Acute Vertebral Fractures in Skiing and Snowboarding

A 20-Year Sex-Specific Analysis of National Injury Data

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Background: The epidemiology of acute vertebral fractures (AVFs) sustained while skiing and snowboarding remains poorly defined in the United States.

Hypothesis: It was hypothesized that there would be no significant differences across sex and a greater number of AVFs in younger age groups associated with skiing and snowboarding.

Study Design: Descriptive epidemiological study.

Methods: The authors utilized the National Electronic Injury Surveillance System to identify patients who were reported in emergency departments in the United States from 2000 to 2019. All patients were noted to have sustained AVFs during skiing or snowboarding. National estimates and demographic analysis were performed.

Results: A total of 466 AVFs were identified, or roughly 23.3 AVFs per year. Compared with women, men accounted for the majority of AVFs sustained in both skiing and snowboarding: 67.8% (95% CI, 62.6%-73.0%) during skiing and 82.1% (95% CI, 76.3%-87.8%) during snowboarding. This represented a significantly larger percentage of AVFs while snowboarding compared with skiing (P = .002). Women accounted for 32.2% (95% CI, 27.0%-37.4%) of AVFs while skiing and 17.9% (95% CI, 12.2%-23.7%) while snowboarding, which indicated a significantly larger percentage of AVFs sustained during skiing compared with snowboarding (P = .002). Snowboarders were more likely than skiers to sustain an AVF in the region of the coccyx (21.5% [95% CI, 14.3%-28.7%] vs 11.5% [95% CI, 3.5%-16.9%], respectively; P = .003) and as a result of a fall at ground level (69.2% [95% CI, 62.1%-76.4%] vs 52.8% [95% CI, 43.2%-62.4%], respectively; P = .009). A significant decrease in the number of snowboarding-related AVFs was identified over the 20-year study period: 899 in 2000-2003 versus 283 in 2016-2019 (P < .01). The change in skiing-related AVFs over the study period was not statistically significant (694 vs 462; P = .5).

Conclusion: This national study of AVFs sustained while skiing and snowboarding identified critical sex- and age-specific differences in the population at risk, anatomic location of injury, and mechanism of injury. The national data generated from this study over a 20-year period may be utilized to better inform public health injury awareness and prevention initiatives in the rapidly growing sports of skiing and snowboarding.

Keywords: skiing; snowboarding; vertebral fracture; sports medicine; trauma

Skiing and snowboarding are 2 popular winter recreational and sporting activities enjoyed by individuals across a wide range of age groups and skill levels. For the 2020-2021 season in the United States, an estimated 10.5 million people participated in recreational skiing or snowboarding activities at US resorts, an increase of 26% over the past 10 years.14 Both skiing and snowboarding involve the navigation of irregular terrain at high speeds, exposing skiers and snowboarders to significant injury risk. A previous study found that the majority of skiing- and snowboarding-related injuries occur in men, typically the result of simple falls.28 Although spinal injuries account for a low burden of skiing- and snowboarding-related injuries (1%-14%), spinal injuries represent 29% of severe injuries in skiers and snowboarders (Injury Severity Score >15).9

Although acute vertebral fractures (AVFs) appear to be relatively common, as an estimated 15.1% and 23.0% of skiing and snowboarding injuries reported in emergency departments (EDs) near ski resorts, respectively, the true epidemiology of these critical injuries has been poorly defined across the United States over the past 2 decades.3,27 A systematic review by Bigdon et al26 evaluated the characteristics of spinal injuries in alpine sports but was limited mostly to studies with small sample sizes and variable...
Methods

We retrospectively identified cases of AVFs associated with skiing and snowboarding in the National Electronic Injury Surveillance System (NEISS), operated by the US Consumer Product Safety Commission (CPSC; http://www.cpsc.gov/Research–Statistics/NEISS-Injury-Data). The NEISS database documents product- or activity-related injuries reporting to US EDs. The database is a publicly available, de-identified, weighted survey that serves as a nationally representative probability sample of designated US hospital EDs with adequate geographic distribution and stratifications for hospital size and geographic location, from which weighted national estimates and sampling errors for queries may be derived. Available data include patient age, date of ED visit, sex, race, anatomic location of injury, diagnoses, associated consumer products, and a short narrative description of events leading up to the injury. Since its inception, the database has been used for a multitude of reliable, reproducible epidemiological studies on injury-related ED visits.21,26 Specific data collection methodologies and quality control precautions are available on the CPSC website.7,19

This study was exempt from institutional review board review because our analysis used de-identified survey data that are freely published and publicly accessible on a government website.

Selection Criteria

We initially identified all patients evaluated at a US ED between 2000 and 2019 with any injury associated with either skiing (product code 3283, “snow skiing [activity, apparel, or equipment]”) or snowboarding (product code 5031, “snowboarding [activity, apparel, or equipment]”). This necessarily excluded injuries associated with water skiing or jet skiing. In all, we identified 40,019 raw survey sample cases in the NEISS database of injuries associated with skiing or snowboarding, which amounted to 1,825,887 national weighted estimates of such injuries during the study period.

We limited our analyses only to cases in which patients were diagnosed in the ED with one or more AVFs by applying Microsoft Excel formulæ to the narrative sections of each unique survey entry. The formulæ searched narratives of cases coded as fractures (diagnosis code 57) for explicit mentions of AVFs (ie, anywhere from C1 to S5, including the coccyx). Formulae additionally searched for specific vertebral regions (ie, cervical, thoracic, lumbar, sacral, coccygeal) and included hyphenated (eg, “C-1” vs “C1”), abbreviated (eg, “T-spine” or “L-spine”), and commonly misspelled (eg, “vertebral”) variants of these phrases. If no vertebral region was specified, the body regions coded in the NEISS database were used to make the designation (eg, “neck” corresponded with “cervical,” “upper trunk” corresponded with “thoracic”). Using these criteria, we identified 573 unique cases in the NEISS database during the study period, which amounted to 26,332 weighted national estimates of patients of any age evaluated at US EDs with AVFs between 2000 and 2019 associated with skiing and snowboarding.

Each of these 573 raw survey sample cases was individually read and reviewed to ensure that participation in skiing or snowboarding was directly related to the injury event; 107 raw survey sample cases were excluded from our analysis because the injury did not truly involve an activity-related injury (ie, patient used a plastic lid as a snowboard in his or her driveway or was injured while storing winter apparel in their attic). Thus, 466 raw survey sample cases were included for final analysis, amounting to 21,076 total weighted national estimates of patients evaluated at US EDs with AVFs related to skiing or snowboarding.
snowboarding during the study period. Finally, the mechanism of injury for each of these 466 cases was designated by individually reviewing these remaining case narratives. Mechanisms were categorized as related to striking an object (ie, tree, pole, or building) or person, falling from ground height, falling from height because of a jumping failure in which the patient was airborne, or falling from a chair lift.

Statistical Analyses

All national weighted estimates, standard errors (SEs), simple univariate regression statistics, and 95% confidence intervals (CIs) were calculated by using the \texttt{svyset} function in Stata/IC 15.1 statistical software (StataCorp LLC). Significances of trends and group comparisons were determined using adjusted Wald tests, given the use of weighted survey data.

RESULTS

Figure 1 depicts the average annual number of AVFs associated with skiing and snowboarding that were reported in US emergency departments, 2000-2019. Data were stratified into 4-year time periods.

Figure 1. Average annual number of vertebral fractures associated with skiing and snowboarding that were reported in US emergency departments, 2000-2019. Data were stratified into 4-year time periods.

The injury characteristics of the NEISS cohort are shown in Table 2. AVFs most commonly occurred at the lumbosacral level for both skiing and snowboarding. Subanalyses on anatomic location of injury revealed that AVFs sustained while snowboarding were significantly more likely to occur at the level of the coccyx compared with those sustained while skiing (skiing, 11.5%; snowboarding, 21.5%; \(P = .003\)). Subanalyses on mechanism of injury revealed that a higher percentage of AVFs associated with skiing were caused by striking an object or person (skiing, 17.6%; snowboarding, 9.7%; \(P < .001\)), whereas a higher percentage of AVFs associated with snowboarding occurred from falls at ground level (skiing, 52.8%; snowboarding, 69.2%; \(P = .009\)).

DISCUSSION

This study revealed that women were more likely to sustain an AVF associated with skiing, while men were more likely to sustain an AVF when snowboarding. Additionally, our findings revealed 2 significant differences in anatomic
Ball et al and Bigdon et al identified failed jumps as the leading mechanism of injury to be falls from ground level. However, these previous studies included nonfracture spinal cord injuries, in addition to vertebral fractures, and included patients from international resorts that may vary in safety regulations and slope design compared with skiing and snowboarding sites in the United States. 

The sex-based differences in AVFs between skiing and snowboarding are likely multifactorial. The Snowsports Industries America Participation Study provides the most comprehensive report of skiers and snowboarders subdivided by sex, and proportions of male and female skiers and snowboarders have stayed relatively constant over our study period. The national percentage of male skiers in 2019-2020 (61.0%-66.4%) is similar to the percentage of male skiers we identified as having sustained an AVF (62.6%-73.0%). However, the national percentage of male snowboarders in 2019-2020 (66.0%-72.2%) is lower than the percentage of male snowboarders we identified as having sustained an AVF (76.3%-87.8%). The literature suggests that male snowboarders tend to ride at higher speeds than female snowboarders, which may contribute to the disproportionate burden of men sustaining AVFs while snowboarding. Men may also be more likely to engage in risk-taking behaviors that may contribute to injury, such as jumps or stunts while snowboarding. Additionally, women comprised only 27.8% of those who snowboarded at least 7 times in the 2019-2020 season. 

The difference in injury mechanisms between snowboarding and skiing is also likely multifactorial and not completely understood. However, snowboarders may be more prone to AVFs at the level of the coccyx based on their pattern of fall. Studies by Steenstrup et al analyzing crash sequence videos of skiers and snowboarders and studies by Nakaguchi and Tsutsumi evaluating skiing and snowboarding crashes found that snowboarders tend to fall backward, while skiers tend to fall forward. Falling backward can lead to more axial loading through the spine, resulting in anterior compression

| Variable | Skiing | Snowboarding | P |
|----------|--------|--------------|---|
| Sex      |        |              |   |
| Male     | 67.8   | 62.6-73.0    | 82.1 76.3-87.8 | .002 |
| Female   | 32.2   | 27.0-37.4    | 17.9 12.2-23.7 | .002 |

| Age group, y |        |              |   |
| <18          | 23.6    | 15.4-31.7    | 23.5 17.4-29.5 | .995 |
| 18-64        | 69.7    | 62.6-76.7    | 76.5 70.5-82.6 | .037 |
| ≥65          | 6.8     | 0.0          |              |   |

| Reported race |        |              |   |
| White        | 81.2    | 71.3-91.1    | 78.1 67.8-88.3 | .293 |
| Black        | 0.0     | 0.0          |              |   |
| Other        | 4.9     | 2.9          |              |   |
| Unspecified  | 13.4    | 18.0         |              |   |

| Injury disposition |        |              |   |
| Treated and released | 45.5    | 33.6-57.3    | 69.4 60.6-78.3 | <.001 |
| Treated and transferred | 16.3    | 11.9-20.7    | 11.2 3.9-17.6 | .075 |
| Treated and admitted | 34.5    | 16.8-52.3    | 18.3 10.7-26.0 | .018 |
| Other          | 3.6     | 1.5          |              |   |

**TABLE 1**

**Characteristics of Patients Reporting to US Emergency Departments With Vertebral Fractures Associated With Skiing and Snowboarding, 2000-2019**

| Injury Variable |        |              |   |
| Vertebral region |        |              |   |
| Cervical | 19.0    | 13.4-24.5    | 13.7 9.1-18.3 | .182 |
| Thoracic | 37.4    | 28.5-46.4    | 31.1 24.7-37.5 | .116 |
| Lumbar | 43.4    | 36.3-50.5    | 44.2 36.0-52.4 | .892 |
| Coccyx | 11.5    | 3.5-16.9     | 21.5 14.3-28.7 | .003 |
| Unspecified | 0.8     | 0.0          |              |   |

| Mechanism of injury |        |              |   |
| Struck object or person | 17.6    | 12.1-23.2    | 9.7  <.001 |
| Fall (ground level) | 52.8    | 43.2-62.4    | 69.2 62.1-76.4 | .009 |
| Fall from height (jumps) | 21.9    | 10.0-33.7    | 20.9 16.6-25.2 | .884 |

**TABLE 2**

**Injury Characteristics of Patients Reporting to US Emergency Departments With Vertebral Fractures Associated With Skiing and Snowboarding, 2000-2019**

*aBoldface P values indicate a statistically significant difference between groups (P < .05).*

*bCategory percentages sum to >100% because patients may have injured multiple vertebral regions.

The estimate is considered to be potentially unstable because of the number of unweighted cases from the sample frame totaling <20, the weighted national estimate totaling <1200, or a coefficient of variation >33%. Therefore, no standard errors or CIs are provided; the unstable percentage estimate is provided for reference purposes only. Variable results with sample frame totals <20 cases or percentages <0.1% were omitted from this table, resulting in percentage totals not necessarily summing to 100%.
fractures in snowboarders. Additionally, given that the average age of snowboarders is less than that of skiers, young snowboarders may also demonstrate better reaction times than older skiers. Furthermore, skiers may be more likely to strike a person or object because of the relative popularity of the sport compared with snowboarding. With around 3 times as many skiers in the United States as snowboarders, the increased density of skiers likely contributes to this particular mechanism of injury. Given that our study demonstrated similar levels of AVFs in skiing and snowboarding, the higher numbers of skiers suggest a much higher injury risk in snowboarding compared with skiing.

The observed decline in AVFs from snowboarding over this study’s time period is not well defined. Snowboarding was banned at many ski resorts until the 1980s because of safety concerns for skiers. As snowboarding has increased in popularity, factors such as higher skill levels of participants, better policing over aggressive behaviors, and increased safety measures by ski resorts have likely led to a decrease in AVFs associated with snowboarding. Campaigns such as “Lids on Kids” led to a more than 1000% increase in helmet use in snow sports from 1995 to 2012, with a decreased incidence in head injuries over that time period, demonstrating an increased focus on promoting safety in snow sports. Another study identified a similar trend of decreased snowboarding injuries relative to skiing injuries without a clear mechanism, but it has been postulated that increased safety has played a role. The use of spinal protection devices has been controversial, with 1 study demonstrating that these devices do not confer protection against the most common mechanism of injury. The number of patients with AVFs from skiing and snowboarding who were treated and released suggests that many sustained “minor” AVFs. The classification of fracture type is not available with the NEISS database, but the fractures not requiring surgical treatment at presentation may be transverse process fractures, minor compression fractures, coccyx fractures, or other more minor fracture types.

Several recommendations may be considered to reduce the number of AVFs sustained while skiing and snowboarding. To combat the underestimation of speed obtained by both skiers and snowboarders contributing to AVFs, trails with increased difficulty (black diamond) and increased verticality could include more information on speed self-awareness as a preventative measure. Limiting the number of skiers and snowboarders on a particular section of the mountain at a given time and deliberate slope design could avoid overcrowding, thus decreasing the incidence of collisions leading to AVFs. Given the relationship between osteoporosis and vertebral fractures, it may prove beneficial to increase osteoporosis awareness and related public health initiatives near snow resorts and design future studies analyzing the effect of osteoporosis and osteopenia and subsequent impact of improving bone health in these populations.

Limitations

Given that this study utilized a national database, several inherent limitations exist. The NEISS database only captures injuries evaluated at US EDs; thus, AVFs associated with skiing and snowboarding are likely underrepresented in this analysis. Long-term and follow-up data are not available within the NEISS database, such as subsequent surgical intervention, neurologic injury, and related costs and outcomes. Geographic bias is possible if the sample of participating hospitals misrepresents the proportion of EDs close to areas of winter sports. Furthermore, the NEISS database does not allow for the querying of data related to product and equipment details, which could be useful in the identification of specific types of equipment, or the lack thereof, contributing to AVFs. Data are also limited regarding the overall percentages of male and female skiers and snowboarders over time, restricting our analysis of sex between the 2 sports. The analysis by age was limited given the statistical instability of the estimates if groups were divided further. Finally, skiing data could not be further classified into subtypes such as alpine or cross-country, and there is no information available on conditions that could have contributed to injury, such as snow conditions, difficulty of terrain, or number of skiers and snowboarders on a given day.

CONCLUSION

This national study of AVFs sustained while skiing and snowboarding identifies critical sex- and age-specific differences in the population at risk, anatomic location of injury, and mechanism of injury. The national data generated from this study over a 20-year period may be utilized to better inform public health injury awareness and prevention initiatives in the rapidly growing sports of skiing and snowboarding.

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