Adult sports-related traumatic spinal injuries: do different activities predispose to certain injuries?

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OBJECTIVE Sports injuries are known to present a high risk of spinal trauma. The authors hypothesized that different sports predispose participants to different injuries and injury severities.

METHODS The authors conducted a retrospective cohort analysis of adult patients who experienced a sports-related traumatic spinal injury (TSI), including spinal fractures and spinal cord injuries (SCIs), encoded within the National Trauma Data Bank from 2011 through 2014. Multiple imputation was used for missing data, and multivariable linear and logistic regression models were estimated.

RESULTS The authors included 12,031 cases of TSI, which represented 15% of all sports-related trauma. The majority of patients with TSI were male (82%), and the median age was 48 years (interquartile range 32–57 years). The most frequent mechanisms of injury in this database were cycling injuries (81%), skiing and snowboarding accidents (12%), aquatic sports injuries (3%), and contact sports (3%). Spinal surgery was required during initial hospitalization for 9.1% of patients with TSI.

Compared to non-TSI sports-related trauma, TSIs were associated with an average 2.3-day increase in length of stay (95% CI 2.1–2.4; p < 0.001) and discharge to or with rehabilitative services (adjusted OR 2.6, 95% CI 2.4–2.7; p < 0.001). Among sports injuries, TSIs were the cause of discharge to or with rehabilitative services in 32% of cases. SCI was present in 15% of cases with TSI. Within sports-related TSIs, the rate of SCI was 13% for cycling injuries compared to 41% and 49% for contact sports and aquatic sports injuries, respectively. Patients experiencing SCI had a longer length of stay (7.0 days longer; 95% CI 6.7–7.3) and a higher likelihood of adverse discharge disposition (adjusted OR 9.69, 95% CI 8.72–10.77) compared to patients with TSI but without SCI.

CONCLUSIONS Of patients with sports-related trauma discharged to rehabilitation, one-third had TSIs. Cycling injuries were the most common cause, suggesting that policies to make cycling safer may reduce TSI.

https://thejns.org/doi/abs/10.3171/2021.1.SPINE201860

KEYWORDS traumatic spinal injury; sports-related injury; traumatic spinal cord injury; trauma

TRAUMATIC spinal injuries (TSIs) in adults can result in significant morbidity and mortality. These acute injuries to the spinal cord and/or surrounding vertebral column have been estimated to occur globally at a rate of 10.5 cases per 100,000 persons annually based on a meta-analysis of multiple cohort studies.1 Neurological recovery depends not only on injury severity, but also on injury mechanism.2 TSIs in adults most commonly result from road accidents and falls.3 These mechanisms of injury are also most frequently implicated in the subset of TSIs that involve the spinal cord.4,4 In particular, the morbidity and mortality of TSIs resulting from motor vehicle accidents have already been characterized from multiple perspectives.5–9 However, comparatively little is known about the morbidity and mortality of sports-related TSIs.

Sports-related TSIs have recently been studied in the pediatric population.10 However, pediatric patients are thought to be more prone to cervical TSI than adults.11,12
Additionally, adult patients with TSI are less likely to recover than pediatric patients with TSI. As sports-related trauma increases in prevalence, it is important to understand the effect of TSI on morbidity and mortality in adult patients with sports-related trauma.

This study aims to determine the most common mechanisms of injury in adult sports-related TSI, the need for surgical intervention by mechanism of injury, and the clinical burden between TSI and non-TSI sports-related injuries to help guide clinical management and policy design.

Methods

Study Design

We used information from the prospectively collected and validated National Trauma Data Bank (NTDB) from the years 2011 through 2014 to conduct a nationwide, multicenter, retrospective cohort study. This database includes information regarding the initial hospitalization of patients presenting with traumatic injuries. The exposures of interest were TSI with and TSI without spinal cord involvement in adult patients whose trauma was precipitated by participating in any sports-related activity.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: 1) age at least 18 years at the time of injury; 2) an International Classification of Diseases, Ninth Revision (ICD-9) external cause of injury code corresponding to a sports-related injury; and 3) an ICD-9 diagnosis code for spinal fracture and/or cord injury (as shown in Appendix 1 and previous literature). Categories of sports-related injuries included cycling, contact sports, skiing/snowboarding, skateboarding/rollerblading, water sports/swimming, and other. Injuries to individuals struck by motorized vehicles while participating in a sports-related activity were included. However, injuries to individuals operating recreational motorized vehicles were not included. The contact sports category encompassed a variety of mechanisms of injury, including pushing, shoving, and physical contact with players or objects taking place in any sport, including American football and rugby.

Statistical Analysis

Our primary outcome of interest was discharge disposition, accounting for both the setting to which the patient was discharged and any requirement for rehabilitation. Discharge disposition categories included discharge home with no rehabilitation services, discharge home with rehabilitation services, discharge to a short- or long-term rehabilitation facility, and transfer to another inpatient hospital. We used this outcome measure as a proxy for the functional status at the time of discharge. We assumed that patients who required a hospital transfer probably required a higher level of care than could be provided at the initial facility and thus would require rehabilitation after discharge. We also evaluated secondary outcomes that included requirement for spinal surgery as defined by ICD-9 procedural codes for laminectomy and/or vertebral fracture repair, requirement for intensive care unit (ICU) admission, length of hospital stay, and death during the documented initial hospitalization.

We performed descriptive statistical analyses using t-tests for continuous variables and chi-square tests for categorical variables. We used multivariable logistic regression to generate adjusted odds ratios (aORs) characterizing the relationship between various spinal injuries and outcome measures. We also used multivariable linear regression for the analysis of continuous outcome variables. Both linear and logistic models were adjusted for the following variables: age (with linear and quadratic terms); sex; race; ethnicity; insurance type (including Medicare, Medicaid, other governmental plans, no-fault automobile, private/commercial insurance, self-pay, and other non-governmental plans); geographic region (Midwest, South, West, and Northeast); obesity; smoking; diabetes; steroid use; Glasgow Coma Scale score; hypotension (systolic blood pressure < 90 mm Hg) at presentation; concomitant nonspine injuries diagnosed in Abbreviated Injury Scale zones (categorized as head, face, neck, thoracic, abdominal, upper-extremity, and lower-extremity injuries); and ICD-9 coding for specific concomitant injuries. We aimed to account for the potential confounding effects of demographics, comorbidities, and injury severity. Covariate information was extracted from the NTDB. All statistical analyses were conducted using R version 3.3.3 (The R Project).

Missing Data

We used multiple imputation via the R “Amelia II” package. This package performs multiple ratio imputation via a bootstrapping algorithm in which expectation-maximization is used. We performed 10 iterations of the multiple imputation to construct 10 imputed data sets containing demographic information, clinical characteristics, procedures performed during the initial hospitalization, and disposition information. We generated all statistical estimates from pooling these 10 imputed data sets.

Results

Demographics

We included 80,040 cases of adult sports-related trauma, and 12,031 (15%) of these cases involved sports-related TSI (Table 1). Patients with sports-related TSI had a median age of 48 years (interquartile range [IQR] 32–57 years). This trended toward patients being slightly older than most adults presenting with any type of sports-related injury (median age 43 years, IQR 27–55 years). Patients with sports-related TSI were predominantly male (81.6%) and White (77.8%), which was comparable to the demographics of the full sports-related injury cohort. The plurality of patients with sports-related TSI had private insurance coverage (43%).

Mechanism of Injury

Among patients with sports-related TSI, the mechanisms of injury included cycling (80.9%), skiing/snowboarding (11.6%), water sports/swimming (2.9%), contact sports (2.8%), skateboarding/rollerblading (1.3%), and other (0.6%) (Fig. 1 upper). The prevalence of spinal cord injury (SCI) varied considerably across mechanisms of injury (Fig. 1 lower). Water sports/swimming (48.9%) and
contact sports (41.3%) had the highest prevalence of traumatic SCI (TSCI).

Overall, most sports-related TSIs could be traced back to motor vehicle accidents (81.0%) and falls (13.7%). Importantly, the individuals participating in sports-related activities were not operating the motor vehicles in question. This mirrored the overall breakdown of sports-related injuries among adults, with 75.6% attributable to motor vehicle accidents and 18.6% attributable to falls.

Clinical Characteristics at Presentation

Patients with TSI presented with TSCI in 14.9% of cases. Cervical spine fractures were the most common, occurring among 40.2% of patients with TSI. Thoracic (35.8%) and lumbar (29.4%) fractures were also fairly prevalent, with many patients presenting with fractures at multiple spinal levels (3.2%). Among all patients with TSI, cervical spine TSCI was also most prevalent (11.6%), followed by thoracic (2.5%) and lumbar (0.9%) SCI.

Among patients with sports-related TSI, concomitant traumatic brain injury (TBI; 38.5%) and lower-extremity (38.8%), thoracic (37.5%), and upper-extremity (37.1%) injuries were the most prevalent. The median Glasgow Coma Scale score of patients with sports-related TSI at presentation was 15 (IQR 15–15), and the median Injury Severity Score was 12 (IQR 8–18).

Hospital Course

On admission to the hospital, 9.1% (n = 1094) of patients with sports-related TSI required spinal surgery, defined as laminectomy and/or vertebral fracture repair. There was no significant difference in likelihood of undergoing spinal surgery as stratified by mechanism of injury in comparison to contact sports–related TSI (Fig. 2).

Male sex (aOR 1.37, 95% CI 1.15–1.64); obesity (aOR 1.58, 95% CI 1.14–2.22); and steroid use prior to admission to the hospital with TSI (aOR 5.53, 95% CI 1.72–17.72) were all associated with increased likelihood of undergoing spinal surgery during the initial hospitalization. Concomitant injuries were also associated with an increased likelihood of undergoing spinal surgery during the initial hospitalization. Concomitant injuries were also associated with an increased likelihood of spinal surgery, including neck injury (aOR 1.82, 95% CI 1.35–2.45) and thoracic injury (aOR 1.18, 95% CI 1.02–1.36). In contrast, upper-extremity injury (aOR 0.80, 95% CI 0.69–0.93); lower-extremity injury (aOR 0.74, 95% CI 0.64–0.85); and TBI (aOR 0.60, 95% CI 0.51–0.71) were all associated with reduced odds of undergoing spinal surgery during initial hospitalization.

Length of stay among patients with contact sports–related TSI (median 4 days, IQR 2–8 days) was greater than that of all patients with sports-related injuries (median 2 days, IQR 1–4 days). These differences were statistically significant in an adjusted model, in which patients with

| TABLE 1. Demographic data in patients with sports-related injuries |
|-----------------|-----------------|-----------------|
| Variable       | Total (N = 80,040) | TSI (n = 12,031) | Non-TSI (n = 68,009) |
|                | No. %            | No. %           | No. %            |
| Age in yrs, mean ± SD | 43 ± 27          | 55 ± 48         | 32 ± 57          |
| Sex            |                  |                 |                 |
| Male           | 63,425 79.2      | 9,817 81.6      | 53,608 78.8      |
| Female         | 16,575 20.7      | 2,211 18.4      | 14,364 21.1      |
| Unknown        | 40 0.05          | 3 0.02          | 37 0.1           |
| Race           |                  |                 |                 |
| White          | 59,787 74.7      | 9,366 77.8      | 50,421 74.1      |
| Black/African American | 6,416 8.0      | 867 7.2         | 5,549 8.2       |
| Asian          | 2,149 2.7        | 290 2.4         | 1,859 2.7       |
| American Indian| 412 0.5          | 41 0.3          | 371 0.5         |
| Pacific Islander | 180 0.2        | 22 0.2          | 158 0.2         |
| Other          | 7,442 9.3        | 886 7.4         | 6,556 9.6       |
| Unknown        | 3,654 4.6        | 559 4.6         | 3,095 4.6       |
| Insurance      |                  |                 |                 |
| Private/BCBS insurance | 34,670 43.3  | 5,217 43.4      | 29,453 43.3     |
| Medicare       | 6,790 8.5        | 1,069 8.9       | 5,721 8.4       |
| Medicaid       | 7,094 8.9        | 1,013 8.4       | 6,081 8.9       |
| Self-pay       | 13,466 16.8      | 1,589 13.2      | 11,877 17.5     |
| No-fault automobile | 4,522 5.6      | 1,043 8.7       | 3,479 5.1       |
| Other governmental plan | 2,851 3.6      | 430 3.6         | 2,421 3.6       |
| Other nongovernmental plan | 3,147 3.9    | 494 4.1         | 2,653 3.9       |
| Unknown        | 7,163 8.9        | 1,119 9.3       | 6,044 8.9       |

BCBS = Blue Cross Blue Shield.
The demographic breakdown between the cohort with sports-related TSI and that with overall sports-related trauma was similar in most respects.
sports-related TSI were likely to stay 2.3 days longer (95% CI 2.1–2.4) than patients with non-TSI sports-related injuries (Fig. 3). Additionally, patients with sports-related TSCI were likely to stay 7.0 days longer (95% CI 6.7–7.3) than patients with non-TSI sports-related injuries in the same adjusted model.

FIG. 1. Upper: Mechanisms of injury. The majority of adult sports-related TSIs were attributed to cycling-related injuries, with skiing/snowboarding, water sports/swimming, contact sports, skateboarding/rollerblading, and other mechanisms of injury also reflected in this cohort. Lower: SCI prevalence by mechanism of injury. Prevalence of TSCI among patients with sports-related TSI varied based on mechanism of injury. TSCIs were most prevalent in patients with water sports/swimming- and contact sports-related injuries. Figure is available in color online only.

In comparison to patients with non-TSI sports-related injuries, patients with sports-related TSI were significantly more likely to require ICU admission during their initial hospitalization (aOR 2.06, 95% CI 1.95–2.18) (Fig. 4). Overall, 17.1% of all patients with sports-related injuries experienced an adverse discharge disposition, as compared to 32.1% of patients with sports-related TSI. This was defined as transfer to another hospital, discharge to a rehabilitation facility, or discharge home with rehabilitative services. Patients with sports-related TSI were more likely to experience adverse discharge in an adjusted model (aOR 2.56, 95% CI 2.44–2.68) as well. Covariates associated with adverse discharge in the multivariable model included TBI (aOR 1.33, 95% CI 1.27–1.40); skull base fracture (aOR 2.48, 95% CI 2.31–2.66); abdominal injury (aOR 1.32, 95% CI 1.23–1.40); thoracic injury (aOR 1.32, 95% CI 1.26–1.38); lower-extremity injury (aOR 1.82, 95% CI 1.57–2.12); diabetes mellitus (aOR 1.36, 95% CI 1.24–1.49); and obesity (aOR 1.23, 95% CI 0.77–0.90); self-pay insurance coverage (aOR 0.64, 95% CI 0.58–0.69); upper-extremity injury (aOR 0.86, 95% CI 0.83–0.90); facial injury (aOR 0.86, 95% CI 0.82–0.90); and smoking (aOR 0.81, 95% CI 0.76–0.86) all appeared

FIG. 2. Odds of spinal surgery during initial hospitalization by mechanism of injury. There was no significant difference in the likelihood of undergoing spinal surgery, defined as laminectomy and/or vertebral fracture repair, during initial hospitalization as stratified by mechanism of injury. Patients with contact sports–related TSI were the reference group for this analysis.

FIG. 3. Length of stay. In an adjusted model, patients with sports-related TSI and TSCI had significantly longer hospital stays than patients with non-TSI sports-related injuries. Figure is available in color online only.

FIG. 4. Discharge disposition. Compared to patients with non-TSI sports-related injuries, patients with sports-related TSI were significantly more likely to require ICU admission, to experience adverse discharge, and to die or require hospice care during the initial hospital admission. D/C = discharge. Figure is available in color online only.
to be protective against adverse discharge in this analysis. Age, sex, race, geographic region, steroid use, and other insurance statuses were not significantly associated with adverse discharge.

Patients with sports-related TSI were also more likely to die during their initial hospitalization (aOR 1.46, 95% CI 1.64–1.84), although the prevalence of deaths overall was low, at 2.1% among patients with all sports-related injuries and 4.6% among patients with sports-related TSI.

Compared to patients with TSI, patients with TSCI were also significantly more likely to require ICU admission (aOR 5.14, 95% CI 4.50–5.87) as compared to patients with non-TSI sports-related injuries. Patients with TSCI were also more likely to experience adverse discharge (aOR 9.69, 95% CI 8.72–10.77) and death during initial hospitalization (aOR 4.23, 95% CI 3.45–5.18).

**Discussion**

TSI is a serious traumatic event that can negatively impact patient health and posthospitalization outcomes; trauma outcomes worsen with increased age. The number of reported TSIs in the adult population continues to increase annually within the United States.16–20 The average adult presenting with TSI between 2007 and 2009 was 50.4 years of age and predominantly male.19

Factors significantly associated with adverse discharge include serious concomitant injuries, such as skull base fracture and TBI, which present major challenges to patient recovery. Similarly, lower-extremity injury and obesity may limit patient mobility and increase the risk of venous thrombosis. The association of obesity with adverse discharge may also indicate that patients with a BMI ≥30 kg/m² are more likely to experience poor clinical outcomes.26,27 The prevalence of deaths during hospitalization in sports-related TSI was significantly higher than death in patients with all sports-related injuries. This may be attributed to the clinical characteristics of patients with sports-related TSI, given that location and type of injury impact patient outcome and the type of care that is needed. Patients with sports-related TSI were more likely to present with concomitant TBI and with lower-extremity, thoracic, and upper-extremity injuries; TBIs with concomitant injuries have been shown to be associated with higher mortality rates.24,25

The most common form of TSI in adults is vertebral fracture, which occurs most commonly in the cervical region.26,27 We show that while patients with TSI commonly present with cervical fractures, they also present with thoracic and lumbar fractures at similar rates. Understanding the mechanics that produce these injuries after impact can inform the type of protective gear needed for athletes participating in different sports.28–31

The prevalence of TSCI varied between sporting activities, with water sports and contact sports resulting in the highest prevalence of TSCI within this cohort. Previous studies have identified diving as the primary source of water sports–related injury, highlighting how the lack of protective equipment in this activity and related sports leaves patients more vulnerable to devastating neurological injury.16,32 Rugby has similarly been identified as a leading contributor to TSCI, and the relatively high frequency of diving and rugby-related TSCI holds across data from many different countries.33 Low public awareness regarding the risks inherent to these sports may also contribute to the high prevalence of sports-related TSIs, and existing interventions center on improving participant education.33 Current research on sports-related neurological trauma largely centers on high-contact sports such as football and rugby, leaving lower-contact sports understudied by comparison.1 These existing studies provide a model for implementing evidence-based interventions to prevent sports-related trauma—for instance, identifying dangerous head-first tackle techniques in football prompted new regulations prohibiting this behavior at a local and national level.32 Greater funding should be allocated to developing similar interventions for the sports identified in this study.

Notably, most sports-related TSIs were from motor vehicle–related cycling accidents in which the patient was not operating the vehicle (81.0%). Although many cities with a high volume of traffic acknowledge the importance of helmet safety and have initiated measures to curb motor vehicle–related cycling accidents, including protected bike lanes and helmet laws, there is still a clear disparity between policy and TSI occurrence.34–37 Previous studies reveal a discrepancy between bikers acknowledging the importance of helmet use versus actually choosing to wear helmets, which indicates that helmet advocacy initiatives might improve rates of helmet use.38,39 In conjunction with interventions such as improving bike lanes and educating motorists, helmet advocacy may help to reduce the incidence of cycling-related TSIs.

Falls were identified as the second-most common origin of sports-related TSIs. Although the cause of falls can vary drastically by sport, emphasis on proper technique and maintenance of sports-related surfaces such as roads and fields are two methods to alleviate the severity of falls.40

In addition to causing considerable morbidity among patients, TSI and TSCI in particular can result in tremendous financial burdens for patients and healthcare systems. During initial hospitalization, the cost of receiving treatment and of any required rehabilitative services is most immediate, costing patients on the order of $20,000–$30,000 per year according to published estimates, with variations depending on the nature of the injury and patient characteristics.41,42 However, indirect costs due to...
changes in employment status and lost earnings also merit consideration at both the individual and societal level, and can account for several million dollars over the lifetime of a single injured individual.43,44 These financial considerations provide another motivation for reducing sports-related TSI.

**Clinical Significance**

**Strengths**

Using the multicenter NTDB, we generated a large and diverse cohort of patients with TSI, lending generalizability to the trends reported here. The demographics of this study’s cohort—disproportionately male with an average age of 48 years—mirror those of the average adult patients with TSI in the general population. Although the conclusions of this study may not be generalizable to younger cohorts, they encapsulate the highest-risk population for TSI nationwide. These data can therefore augment evidence-based funding, advocacy, and patient care decision-making.

**Limitations**

Retrospectively analyzing an aggregated data set introduces several important limitations to our analysis. Although multiple imputation allows estimation of values for missing data, bias can be introduced if the causes of missing data are not considered in the imputation model. Inclusion in the NTDB requires initial hospitalization data, which necessarily excludes patients who die of their injuries before hospitalization can occur. As a result, our analysis of those sports-related TSIs that are immediately fatal introduces the possibility for bias. Compared with some other published studies, in our study the proportion of patients with TSI who were identified to have TSCI was considerably lower, although overestimation of TSCI in patients with TSI due to coding limitations has also been described previously.45,46 Previous studies also were not restricted to sports-related TSI, which may encompass a nonrepresentative subset of all patients presenting with TSI. Our approach, considering all ICD-9 codes for each patient entry in the NTDB, is consistent with previously published conservative approaches for estimating TSCI incidence.47 Finally, the retrospective examination of discharge disposition does not facilitate analysis of long-term prognosis and survival. In all, these limitations underscore the necessity for future prospective studies of patient outcomes after sports-related TSI.

**Conclusions**

In this study, we highlight the importance of preventing sports-related TSI in the adult population, and we also illustrate factors associated with adverse discharge and poor hospital disposition. Patients with sports-related TSI were significantly more likely to require ICU admission and to die during hospitalization, underscoring the devastating potential of such injuries to patient health. Cycling injuries comprised the majority of sports-related TSIs; improving policies and education regarding cyclist safety would probably prove to be effective interventions.

**Acknowledgments**

We acknowledge support from the following grants: National Institute of General Medical Sciences T32 GM007753 (B.M.H.) and National Institutes of Health T32 CA009001 (D.J.C.).

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Disclosures
Dr. Chi is a consultant for K2M and received clinical or research support from Spineology for the study described. Dr. Groff is a consultant for DePuy Spine, NuVasive Spine, and SpineArt.

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Supplemental Information
Online-Only Content
Supplemental material is available with the online version of the article.

Previous Presentations
These findings were presented in poster form at the CNS 2019 Annual Meeting in San Francisco, CA, and in oral presentation format at the New England Neurosurgical Society 2019 Annual Meeting in Brewer, MA.

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