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Pediatric snow sport injuries differ by age☆,☆☆

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ABSTRACT

Background: Unintentional injury is the leading cause of death among pediatric patients. There were 13,436 injuries related to snow sports in those younger than 15 in 2015, with 4.8% requiring admission. These sports are high-risk given the potential for injury even when using protective equipment. We hypothesized that snow sport injury patterns would differ based on patient age.
Methods: A cross-sectional analysis of the 2009 and 2012 Kids' Inpatient Database was performed.
Cases of injuries were identified and analyzed using ICD-9 codes. National estimates were obtained using case weighting. Multivariable logistic regression was used to assess for confounders.
Results: Within 745 admissions, there was a statistically significant decrease in skull/facial fractures with increasing age and a statistically significant increase in abdominal injuries with increasing age. Children in early and middle childhood were at increased odds of being hospitalized with skull/facial fractures, while older children were more likely hospitalized with abdominal injuries.
Conclusions: Within the pediatric snow sport population, younger children are more likely to experience head injuries, while older children are more likely to experience abdominal injuries.
Further research is needed to determine the origin of this difference, and continued legislation on helmets is also necessary in reducing intracranial injuries.
Level of Evidence: III

Unintentional injury is the leading cause of death in pediatric patients aged 1 to 15 in the United States [1]. In 2015, there were an estimated 13,436 injuries related to downhill skiing or snowboarding in patients younger than 15, and of these, approximately 5% required admission to a hospital [2]. Falls and other non-collision events more commonly caused injuries while skiing, but fatalities were more commonly associated with head injuries, blunt abdominal trauma, and spinal trauma [3]. A 2013 study estimated that the average incidence rate for traumatic brain injuries at 2.24 per 10,000 resort visits in children, compared with 3.13 per 10,000 resort visits in adolescents [4]. A separate study noted that traumatic brain injury was the leading cause of death at 67% of fatalities in 1980–2001 among pediatric snow sport patients [5]. Despite the strong history of traumatic brain injury in this population, only 67% of patients wore helmets in 2008, and predictors of helmet use included level of experience, past crash requiring medical assistance, snow sport training, and location [6].

Injuries on the slopes incur significant cost; one 1999 study estimated that per patient, there were $27,936 of hospital costs, $15,243 of outpatient costs, and $1500 of lost parental income [7]. The most recent data on ski and snowboard fatality comes from the 2017–2018 bulletin published by the National Ski Areas Association (NSAA), in which there were 37 fatal snow sport injuries, and the majority were secondary to collisions with trees and manmade objects [8]. Of these deaths, 23 of the 37 were in non-helmeted individuals, and skiers accounted for 75% of fatalities [8]. While skiing and snowboarding are traditionally reported at high rates of injury, sledding and tobogganing have also been shown to cause significant injury. These injuries occur more commonly in the 0–9-year-old population [9], and the most common mechanism of injury was hitting trees and other stationary objects [10]. In one study, among 22 admitted patients for tobogganing-related head injury, only one patient was helmeted [11]. Overall, these data suggests that skiing and snowboarding, as well as more commonplace activities

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such as tobogganing and sledding, are all significant sources of injury in the pediatric population, and these sports should be considered high-risk.

While there have been many studies comparing adult and pediatric injuries on the slopes [12], there has not been a study analyzing the differences between how snow sport injuries differ within the age range of pediatrics. Studies have demonstrated that there are differences in general athletic-related injuries between younger and older children [13], and that causes of traumatic brain injuries vary based on the age of the child [14]. There has not yet been a large-scale comprehensive analysis of pediatric snow sport injury demographics and injury variation by patient age. Our objectives were to analyze the spectrum of injury while participating in snow sports within the pediatric trauma population to understand how children are injured in these activities.

1. Methods

1.1. Data source

A cross-sectional analysis of the Kid's Inpatient Database (KID) for the years 2009 and 2012 was performed. As part of the Healthcare Cost and Utilization Project (HCUP), produced by the Agency for Healthcare Research and Quality (AHRQ), the KID is the most extensive publicly available all-payer national sampling of pediatric (≤20 years of age) inpatient discharges. It consists of over 3500 hospitals and 6 million weighted discharges [15].

This study was reviewed by the University of Massachusetts Medical School Institutional Review Board and deemed exempt. In compliance with the KID data use agreement, we do not report information where the number of observations is ≤10, and where there is a concern for patient confidentiality.

1.2. Case selection

Using International Classification of Diseases, Ninth Revision (ICD-9) diagnosis codes, cases of snow sport injury were identified using an ICD-9 code (E003.2) indicating the injury occurred involving snow alpine downhill skiing, snowboarding, sledding, tobogganing and snow tubing in either the primary or secondary diagnoses. Cases were limited to those aged ≥3 years and ≤17 years old. ICD-9 and single-level Clinical Classifications Software (CCS) codes, developed as part of the HCUP [16], were used to identify procedures, injuries, and comorbidities (Appendix I).

Exclusion criteria included ICD-9 coding abnormalities and missing data from the dataset. Coding abnormalities were identified within the ICD-9 codes using a built-in feature of STATA 15.0 statistical software (2017; StataCorp LLC, College Station, TX). If there was data missing from critical variables including age, gender, race, primary payer, mortality, total hospital charges (THC), and median income quartile by zip code, then cases were excluded. Overall, 18% of cases were excluded, predominantly for lack of a race (70%) and income quartile data (14%). Race data was an optional variable for states to include to HCUP and some opted to not include that information.

1.3. Independent and dependent variables

Patient characteristics and hospital course variables assessed included gender, race, payer, median income quartile by zip code, length of stay (LOS), and total hospital charges (standardized to 2018 U.S. dollars) [17]. Age was evaluated both continuously and categorically via three age-groups, defined by the National Institute of Child Health and Human Development (NICHD) – early childhood (3–5 years), middle childhood (6–11 years), and early adolescence (12–18 years) [18]. Seasons were defined in four categories – spring (March, April, May), summer (June, July, August), fall (September, October, November), and winter (December, January, February). Patient setting was condensed into urban (central and fringe counties of ≥1 million population), suburban (counties in metro areas of 250 k–<1 million and counties 50 k–< 250 k), and rural (micropolitan or non-core counties). Payer information was consolidated into private, government (Medicaid, Medicare), and other. Consistent with the U.S. Census Bureau [19] definitions, four hospital regions were defined. A major surgical procedure, an HCUP-defined variable, was determined if ICD-9 codes indicating a major therapeutic or diagnostic procedure were present [20]. An intensive care unit (ICU) admission was defined as the use of an arterial line, ventilator, central line or extracorporeal membrane oxygenation (ECMO) as this represents the level of care required for these interventions at many institutions. Using a program designed to convert ICD-9 diagnoses into severity scores, Injury Severity Scores (ISS) were calculated [21], which has been utilized in other trauma studies. We utilized the New Injury Severity Score (nISS) which is similar to the ISS but does not take into account the region of injury and is the sum of squares of the three highest AIS scores [22], and has been shown to be a superior predictor of mortality than the traditional ISS [23,24].

1.4. Statistical analysis

All analysis was conducted using chi-square and Student's t-test with STATA 15.0 statistical software. National estimates for all U.S. inpatient discharges were generated using provided weights. In order to generate national estimates, HCUP provides a weighting

Table 1
Patient demographics.

	N (%)
Total	745
Male	536 (72)
Age, mean (±SD)	12.6 (4)
Age category	
Early childhood, age 3–5 years	39 (5)
Middle childhood, age 6–11 years	202 (27)
Early adolescence, age 12–18 years	451 (61)
Race	
Non-Hispanic white	540 (73)
Black	5 (1)
Hispanic	20 (3)
Asian or Pacific Islander	20 (3)
Native American	21 (0)
Other	3 (5)
Missing	36 (5)
Region	
Northeast	148 (20)
Midwest	228 (31)
South	20 (3)
West	349 (47)
Weekend admission	326 (44)
Season	
Spring	129 (17)
Summer	7 (1)
Fall	31 (4)
Winter	577 (78)
Length of stay, mean (±SD)	2.4 (2)
Adjusted total hospital charges, mean (±SD)	$31,227 ($30,320)
Type of primary insurance	
Private	634 (85)
Government	72 (10)
Other	38 (5)
Zip income quartile	
1st	47 (6)
2nd	128 (17)
3rd	176 (24)
4th	361 (48)
Missing	32 (4)
Patient location	
Urban	370 (50)
Suburban	204 (27)
Rural	141 (19)
New ISS, mean (±SD)	9.8 (8)

variable which when used in conjunction with the svy function in STATA allows users to generate numbers that are nationally reflective. The svy function performs variance estimation accounting for multiple stages of clustered samples. All statistical tests were two-sided. Multivariable regression analysis was performed to control for confounding by gender, race, age group, patient setting, median income quartile by zip code, in examining the association between specific injuries and snow sport injuries. Statistical significance was defined as a p-value <0.05.

2. Results

We identified 745 admissions for snow sport-related injuries in the 2 study years (Table 1). Patients were predominately male (72%), non-Hispanic white (73%), lived in an urban environment (50%), resided in the West (47%), and had private health insurance (85%). Almost half were in the highest income quartile. The mean age of hospitalized children was 12.6 years old and when looking at age by developmental categories, the majority occurred in early adolescence (61%). Admissions occurred on a weekend in 44% of cases, and the majority occurred in the winter (78%). The mean LOS was 2.4 days, with a mean THC of $31,227. The mean nISS was 9.8.

2.1. Specific injuries associated with snow sport injuries

The most common injuries were fractures (63%, specifically lower limb fractures - 30%), intracranial injuries (26%), and abdominal injuries (20%) (Table 2). Other notable injuries included thoracic injuries (6%) and contusions (14%).

When investigating injury patterns by age, several patterns were observed (Fig. 1). There was a statistically significant decrease in the proportion of skull and facial fractures from the youngest age group (26%) to those in early adolescence (7%). A similar pattern was seen in lower limb fractures with a statistically significant decrease in the proportion of lower limb fractures from the youngest age group (52%) compared to early adolescence (24%). Conversely, the proportion of other fractures increased from the youngest age group (3%) to those in early adolescence (15%). Abdominal injuries had a statistically significant increase from 3% in the youngest age group to 25% in those in early adolescence. Specifically, splenic injuries increased from 0% in the early childhood group to 19% in those in early adolescence.

2.2. Multivariable logistic regression examining injuries

To adjust for confounders, we performed multivariable logistic regression to assess the relationship between age group and specific injuries (Table 3). Children in early and middle childhood were at significantly increased odds of being hospitalized with a skull or facial fracture than those in early adolescence, at 7.52 and 2.73 respectively. Children in the middle childhood group had significantly decreased odds (odds ratio 0.54) of being hospitalized with an intra-abdominal injury compared to those in early adolescence.

3. Discussion

3.1. Helmet use and activities on slopes depends upon age

Overall, younger children were admitted for head injuries more frequently than older children. Skull and facial fractures, as well as intracranial injuries, were among the most common causes of admission in the 3–5-year-old population, behind lower limb fracture and contusion. Previous studies have confirmed better outcomes, including fewer rates of fracture, in younger children wearing protective helmets while participating in skiing and snowboarding activities [25,26]. Despite this, children wear helmets at low rates, in one study found to be only 28% when accompanied by other children [27]. While there are few studies on rates of helmet usage when tobogganing or sledding, one study demonstrated injury patterns in the unhelmeted tobogganer to be similar to an unhelmeted biker [28]. The activities that younger children are participating in on the slopes are unclear, and the KID database utilized in this study does not differentiate between skiing, snowboarding, and sledding. However, this may be where the answer to the increase in intracranial injuries within this age group lies. Younger children are often allowed to sled in backyards and hills where there may be more obstacles, including trees, mailboxes, and swing sets. There is little research into either the activity choices of younger children or the landscape in which these activities are conducted, which may expose why there is this discrepancy in head injuries. Additionally, despite no significant change in helmet legislation nationwide, studies demonstrate a continued rise in helmet utilization while skiing and snowboarding over time [29]. The KID dataset does not report helmet utilization or activity of choice within the population, which leaves both variability in helmet usage as well as differences in activities on the slopes as the potential etiology of this major difference.

Table 2
Injuries caused by snow sport participation by age group.

	Early childhood, age 3–5	Middle childhood, age 6–11	Early adolescence, age 12–18	Total	p-Value
	n (%)	n (%)	n (%)	n (%)	
Any fracture	30 (78)	135 (67)	268 (59)	433 (63)	0.07
Hip fracture	1 (4)	11 (6)	11 (3)	24 (4)	0.27
Skull or face fracture	10 (26)	30 (15)	2 (7)	69 (10)	0.00
Upper limb fracture	1 (3)	25 (12)	79 (18)	105 (15)	0.06
Lower limb fracture	20 (52)	77 (38)	107 (24)	205 (30)	0.00
Other fracture	1 (3)	10 (5)	68 (15)	68 (11)	0.00
Sprain or strain	- (0)	4 (2)	27 (6)	31 (5)	0.13
Intracranial injury	10 (26)	59 (29)	110 (34)	179 (26)	0.53
Thoracic injury	- (0)	13 (7)	29 (7)	43 (6)	0.39
Traumatic pneumothorax	- (0)	8 (4)	13 (3)	21 (3)	0.53
Any traumatic hemo or pneumothorax	- (0)	9 (5)	17 (4)	26 (4)	0.55
Abdominal injury	1 (3)	26 (13)	111 (25)	139 (20)	0.00
Spleen injury	- (0)	19 (10)	84 (19)	103 (15)	0.01
Kidney injury	1 (3)	15 (7)	26 (6)	42 (6)	0.70
Open wound of head, neck, trunk	4 (11)	18 (9)	19 (4)	41 (6)	0.06
Open wound of extremities	- (0)	6 (3)	3 (1)	8 (1)	0.11
Contusion	11 (29)	25 (12)	60 (13)	96 (14)	0.08

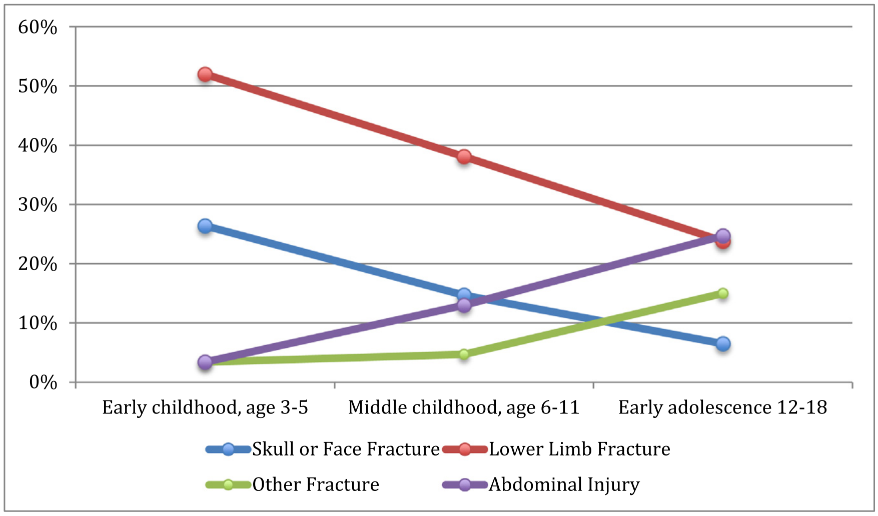

Fig. 1. Injury patterns by age group.

3.2. Age-related risk-taking behavior

In contrast, our data demonstrate that older children, especially in the 12–18-year-old population, were more likely to be hospitalized for intra-abdominal injury, including splenic injury, kidney injury, or other abdominal pathology, compared to the early childhood population. Multiple studies, including articles from 2002 [30] and 2005 [31] have demonstrated high incidence of splenic injuries specifically in the snowboarding population, referred to as the "Snowboarder Spleen". Splenic injuries were found to be infrequent but significant in this population, often requiring hospital admission. Additionally, self-identified expert skiers were often more likely to experience significant injury on the slopes, including injuries requiring ambulance evacuation [32]. Adolescents aged 12–18 are more likely to be skilled skiers compared to the aged 3–5 population, and thus it is possible that this age group engages in riskier behaviors on the slopes, including jumps, rails, moguls, and excessive speed. Within the adult population, younger male skiers are more likely to undertake risky behaviors on the slopes [33], and this is not affected by helmet use. Previous studies have also demonstrated that, when helmeted, high school students had an increased risk of solid organ injury, with an odds ratio of 4.86 [34]. Additionally, our data analyzes admitted pediatric patients but fails to capture the patients that are treated in the emergency department and released.

3.3. Study strengths and limitations

Overall, the data we analyzed demonstrate that younger children are more likely to experience head injuries when compared to the older adolescent population, and adolescents are more likely to experience intra-abdominal pathology compared to the younger population. This suggests a difference in sport choice and activities while undertaking those sports. This study has several strengths. The Kids' Inpatient Database is the largest publicly available all-payer pediatric inpatient database in the country [15]. It includes data on all hospital admissions and is published every 3 years, allowing for analysis of two separate time points. In addition to information on primary diagnoses, the KID also includes information on patient demographics, severity, length of stay, and charge information. This large sample size allows for adequate control of confounding variables. Given that the KID contains nationwide data, it reflects both variance in regional activities as well as regional differences in care, which allows for evaluation of locations across the United States that are both heavy and light in snow sport activities. The 2009 and 2012 KID databases utilize ICD-9 coding, allowing for easily grouped identification of primary and secondary diagnoses of snow sport injuries.

The study is subject to limitations as well. The KID includes only patients that were admitted to a hospital bed, and fails to include emergency department visits, office visits, and non-presenters with injuries that may fall into these categories. Therefore, our analysis may miss these less significant injuries that did not require admission, but does still capture injuries severe enough to require hospitalization. Additionally, the KID utilizes ICD-9 coding, which means we are not able to identify the sport children are participating in, such as skiing or sledding, or the activities during those activities, such as traveling at an unsafe speed or engaging in riskier behaviors. There is additionally no data on safety equipment, including helmets, in this dataset. While this would allow for further analysis, it does not affect the injury patterns and conclusions as demonstrated and does not change the discrepancies in injuries by age as previously set forth.

4. Conclusions

We demonstrate a significant difference in injury patterns of the admitted pediatric patient while undertaking snow sport activities.

Table 3
Multivariable logistic regression evaluating specific injuries by age group.*

	Age group (years)	Odds ratio	p-Value	95% C.I.
Skull or facial fractures	Early childhood, age 3–5	7.52	<0.01	(2.74, 20.6)
	Middle childhood, age 6–11	2.73	<0.01	(1.37, 5.45)
	Early adolescence, age 12–18	Reference		
Any intra-abdominal injury	Early childhood, age 3–5	0.12	0.052	(0.02, 1.02)
	Middle childhood, age 6–11	0.54	0.03	(0.31, 0.94)
	Early adolescence, age 12–18	Reference		

* Adjusted for sex, race, region, patient setting, income quartile, season, weekend occurrence.

Younger children are more likely to experience intracranial injuries and skull/facial fractures, while older children are more likely to experience intra-abdominal injuries. Further research is necessary to determine the etiology of this difference, but hypotheses include higher rates of unhelmeted sledding in the younger child population and higher rates of unsafe behaviors on the slopes in the adolescent population. We recommend that in addition to increased research, additional efforts be focused on educating children about safe behaviors on the slopes and educating parents on protective equipment. We advocate for the use of helmets while undertaking all kinds of snow sports. Finally, while there have been recent improvements, continued legislation on mandatory helmets while participating in snow sports can be beneficial in eliminating many of the continued high proportion of intracranial injuries.

Appendix I

Table 1
Procedure and diagnosis codes.

Diagnosis/procedure	Code
Skiing or snowboarding related injury	*External cause of injury diagnosis code* E0032
Any fracture	*Clinical Classifications Software diagnosis code* 226, 228, 229, 230, 231
Hip fracture	*Clinical Classifications Software diagnosis code* 226
Skull or face fracture	*Clinical Classifications Software diagnosis code* 228
Upper limb fracture	*Clinical Classifications Software diagnosis code* 229
Lower limb fracture	*Clinical Classifications Software diagnosis code* 230
Other fracture	*Clinical Classifications Software diagnosis code* 231
Sprain or strain	*Clinical Classifications Software diagnosis code* 232
Intracranial injury	*Clinical Classifications Software diagnosis code* 233
Thoracic injury	*ICD-9 diagnosis code* 8600, 8601, 8602, 8603, 8604, 8605, 86100, 86101, 86102, 86103, 86110, 86110, 86111, 86112, 86113, 86120, 86121, 86122, 86130, 86131, 86132 8620, 8621, 86221, 86222, 86229, 86231, 86232, 86239, 8628, 8629
Traumatic pneumothorax	*ICD-9 Diagnosis code* 8600, 8601
	ICD-9 diagnosis code
Any traumatic hemo- or pneumothorax	8600, 8601, 8602, 8603, 8604, 8605
Abdominal injury	*ICD-9 diagnosis code* 86400, 86401, 86402, 86403, 86404, 86405, 86409, 86410, 86411, 86412, 86413, 86414, 86415, 86419, 86500, 86501, 86502, 86503, 86504, 86509, 86510, 86511, 86512, 86513, 86514, 86519, 8630, 8631, 86320, 86321, 86329, 86330, 86331, 86339, 86340, 86341, 86342, 86343, 86344, 86345, 86346, 86349, 86350, 86351, 86352, 86353, 86354, 86355, 86356, 86359, 86381, 86382, 86383, 86384, 86391, 86392, 86393, 86394, 86380, 86385, 86389, 86390, 86395, 86399, 86600, 86601, 86602, 86603, 86610, 86611, 86612, 86613, 8670, 8671, 8672, 8673, 8674, 8675, 8676, 8677, 8678, 8679, 8680, 86800, 86801, 86802, 86803, 86804, 86809, 86810, 86811, 86812, 86813, 86814, 86819
Spleen injury	*ICD-9 diagnosis code* 86500, 86501, 86502, 86503, 86504, 86509, 86510, 86511, 86512, 86513, 86514, 86519
Kidney injury	*ICD-9 diagnosis code* 86600, 86601, 86602, 86603, 86610, 86611, 86612, 86613
Open wound of head, neck, trunk	*Clinical Classifications Software diagnosis code* 235
Open wound of extremities	*Clinical Classifications Software diagnosis code* 236
Contusion	*Clinical Classifications Software diagnosis code* 239

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