

Acute Vertebral Fractures in Skiing and Snowboarding

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

William H. Huffman,^{*†} BS, Lori Jia,[†] BS, Kevin Pirruccio,[‡] MD, Xinning Li,[§] MD, Andrew C. Hecht,^{||} MD, and Robert L. Parisien,^{||} MD

Investigation performed at University of Pennsylvania, Philadelphia, Pennsylvania, USA

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 al³ evaluated the characteristics of spinal injuries in alpine sports but was limited mostly to studies with small sample sizes and variable

The Orthopaedic Journal of Sports Medicine, 10(7), 23259671221105486
DOI: 10.1177/23259671221105486
© The Author(s) 2022

This open-access article is published and distributed under the Creative Commons Attribution - NonCommercial - No Derivatives License (<https://creativecommons.org/licenses/by-nc-nd/4.0/>), which permits the noncommercial use, distribution, and reproduction of the article in any medium, provided the original author and source are credited. You may not alter, transform, or build upon this article without the permission of the Author(s). For article reuse guidelines, please visit SAGE's website at <http://www.sagepub.com/journals-permissions>.

time periods. Similarly, Xiang et al²⁸ evaluated skiing- and snowboarding-related injuries in the United States but only for the year 2002. Other studies have attempted to provide estimates of AVFs for skiing and snowboarding, but these studies have consisted of single institutions with limited time periods.^{6,12,27} There has yet to be a comprehensive national evaluation of AVFs associated with skiing and snowboarding in the United States. A better understanding of the epidemiology and characteristics of this particular injury pattern may allow for improved strategies to mitigate the prevalence of AVFs in the greater than 9 million skiers and snowboarders in the United States.²⁰

The purpose of this study was to provide a comprehensive national estimate of patients who were reported in US EDs between 2000 and 2019 with AVFs associated with skiing and snowboarding. We hypothesized that there would be no significant difference in the prevalence and incidence of skiing-versus snowboarding-related AVFs across sex, while we hypothesized there would be an increased prevalence and incidence of AVFs in younger age groups.

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 formulae to the narrative sections of each unique survey entry. The formulae 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, “vertebrel”) 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 amount 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

*Address correspondence to William H. Huffman, BS, Perelman School of Medicine, University of Pennsylvania, 3400 Spruce Street, Philadelphia, PA 19104, USA (email: williamhuffman24@gmail.com).

[†]Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania, USA.

[‡]Department of Orthopaedic Surgery, Yale-New Haven Hospital, New Haven, Connecticut, USA.

[§]Boston University Medical Center, Boston, Massachusetts, USA.

^{||}Department of Orthopaedic Surgery, Mount Sinai, New York, New York, USA.

Final revision submitted March 14, 2022; accepted March 23, 2022.

One or more of the authors has declared the following potential conflict of interest or source of funding: X.L. has received consulting fees from DePuy and Orthopedics and honoraria from Wright Medical. A.C.H. has received consulting fees from Atlas Spines and Medtronic, speaking fees from Medtronic, and royalties from Atlas Spines and Zimmer Biomet. R.L.P. has received grant support and education payments from Arthrex. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval was not sought for the present study.

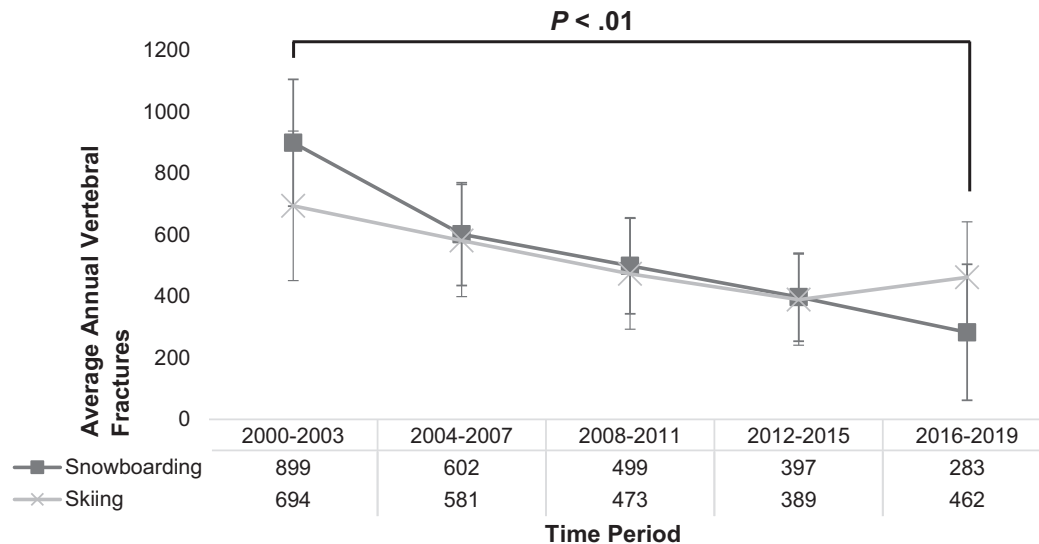


Figure 1. Average annual number of vertebral fractures associated with skiing and snowboarding that were reported in US emergency departments, 2000-2019. Data were stratified into 4-year time periods.

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 *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 or snowboarding injuries that were reported in US EDs from 2000 to 2019. The data are stratified into 4-year periods. Overall, there were no significant differences in the number of patients with AVFs associated with either skiing or snowboarding between each preceding or consequent 4-year time period. However, between the first time period (2000-2003) and the final time period (2016-2019), there was a statistically significant overall decrease in the number of AVFs associated with snowboarding (899 vs 283, respectively), with a corresponding *P* value less than .01. Comparing the 2 sports, the estimated numbers of AVFs were fairly similar, and the annual estimates between 2004 and 2015 were within 25 injuries per year.

The demographic characteristics of the study cohort are shown in Table 1. The majority of patients were men for

both sports. Women comprised 32.2% of patients with AVFs from skiing and 17.9% of patients with AVFs from snowboarding, which was a significant difference across the 2 sports (*P* = .002). Men comprised 67.8% of patients with AVFs from skiing and 82.1% of patients with AVFs from snowboarding, which was also a significant difference across the 2 sports (*P* = .002). Individuals 18 to 64 years of age represented the majority of AVFs in both sports and were more likely to be evaluated with an AVF from snowboarding compared with skiing (skiing, 69.7%; snowboarding, 76.5%; *P* = .037). The majority of snowboarders sustaining an AVF were treated and released from the ED (69.4%), whereas athletes sustaining an AVF from skiing were more likely to be admitted to the hospital (34.5%) or transferred to another facility (16.3%).

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

TABLE 1

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

Variable ^b	Skiing		Snowboarding		P
	%	95% CI	%	95% CI	
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 ^c	6.8		0.0		
Reported race					
White	81.2	71.3-91.1	78.1	67.8-88.3	.293
Black ^c	0.0		1.0		
Other ^c	5.4		2.9		
Unspecified ^c	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 ^c	3.6		1.5		

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

^bVariable 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%.

^cThe 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.

location of injury and mechanism of injury. Snowboarders had a higher proportion of coccygeal fractures and were significantly more likely to be evaluated with an AVF after falling from ground level, while skiers were more likely to be evaluated with an AVF after striking an object or person.

Our results are consistent with existing literature identifying the lumbar region as the most common site of AVFs among skiing and snowboarding injuries.^{1,3,11} Whereas Ball et al¹ and Bigdon et al³ identified failed jumps as the leading mechanism for snowboarding spinal injuries, our study found 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

TABLE 2

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

Injury Variable	Skiing		Snowboarding		P
	%	95% CI	%	95% CI	
Vertebral region ^b					
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
Lumbosacral	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 ^c	0.8		0.0		
Mechanism of injury					
Struck object or person ^c	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
Fall from chair lift ^c	7.7		0.2		

^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.

^cThe 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%.

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%).² 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%).² 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.⁴ Men may also be more likely to engage in risk-taking behaviors that may contribute to injury, such as jumps or stunts while snowboarding.¹⁵ Additionally, women comprised only 27.8% of those who snowboarded at least 7 times in the 2019-2020 season.²

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 al²⁵ analyzing crash sequence videos of skiers and snowboarders and studies by Nakaguchi and Tsutsumi¹⁸ 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

fractures in snowboarders.¹⁶ 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.^{10,13,29} 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.¹⁷ 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.^{8,24} 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.²² 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.³

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.^{4,5} 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.¹⁶ 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.²³

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.

REFERENCES

- Ball JR, Harris CB, Lee J, Vives MJ. Lumbar spine injuries in sports: review of the literature and current treatment recommendations. *Sports Med Open*. 2019;5(1):26. doi:10.1186/s40798-019-0199-7
- Barker A. SIA participation study 2019-2020. Published online 2020. Accessed May 31, 2022. <https://members.snowsports.org/research-center/>
- Bigdon SF, Gewiess J, Hoppe S, et al. Spinal injury in alpine winter sports: a review. *Scand J Trauma Resusc Emerg Med*. 2019;27(1):69. doi:10.1186/s13049-019-0645-z
- Carus L, Castillo I. Injury prevention: individual factors affecting adult recreational snowboarders' actual and estimated speeds on regular slopes. *PLoS One*. 2021;16(2):e0246931. doi:10.1371/journal.pone.0246931
- Carus L, Castillo I. Managing risk in ski resorts: environmental factors affecting actual and estimated speed on signposted groomed slopes in a cohort of adult recreational alpine skiers. *PLoS One*. 2021;16(8):e0256349. doi:10.1371/journal.pone.0256349
- Corra S, Girardi P, de Giorgi F, Braggion M. Severe and polytraumatic injuries among recreational skiers and snowboarders: incidence, demographics and injury patterns in South Tyrol. *Eur J Emerg Med*. 2012;19(2):69-72. doi:10.1097/MEJ.0b013e328347c1e9
- CPSC NEISS On-Line Query System. US Consumer Product Safety Commission. Accessed October 19, 2021. <https://www.cpsc.gov/cgibin/NEISSQuery/home.aspx>
- Davey A, Endres NK, Johnson RJ, Shealy JE. Alpine skiing injuries. *Sports Health*. 2019;11(1):18-26. doi:10.1177/1941738118813051

9. de Roulet A, Inaba K, Strumwasser A, et al. Severe injuries associated with skiing and snowboarding: a national trauma data bank study. *J Trauma Acute Care Surg.* 2017;82(4):781-786. doi:10.1097/TA.0000000000001358
10. Franz T, Hasler RM, Benneker L, Zimmermann H, Siebenrock KA, Exadaktylos AK. Severe spinal injuries in alpine skiing and snowboarding: a 6-year review of a tertiary trauma centre for the Bernese Alps ski resorts, Switzerland. *Br J Sports Med.* 2008;42(1):55-58. doi:10.1136/bjsm.2007.038166
11. Gertzbein SD, Khoury D, Bullington A, St John TA, Larson AI. Thoracic and lumbar fractures associated with skiing and snowboarding injuries according to the AO Comprehensive Classification. *Am J Sports Med.* 2012;40(8):1750-1754. doi:10.1177/0363546512449814
12. Hosaka N, Arai K, Otsuka H, Kishimoto H. Incidence of recreational snowboarding-related spinal injuries over an 11-year period at a ski resort in Niigata, Japan. *BMJ Open Sport Exerc Med.* 2020;6(1):e000742. doi:10.1136/bmjsem-2020-000742
13. Hubbard ME, Jewell RP, Dumont TM, Rughani AI. Spinal injury patterns among skiers and snowboarders. *Neurosurg Focus.* 2011;31(5):E8. doi:10.3171/2011.8.FOCUS11179
14. Industry Stats. National Ski Area Association. Accessed October 19, 2021. https://www.nsaa.org/NSAA/Resources/Industry_Stats/NSAA/Media/Industry_Stats.aspx?hkey=8247ed3b-e20e-46d2-9c5d-36b92782c297
15. Johnson RJ. *Skiing Trauma and Safety.* Vol 13. ASTM International; 2000.
16. Kary JM. Acute spine injuries in skiers and snowboarders. *Curr Sports Med Rep.* 2008;7(1):35-38. doi:10.1097/01.CSMR.0000308670.07441.4f
17. Meyers S. Meyers: Colorado ski resorts used to ban snowboarding, too. *The Coloradoan.* Accessed February 20, 2022. <https://www.coloradoan.com/story/news/2014/04/02/meyers-colorado-ski-resorts-used-to-ban-snowboarding-too-/7223643/>
18. Nakaguchi H, Tsutsumi K. Mechanisms of snowboarding-related severe head injury: shear strain induced by the opposite-edge phenomenon. *J Neurosurg.* 2002;97(3):542-548. doi:10.3171/jns.2002.97.3.0542
19. National Electronic Injury Surveillance System (NEISS). US Consumer Product Safety Commission. Accessed October 19, 2021. <https://www.cpsc.gov/Research-Statistics/NEISS-Injury-Data>
20. Number of active skiers & snowboarders in the United States from 1996 to 2018. Statista. Accessed October 7, 2021. <https://www.statista.com/statistics/376710/active-skiers-and-snowboarders-in-the-us/>
21. Pirruccio K, Yoon YM, Ahn J. Fractures in elderly Americans associated with walking leashed dogs. *JAMA Surg.* 2019;154(5):458-459. doi:10.1001/jamasurg.2019.0061
22. Polites SF, Mao SA, Glasgow AE, Moir CR, Habermann EB. Safety on the slopes: ski versus snowboard injuries in children treated at United States trauma centers. *J Pediatr Surg.* 2018;53(5):1024-1027. doi:10.1016/j.jpedsurg.2018.02.044
23. Salari N, Ghasemi H, Mohammadi L, et al. The global prevalence of osteoporosis in the world: a comprehensive systematic review and meta-analysis. *J Orthop Surg Res.* 2021;16(1):609. doi:10.1186/s13018-021-02772-0
24. Shealy J, Johnson R, Ettlinger C, Scher I. Role of helmets in mitigation of head injuries: epidemiologic study of head injuries to skiers. ASTM International symposia paper STP158220140079. Published July 30, 2015. Accessed February 20, 2022. <https://www.astm.org/stp158220140079.html>
25. Steenstrup SE, Bakken A, Bere T, Patton DA, Bahr R. Head injury mechanisms in FIS World Cup alpine and freestyle skiers and snowboarders. *Br J Sports Med.* 2018;52(1):61-69. doi:10.1136/bjsports-2017-098240
26. Stoneback JW, Owens BD, Sykes J, Athwal GS, Pointer L, Wolf JM. Incidence of elbow dislocations in the United States population. *J Bone Joint Surg Am.* 2012;94(3):240-245. doi:10.2106/JBJS.J.01663
27. Wasden CC, McIntosh SE, Keith DS, McCowan C. An analysis of skiing and snowboarding injuries on Utah slopes. *J Trauma.* 2009;67(5):1022-1026. doi:10.1097/TA.0b013e3181b0d559
28. Xiang H, Kelleher K, Shields BJ, Brown KJ, Smith GA. Skiing- and snowboarding-related injuries treated in U.S. emergency departments, 2002. *J Trauma.* 2005;58(1):112-118. doi:10.1097/01.ta.0000151270.26634.dd
29. Yamakawa H, Murase S, Sakai H, et al. Spinal injuries in snowboarders: risk of jumping as an integral part of snowboarding. *J Trauma.* 2001;50(6):1101-1105. doi:10.1097/00005373-200106000-00020