Original Article

Pediatric Snowboarding-Related Concussions and Musculoskeletal Injuries Decreased From 2012 to 2022

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Purpose: To analyze mechanisms, diagnoses, and incidence of youth snowboarding-related injuries presenting to US emergency departments. **Methods:** Data from the National Electronic Injury Surveillance System were analyzed for pediatric snowboarding injuries (≤18 years old) from 2012 to 2022. Data were collected for mechanism of injury, diagnosis, location of injury, and disposition. National estimates (NEs) were calculated using the statistical sample weight of the corresponding hospital assigned by the National Electronic Injury Surveillance System. Linear regressions were used to analyze injuries over time. **Results:** In total, 3,036 (NEs = 120,140) pediatric snowboarding injuries were included in this study. Average age was 14.0 ± 2.7 years. The most common mechanism of injury was impact with the ground (NEs = 97,120, 80.8%). The most injured body parts were 719 wrists (NEs = 115,505, 96.1%), 580 heads (NEs = 22,258, 18.5%), and 381 shoulders (NEs = 17,269, 14.4%). The most common diagnoses were fractures (NEs = 48,886, 40.7%), strains/sprains (NEs = 22,948, 19.1%), and concussions (NEs = 12,553, 10.4%). Fractures primarily involved the wrist (NEs = 18,122, 37.1%), lower arm (NEs = 12,348, 25.3%), and shoulder (NEs = 9,073, 18.6%). From 2012 to 2022, there were average decreases of 1,051 overall injuries per year ($P < .01$), 299 fractures per year ($P = .04$), 298 strains/sprains per year ($P < .01$), and 143 concussions per year ($P < .01$). There were average decreases of 784 impact with ground injuries per year ($P < .01$), 161 not specified injuries per year ($P < .01$), and 42 impact with inanimate object injuries per year ($P = .03$) from 2012 to 2022. **Conclusions:** Pediatric snowboarding injuries demonstrated a large decline from 2012 to 2022. Fractures are the most common diagnosis, primarily affecting the wrist and shoulder. The head was the second most injured body part, and concussions were the third most common diagnosis. **Clinical Relevance:** This study highlights decreasing injuries despite growing popularity of snowboarding, bringing to light the importance of protective equipment, on-site injury management, and implementation of clinics at resort bases.

Snowboarding is a popular sport, garnering participants from a wide range of ages and skill levels. Global interest in snowboarding as both a professional and a recreational sport has increased over the past several decades following introduction as an official winter sport in the 1998 Tokyo Olympic Games. In the United States, there has been a steady increase in snowboarders of all levels from 6.42 million in 2013 to 7.96 million in 2021.[1]

Considering the increasing popularity of snowboarding, numerous studies in recent years have investigated injuries. Although the current literature includes participants of all ages, snowboarding remains a youth-dominated sport, with up to 80% of snowboarders beginning prior to the age of 12 years and the typical snowboarder in their late teens or early 20s.[2,3] Pediatric snowboarders constitute 60% of overall injuries, which is likely attributed to lack of experience and underdeveloped physiology, leading to a higher propensity to fall.[2,4-9] However, the treatment of pediatric snowboarding injuries in an orthopaedic setting is not well understood.[8-13]

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The National Electronic Injury Surveillance System (NEISS) provides data on injuries presenting to US emergency departments (EDs) and has been used to analyze injuries in youth sports.[14-17] Currently, there are few NEISS studies analyzing snowboarding-related injuries and no studies on pediatric snowboarders.[8,10-12] With implementation of mountain base resort clinics and improved on-site management to reduce ED burden, it is important to identify the injury burden warranting ED presentation.[8] The purpose of this study was to analyze mechanisms, diagnoses, and incidence of youth snowboarding-related injuries presenting to US EDs. We hypothesized that there will be a large proportion of upper extremity injuries, particularly involving the wrist, and there will be a decreasing trend in injuries presenting to EDs due to greater on-site management.

Methods

Data Collection

This study did not require institutional review board approval. The NEISS database from the Consumer Product Safety Commission for sports-related injuries was accessed. The NEISS is a publicly accessible database that is a representative sample of all 5,000 US EDs that contains visits from 100 hospitals with a minimum of 6 beds and 24-hour services. The hospital for each data point is assigned a statistical sample weight based on the hospital's corresponding volume, which is used to calculate a national estimate (NE).

Data were collected by querying all snowboarding-related injuries (product code 5031: snowboarding [activity, apparel, or equipment]) occurring from 2002 to 2022. Age was queried by selecting "age in years" from <1 year to 18 years. All body parts, diagnoses, and dispositions were included.

The narratives were reviewed to identify injuries sustained during nonsnowboarding activities, which may be incidentally coded as snowboarding within the NEISS. Examples included snowboarding injuries that did not take place in the snow (e.g., snowboarding down muddy hill), snowboard-related injuries that did not occur while snowboarding (e.g., trip and fall while holding snowboard), nonsnowboarding activities (e.g., skier injured by getting hit by a snowboarder), and injuries that did not specify activity.

Variables collected included date of presentation, age, sex, race, body part, injury diagnosis, disposition, and a narrative written by the health care provider and inputted by a trained coder. The second author (A.Y.) reviewed each individual narrative to confirm the injury took place while snowboarding and to identify the mechanism of injury. The first author (K.K.O.) reviewed the data and mechanisms of injury included by the second author. Mechanisms of injury included impact with another person, impact with inanimate object, impact with ground, impact with snowboard, twisting, other, or not specified. The narrative was reviewed to differentiate between strain and sprain (product code 64).

Narratives were also used to subdivide fracture categories. All "lower leg" fractures were subdivided into "fibula," "tibia," "tibia and fibula," or "unspecified lower leg." All lower arm fractures were subdivided into "radius," "ulna," "radius and ulna," or "unspecified lower arm." All wrist fractures were subdivided into "radius," "ulna," "radius and ulna," or "unspecified wrist." All shoulder fractures were subdivided into "acromion," "acromioclavicular joint," "clavicle," "humerus," "glenoid," "humerus and glenoid," or "unspecified shoulder."

Table 1. Distribution of Patient Sex and Race

Demographics	Raw	National Estimate	%
Males	22,67	89,024	74.1
Females	769	31,116	25.9
Race			
White	2,240	96,265	80.1
Not specified	565	17,580	14.6
Asian	74	2,440	2.0
Other	89	2,332	1.9
Black/African American	59	1,249	1.0
American Indian/Alaska Native	8	269	0.2
Native Hawaiian/other Pacific Islander	1	5	0.0

Statistical Analysis

Statistical analyses were performed using STATA/MP Software 13.0 (StataCorp). Linear regression analyses were performed to analyze annual overall injuries, mechanisms of injury, and diagnoses. Statistical significance was set at $P < .05$. NEs were calculated by multiplying each raw data point with the respective statistical weight of the corresponding hospital.

Results

A total of 3,097 snowboarding injuries (NEs = 122,456) were queried from January 1, 2012, to December 31, 2022. After applying inclusion and exclusion criteria, 3,036 injuries (NEs = 120,140) were included in the study. Average age of patients was 14.0 ± 2.7 (range, 2-18 years). There were 2,267 males (NEs = 89,024, 74.1%) in the study. There were 2,240 White (NEs = 96,265, 80.1%) and 74 Asian (NEs = 2,440, 2.0%) patients. Full patient demographics are listed in Table 1.

The most common body parts injured involved 719 wrists (NEs = 115,505, 96.1%), 580 heads (NEs = 22,258, 18.5%), 381 shoulders (NEs = 17,269, 14.4%), and 465 lower arms (NEs = 13,793, 11.5%) (Table 2).

Table 2. Distribution of Pediatric Snowboarding Body Parts Injured From 2012 to 2022

Body Part	Raw	National Estimate	%
Wrist	719	31,375	26.1
Head	580	22,258	18.5
Shoulder	381	17,269	14.4
Lower arm	465	13,793	11.5
Knee	145	6,244	5.2
Lower trunk	108	4,710	3.9
Upper trunk	102	3,963	3.3
Ankle	81	3,627	3.0
Elbow	78	3,283	2.7
Upper arm	81	3,038	2.5
Face	61	2,309	1.9
Lower leg	63	2,280	1.9
Neck	49	1,763	1.5
Finger	37	1,472	1.2
Hand	27	1,081	0.9
Foot	20	769	0.6
Upper leg	18	420	0.3
Mouth	12	301	0.3
Not specified	3	95	0.1
Pubic region	4	66	0.1
Toe	2	24	0.0
Total	3,036	120,140	100

Table 3. Distribution of Pediatric Snowboarding Injury Diagnoses From 2012 to 2022

Diagnosis	Raw	National Estimate	%
Fracture	1,330	48,886	40.7
Strain/sprain	516	22,948	19.1
Concussion	346	12,553	10.4
Other	235	10,444	8.7
Contusion or abrasion	228	9,825	8.2
Internal organ injury	230	8,742	7.3
Laceration	86	3,752	3.1
Dislocation	44	2,426	2.0
Hematoma	7	263	0.2
Dental injury	6	117	0.1
Puncture	2	94	0.1
Avulsion	1	40	0.0
Nerve damage	2	21	0.0
Frostbite	1	16	0.0
Hemorrhage	1	7	0.0
Foreign body	1	6	0.0
Total	3,036	120,140	100.0

The most common diagnoses were 1,330 fractures (NEs = 48,886, 40.7%), 516 strains/sprains (NEs = 22,948, 19.1%), and 346 concussions (NEs = 12,553, 10.4%) (Table 3, Fig 1). The most common mechanisms of injury were 2,444 impact with the snow/ground (NEs = 97,120, 80.8%), 284 not specified (NEs = 11,980, 10.0%), and 115 impact with an inanimate object (NEs = 4,094, 3.4%) (Table 4, Fig 2).

The most common fractures involved 438 wrists (NEs = 18,103, 37.0%), 427 lower arms (NEs = 12,388, 25.3%), and 213 shoulders (NEs = 9,053, 18.5%). Wrist fractures involved 304 unspecified wrist (NEs = 12,279, 68.1% of wrist fractures), 104 radii (NEs = 4,650, 25.8%), 21 radius and ulna (NEs = 827, 4.6%), 6 scaphoid (NEs = 267, 1.5%), and 3 ulna (NEs = 80, 0.4%). Lower arm fractures involved 262 radii (NEs = 8,360, 67.7% of lower arm fractures), 70 radius and ulna (NEs = 1,852, 15.0%), 79 unspecified lower arm (NEs = 1,653, 13.4%), and 16 ulna (NEs = 523, 4.2%). The most common bones in shoulder fractures involved 181 clavicles (NEs = 7,962, 88.3% of shoulder fractures), 25 unspecified shoulders (NEs = 773, 8.6%), 3 scapula fractures (NEs = 173, 1.9%), 3 humerus fractures (NEs = 140, 1.6%), and 1 acromion fracture (NEs = 5, 0.1%).

Linear regressions demonstrated a decreasing number of 1,051 overall injuries ($P < .01$; 95% confidence interval [CI], −1,586.7 to −516.7) per year from 2012 to 2022. Mechanisms of injury demonstrated decreasing annual impact with ground injuries of 784 per year ($P < .01$; 95% CI, −1,253.6 to −313.9), 42 impact with inanimate object injuries per year ($P = .03$; 95% CI, −77.6 to −6.6), and 161 not specified injuries per year ($P < .01$; 95% CI, −237.7 to −84.4) but not impact with another person injuries ($P = .58$), twisting injuries ($P = .39$), impact with snowboard injuries ($P = .23$), or other mechanism injuries ($P = .14$). There were also decreasing annual fractures of 299 per year ($P = .04$; 95% CI, −577.9 to −20.0), 298 strains/sprains per year ($P < .01$; 95% CI, −399.2 to −196.2), and 143 concussions per year ($P < .01$; 95% CI, −238.9 to −47.0).

Patients not admitted to the hospital consisted of 2,891 (NEs = 115,505, 96.1%) who were treated and released or examined and released without treatment, as well as 11 (NEs = 585, 0.5%) who left without being seen. Patients requiring further admission or management consisted of 98 (NEs = 2,413, 2.0%) who were treated and admitted for hospitalization, 22 (NEs = 1,446, 1.2%) who were treated and transferred, and 14 (NEs = 191, 0.2%) who were held for observation.

Discussion

In this study, the authors found that pediatric snowboarding injuries are decreasing. This is consistent with prior literature.[8,10,18] This may be due to progressive implementation of medical clinics at the base of mountain resorts to treat nonacute injuries, greater utilization and improvements in protective equipment, and effective training by ski patrol to manage injuries on-site, thus mitigating ED presentation and inclusion in these data. Furthermore, the 3 most common mechanisms of injury (impact with ground, impact with inanimate object, and not specified) decreased in annual incidence during the study period and have the potential to be influenced by these changes.

Concussions were the third most common ED diagnosis and decreased at 143 concussions per year in the current study. These findings are in contrast to prior

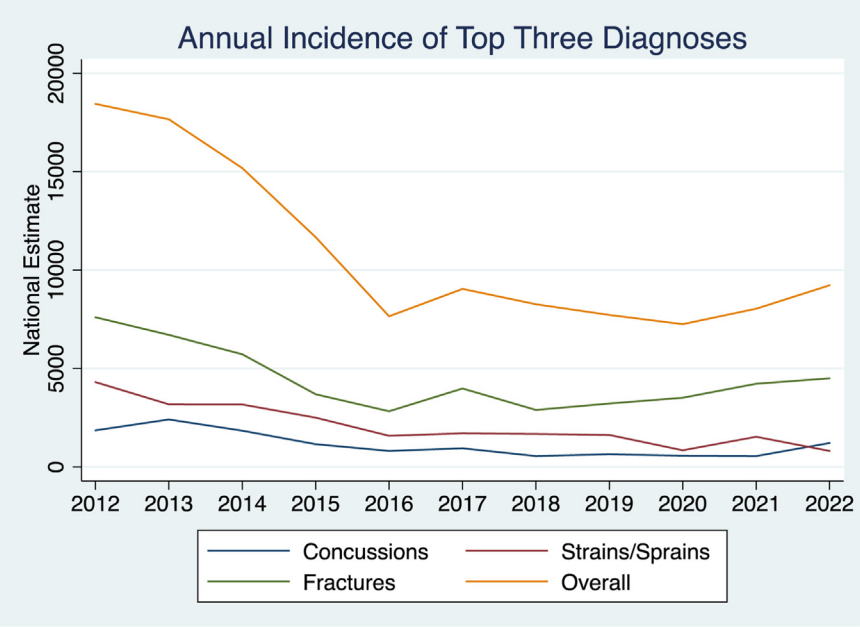

Fig 1. Annual incidence of overall and top 3 pediatric snowboarding injury diagnoses from 2012 to 2022.

reports of increasing snow sport-related traumatic brain injury in the 1990s and early 2000s.[11] Although this may be multifactorial, it is likely attributed to the increasing utilization of helmets in skiers and snowboarders from 2003 to 2022.[19] This is noteworthy, as sports-related concussion awareness and prevention have garnered interest in recent years due to the short- and long-term functional impact.[11,14,15,20-24] Studies report that approximately 20% of all ski- and snowboard-related injuries are due to head trauma, and 22% of these impacts cause loss of consciousness or concussion.[25,26] However, unlike organized sports such as football, hockey, and lacrosse, much of snowboarding is recreational, with minimal rules governing injury prevention. It is not surprising that snowboarders who do not wear helmets are at nearly 2 times greater risk of head injury.[27] Head trauma is also the leading cause of death and critical injury in snowboarders and skiers. Snowboarders are at higher risk for sustaining severe head trauma compared to that of skiers, largely associated with routine falls, collisions with inanimate objects, and landing failure following aerial maneuvers.[11,13] Additionally, adolescents are less inclined to wear helmets compared to children.[19] Recently, New Jersey passed a law requiring all individuals 18 years of age or younger to wear a helmet while skiing or snowboarding.[28] Rental companies have begun offering free helmets included in ski and snowboard rentals.[29] Universal implementation of regulations requiring helmet use for snowboarders and increased access to protective equipment will likely reduce the incidence and severity of head trauma going forward, particularly in children and adolescents. In turn, the increasing utilization of helmets among youth snowboarders, both by choice and regulation, may be a potential contributor to the decreasing concussions in this study.

Table 4. Distribution of Pediatric Snowboarding Mechanisms of Injury From 2012 to 2022

Mechanism	Raw	National Estimate	%
Impact with ground	2,444	97,120	80.8
Not specified	284	11,980	10.0
Impact with inanimate object	115	4,094	3.4
Twist	77	3,018	2.5
Impact with snowboard	38	1,619	1.3
Impact with person	46	1,393	1.2
Other	32	916	0.8
Total	3,036	120,140	100

The most frequently injured body parts in this study were the wrist (26.1%), head (18.5%), shoulder (14.4%), and lower arm (11.5%). The proportions of wrist and shoulder injuries are similar to that of snowboarders in prior studies of 22% to 38% and 8% to 16%, respectively.[6,8,9,30-32] The wrist is the most common body part involved given the propensity for snowboarders, particularly inexperienced youth, to fall on outstretched hands.[6,8,33-35] Not surprisingly, most wrist injuries were fractures (57.7%). The shoulder is implicated due to direct trauma or translated energy from falling onto an outstretched hand. Additionally, the upper extremity constituted 59.1% of injuries, which is consistent with prior reports of 45% to 61%.[30,31,34,36,37] Researchers hypothesize the high propensity for upper extremity injuries in snowboarders compared to skiers is caused by the fixed positioning of both feet on the board, reducing torsional

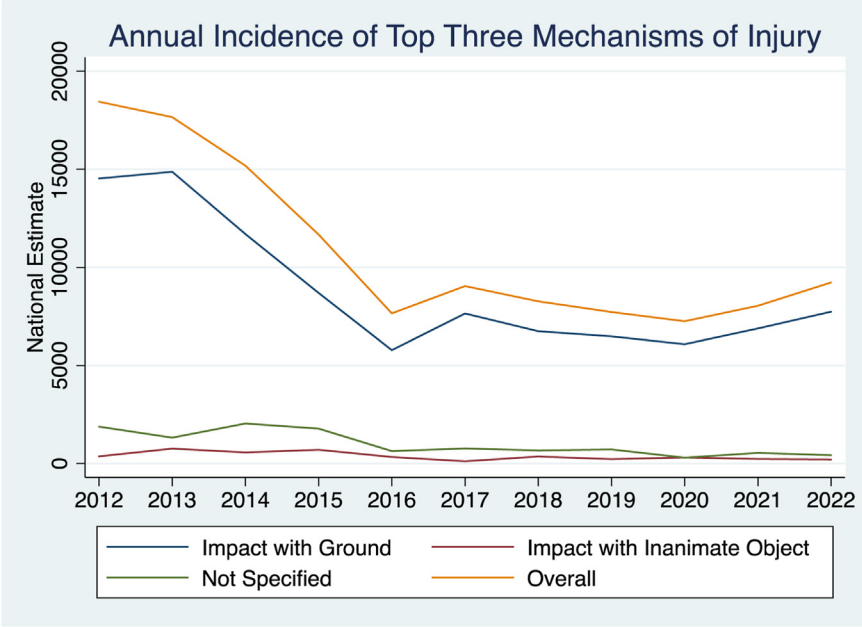

Fig 2. Annual incidence of overall and top 3 mechanisms of pediatric snowboarding injuries from 2012 to 2022.

forces on the lower extremity and forcing off-balance snowboarders to fall on outstretched hands.[6-8,13,31,34,36,37] Consequently, this decreases the proportion of lower extremity injuries and increases the proportion of upper extremity injuries relative to skiers. Snowboarders wearing wrist guards are 2 to 3 times less likely to sustain moderate-to-severe wrist injury without increasing risk of injury to the shoulder, highlighting the role of protective equipment in injury prevention.[30,37]

Fractures were the most common diagnosis, constituting approximately 40% of all injuries and primarily involving the wrist (37.0%), lower arm (25.3%), and shoulder (18.5%). This is consistent with prior reports of fractures being the most common snowboarding diagnosis presenting to EDs, particularly in inexperienced snowboarders with a greater propensity to fall.[8] Prior reports have demonstrated that radius fractures are the most common diagnosis in recreational snowboarders and the second most common diagnosis in professional snowboarders.[38] This is consistent with the current study, as the radius constituted 25.8% of wrist fractures and 67.7% of lower arm fractures, although location was not specified in 68.1% of wrist fractures. The proportion of wrist (37.0%) and upper extremity fractures in this study is larger than that of all age snowboarding injuries (22% to 32% and 56% to 63%), which may highlight both the greater proportion and/or severity of fractures in the youth population warranting ED presentation.[2,6,30,37] Snowboarders injured on slopes that lack access to radiographs or immediate care are more likely to be transported to the nearest hospital, increasing the proportion of fractures seen in the ED. This may elucidate why the upper extremity constituted 91.1% of fractures in the current study but only 63% of fractures in non-ED studies.[39] However, the decreasing incidence of fractures in this study is consistent with prior studies and is likely attributed to improved snowboard training, access to clinics with radiographic imaging at the base of mountain resorts, and greater utilization of protective equipment.[8]

Limitations

There are multiple limitations to this study inherent to using a retrospective national database. First, information in the narrative was limited to what was provided by the health care provider and trained coder. Injuries without a specified mechanism were labeled "not specified." Although the percentage of these injuries (10.8%) is smaller than reported in other NEISS studies (23% to 67%), lack of detailed information may influence accuracy of our results.[9,15,17] Second, the authors were unable to delineate whether the injury took place on a mountain with or without access to an on-site clinic. Access to immediate, high-quality care is a limiting factor when snowboarders sustain injuries on the slopes, particularly in remote destinations. Ski patrol are the first on-site responders to manage snowboarding injuries and triage the patients to either mountain base clinics or an ED at the nearest hospital. While large ski resorts are often well equipped with radiographs and ultrasound, many smaller mountains or remote locations may not have these resources, warranting ED disposition. Third, NEs are not perfectly representative of data across all 5,000 EDs and do not encompass acute injuries seen at mountain base clinics or urgent cares.

Conclusions

Pediatric snowboarding injuries demonstrated a large decline from 2012 to 2022. Fractures are the most common diagnosis, primarily affecting the wrist and shoulder. The head was the second most injured body part, and concussions were the third most common diagnosis.

Disclosures

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: R.L.P. is a board member of the Arthroscopy Association of North America. All other authors (K.K.O., A.Y., M.S.K., T.J.G., D.P.T.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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