterior cervical discectomy and fusion of C5-6. (E) Postoperative sagittal T2-weighted cervical MRI showing adequate reduction and decompression of the spinal cord.
Franz et al identified 728 patients injured while involved in “snow sports” from a database at a tertiary trauma center in Bern, Switzerland, between 2000 and 2006. Of the 728 patients, 73 had severe spinal injuries, including fractures, dislocations, spinal cord injuries, and subluxations. Overall, 86.3% of these injuries were due to skiing whereas only 13.7% were caused by snowboarding. The most common spinal regions affected in descending order of prevalence include the lumbar spine, thoracic spine, cervical spine, and sacrum. Fractures of the transverse or spinous process were most common, with anterior thoracolumbar compression fractures coming in second, and thoracolumbar burst fractures following thereafter. Risk factors for spinal injury in snowboarders included male gender and younger age.

Corra et al observed that severe spine injuries were more likely to be associated with snowboarding and increased age. The authors studied 105 patients between 2001 and 2005, who had injury severity scores of 16 or higher. Yamakawa et al retrospectively reviewed 13,490 cases of injuries from snowboarding or skiing and found a significantly higher incidence of spinal injuries in beginner snowboarders than beginner skiers. Furthermore, they determined that most (70%) of spinal injuries from skiing were due to simple falls, whereas compared with beginners, more experienced snowboarders were more likely to be injured from jumping.

Diving

Of all spinal cord injuries, 8.5% of cases in the United States are attributed to diving accidents, making it the fourth leading cause of spinal cord injury overall. This number encompasses all diving accidents, not necessarily those encountered during competitive or organized diving activities. Worldwide, the demographic typically involves young, unmarried men and incidence is higher during the summer time.

Vlok et al identified 46 patients admitted to an acute spinal cord injury unit due to diving-related injury between 2003 and 2009 in South Africa. Compression-flexion type injuries were identified as the most common type followed by burst fractures. As expected, subjects were usually young men with an average age of 23 years, and there was increased summer time prevalence. Overall, 37% admitted to alcohol consumption prior to injury.

Similarly Amorim et al assessed 140 patients with spinal trauma following a diving accident between 1991 and 2006 in Salvador, Brazil. Men were much more likely to be affected compared with women (ratio of 12:1) and nearly 50% of the cases occurred during summer time. Overall, 92.1% of injuries affected the cervical region with the C5 level being affected in 42.1% of cases. The authors described this as typical and suggested that it could be attributed to the increased range of motion and narrower vertebral canal diameter in this region.

Conclusions

Spinal injuries are relatively common in sporting activities. Severe injuries, including those with catastrophic neurologic deficits, are most common among collision sports, such as football. Improvements in equipment and technique have significantly decreased the incidence of severe spinal cord injuries in sporting activity. Most spinal injuries resulting from sporting activities are stable and do not require operative treatment.

References
