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Original Contribution

The risk of snow sport injury in pediatric patients

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ABSTRACT

Purpose: In 2015, approximately 13,436 snowboarding or skiing injuries occurred in children younger than 15. We describe injury patterns of pediatric snow sport participants based on age, activity at the time of injury, and use of protective equipment.
Methods: A retrospective analysis was performed of 10–17 year old patients with snow-sport related injuries at a Level-1 trauma center from 2005 to 2015. Participants were divided into groups, 10–13 (middle-school, MS) and 14–17 years (high-school, HS) and compared using chi-square, Student's *t*-tests, and multivariable logistic regression.
Results: We identified 235 patients. The HS group had a higher proportion of females than MS (17.5% vs. 7.4%, $p = 0.03$) but groups were otherwise similar. Helmet use was significantly lower in the HS group (51.6% vs. 76.5%, $p < 0.01$). MS students were more likely to suffer any head injury (aOR 4.66, 95% CI: 1.70–12.8), closed head injury (aOR 3.69 95% CI: 1.37–9.99), or loss of consciousness (aOR 5.56 95% CI 1.76–17.6) after 4 pm. HS students engaging in jumps or tricks had 2.79 times the risk of any head injury (aOR 2.79 95% CI: 1.18–6.57) compared to peers that did not. HS students had increased risk of solid organ injury when helmeted (aOR 4.86 95% CI: 1.30–18.2).
Conclusions: Injured high-school snow sports participants were less likely to wear helmets and more likely to have solid organ injuries when helmeted than middle-schoolers. Additionally, high-schoolers with head injuries were more like to sustain these injures while engaging in jumps or tricks. Injury prevention in this vulnerable population deserves further study.
Level of evidence: Level III (Retrospective Comparative Study).

1. Introduction

Snow sports such as skiing and snowboarding are considered to be high-risk due to the ever-present risk of severe injury or death [1]. A series of high profile celebrity injuries and tragic deaths related to snow sports over the last 20 years has increased attention on injury prevention [2]. In 2015, there were an estimated 13,436 injuries related to snow sports in children younger than 15 years old in the U.S., resulting in over 1300 hospital admissions [3]. The most recent data available from the National Ski Areas Association reported 39 deaths due to skiing or snowboarding, in which, >50% were helmeted at the time of the incident [4].

Pediatric helmet use in these sports has increased over time from 37% in 2004 to 58% in 2010 [5]. More recent data suggests that 57% of pediatric skiers and snowboarders are helmeted [6], suggesting no significant increase in use over the last several years. One study [5] demonstrated a decreased proportion of head injuries in children under the age of 10 while their cohort of 11 to 17 years olds sustained a higher percentage of head injuries (47.7%) than any other group. Studies have shown that these adolescents are more likely to suffer a traumatic brain injury compared with younger children [7].

The current literature shows that experienced snow sports participants are more likely to be injured while performing tricks or jumps at a terrain park [8]. There has been limited research on dangerous maneuvers among young children and adolescents. Girls have been found to have higher rates of injuries at terrain parks than boys [9]. However, these studies are limited because they did not specifically study pediatric snow sports participants nor were they clinically focused. The primary objective of this study were to describe injury patterns among middle and high school aged students who participated in snow sports and who presented to a pediatric level 1 trauma center in central Massachusetts. A secondary objective was to examine the influence of

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helmet use and performance of dangerous tricks on the nature and severity of any injuries.

2. Materials and methods

2.1. Case identification

A retrospective analysis was performed of patients 10–17 years of age who presented with skiing or snowboarding related injuries to a level-I trauma center in Central MA from 2005 to 2017. Patients were divided into two groups, 10–13 (middle school, MS) and 14–17 years (high school, HS) due to perceived differences between the age groups in their level of supervision, risk taking behavior and use of safety equipment.

Study patients were identified through a trauma registry maintained by our institution's Division of Trauma Surgery. The University of Massachusetts Medical Center is the only American College of Surgeons (ACS) verified level I pediatric trauma facility in central Massachusetts and this center treats approximately 135,000 patients annually. After identification of eligible patients, review of the patient's electronic medical record or paper chart was performed by the study team. Data extraction was performed using a structured data extraction form utilizing Research Electronic Data Capture (REDCap 7.1.0, Vanderbilt University) software hosted at the University of Massachusetts Medical School. REDCap is a secure, web-based application designed to support data capture for research studies, providing 1) an intuitive interface for validated data entry; 2) audit trails for tracking data manipulation and export procedures; 3) automated export procedures for seamless data downloads to common statistical packages, and 4) procedures for importing data from external sources [10].

2.2. Independent variables

Patient characteristics included categorical variables such as sex, race, state of residence, and use of helmet at time of injury. Time of injury was determined by either the time of the ambulance dispatch or narrative within the medical record indicating the approximate time of injury. The interval period 2005–2009 was compared to 2010–2017 due to a high profile death [11] which we hypothesized would influence helmet use. A jump or trick was defined from narratives within the medical record indicating the participant was using a rail or grind box, was in a terrain park or going over a jump at the time of the injury. An injury suffered by striking the ground was compared to injuries suffered from striking trees, fences, snow-making equipment, or other skiers and snowboarders. Injuries were determined by discharge diagnoses and any injury to the stomach, pancreas, small or large bowel, liver, kidney or adrenal glands were considered a solid organ injury. Any operative intervention during the incident hospitalization was considered as a binary variable. Continuous variables included length of stay, and injury severity score (ISS).

2.3. Data analysis

Patient characteristics, injuries, and outcomes were compared using chi-square and Student's *t*-tests for categorical and continuous variables, respectively. All analyses were performed using STATA 15.0 statistical software (2017). Odds ratios (ORs) and 95% confidence intervals (C.I.) were calculated to assess the relationship between exposure and outcome. Multiple independent multivariable logistic regression analysis was performed to control for confounding. One model consisted of gender and race, and a second series of models were evaluated consisting of gender and year of injury. Regression models were assessed using Hosmer-Lemeshow's test and receiving operator characteristic (ROC) curve. Collinearity was assessed for using variance inflation factor and tolerance. This research was reviewed and approved by the Institutional Review Board at the University of Massachusetts Medical School.

3. Results

A total of 235 patients met our inclusion criteria during the study period. This patient population was predominantly male (86.0%), white (93.2%), Massachusetts residents (88.9%) and snowboarders (94.5%). The mean age for the MS group was 12.1 years old ($n = 81$), and 15.5 years in the HS group ($n = 235$). Students in the HS group had a higher proportion of girls (17.5% vs. 7.4%, *p*-value 0.03), but the demographics characteristics of MS and HS student were generally similar between our two primary comparison groups (Table 1).

A lower percentage of the HS group wore helmets than the MS group (51.6% vs. 76.5%, *p*-value < 0.01). The HS group struck the ground at higher rates than the MS group whereas the MS group hit objects or another person more commonly (Table 1).

There were no statistical differences in the injury patterns suffered by the MS and HS groups. However, head and pelvic/genitourinary injuries were more frequently observed among HS than MS students. Additionally, there were higher rates of lower extremity injuries in the MS group (17.3% vs. 9.74%).

The HS group underwent any or head CT scans at a higher rate than the MS group. There were no differences seen in the need for operative intervention, length of stay, or the injury severity score (ISS) between the two groups. Injured helmeted high school students were more likely to have engaged in jumps or tricks than injured helmeted middle schoolers (64.1% vs. 36.4%, *p*-value 0.01).

Among the HS students, attempting a trick or jump was associated with an increased risk of head related injury (Table 2; aOR 2.79, 95% C.

Table 1
Patient demographic characteristics and injury details according to school-age.

	Middle-school 10–13 years old $N = 81$		High-school 14–17 years old $N = 154$		*p*-Value
	n	%	*n*	%	
Male	75	92.6%	127	82.5%	0.03
Age, mean (years)	12.06 ± 0.1		15.54 ± 0.1		
White race	76	93.8%	143	92.9%	0.50
MA state resident	81	91.4%	135	87.7%	0.39
Injury year					
2005–2009	34	42.0%	81	52.6%	0.12
2010–2017	47	58.0%	73	47.4%	
Use of a helmet	62	76.5%	79	51.6%	<0.01
Snowsport					
Snowboard	77	95.1%	145	94.2%	0.77
Ski	4	4.94%	9	5.84%	
Injury detail					
Struck ground	40	64.5%	108	87.1%	<0.01
Struck object/other person	22	35.5%	16	12.9%	<0.01
Injury occurred after 4 pm	52	64.2%	85	55.2%	0.18
A jump or trick was involved	24	42.9%	67	58.3%	0.06
Injury severity score, mean	6.44 ± 4.11		7.05 ± 4.72		0.33
Type of injury					
Any head injury	49	60.5%	111	72.1%	0.07
Closed head injury	46	56.8%	105	68.2%	0.08
Loss of consciousness	38	53.5%	89	65.0%	0.11
Spine injury	12	14.8%	23	14.9%	0.98
Any abdominal injury	15	18.5%	23	14.9%	0.48
Splenic injury	12	14.8%	15	9.74%	0.25
Any solid organ injury	12	14.8%	17	11.0%	0.40
Pelvis/genitourinary injury	3	3.70%	17	11.0%	0.06
Upper extremity injury	13	16.1%	28	18.2%	0.68
Lower extremity injury	14	17.3%	15	9.74%	0.10
Any CT	57	70.4%	138	89.6%	<0.01
Head CT	41	50.6%	107	69.5%	<0.01
Abdomen/pelvis CT	80	24.7%	55	35.7%	0.09
Need for operative intervention	17	21.0%	24	15.6%	0.30
Length of stay (days)	1.61 ± 1.46		1.90 ± 2.30		0.29

Table 2
Crude and multivariable adjusted odds ratios for by age groups.

		Middle-school 10–13 years old				High-school 14–17 years old			
Risk factor	Type of injury	Crude OR	95% CI	Adjusted OR[a]	95% CI	Crude OR	95% CI	Adjusted OR[a]	95% CI
A helmet was used	Any head injury	6.84	2.15–21.8	8.46	2.38–30.0	1.03	0.51–2.08	1.08	0.52–2.23
	CHI	5.55	1.73–17.2	7.38	2.07–26.4	0.92	0.47–1.81	1.01	0.50–2.04
	LOC	7.58	1.93–29.9	8.25	1.91–35.6	1.05	0.52–2.13	1.16	0.56–2.43
	Upper extremity injury	0.18	0.05–0.64	0.17	0.05–0.66	1.10	0.48–2.50	1.23	0.52–2.92
	Solid organ injury	1.63	0.33–8.21	1.58	0.30–8.42	5.10	1.40–18.6	4.86	1.30–18.2
A jump or trick was involved	Any head injury	0.60	0.21–1.76	0.56	0.19–1.68	2.48	1.09–5.66	2.79	1.18–6.57
Injury occurred after 4 pm	Any head injury	4.44	1.69–11.7	4.66	1.70–12.8	1.10	0.54–2.23	1.10	0.53–2.26
	CHI	3.37	1.31–8.69	3.69	1.37–9.99	1.28	0.65–2.53	1.30	0.65–2.61
	LOC	3.98	1.41–11.2	5.56	1.76–17.6	0.84	0.41–1.72	0.84	0.41–1.75
	Solid organ injury	0.75	0.21–2.61	0.66	0.18–2.41	0.30	0.10–0.89	0.29	0.09–0.89

CHI – closed head injury, LOC = loss of consciousness.
[a] Adjusted for gender and year of injury (2005–09 vs. 2010–17).

I. 1.18–6.57) whereas the use of a helmet was associated with a significant increase in solid organ injury (aOR 4.86, 95% C.I. 1.30–18.2).

There was a significant increase in the odds of several injuries occurring after 4 pm in the MS group – any head injury (aOR 4.66, 95% C.I. 1.70–12.7), closed head injury (a OR 3.69, 95% C.I. 1.37–9.99), and loss of consciousness (adj OR 5.56, 95% C.I. 1.76–17.5).

Patients with solid organ injury had higher injury severity scores (11.8 vs. 6.15, p-value < 0.01) and increased lengths of stay (4.52 vs. 1.42 days, p-value < 0.01) compared to those without solid organ injury.

3.1. Helmeted versus non-helmeted participants

The helmeted group were younger, more likely to be male, and were more likely to suffer a solid organ injury (Table 3). The proportion of helmeted patients was significantly higher in the period 2010–2017 versus 2005–2009 (70.8% vs. 49.1%, p-value < 0.01). After adjusting for race and gender, high schoolers were 65% less likely to be helmeted (aOR 0.35, 95% C.I. 0.19–0.64) than middle school students. Helmeted patients were 3.43 times (aOR, 95% C.I. 1.43–8.22) more likely to have any abdominal injury and 3.42 times (aOR, 95% C.I. 1.25–9.39) more likely to have experienced a solid organ injury than non-helmeted patients after adjusting for race and gender. The use of helmets was associated with a significant reduction in upper extremity injuries in the MS group (aOR 0.17, 95% C.I. 0.05–0.66).

Table 3
Patient demographic characteristics and injury details according to helmet-use.

	Unhelmeted $N = 93$		Helmeted $N = 141$		
	n	%	n	%	p-Value
Male	74	36.6%	128	63.4%	0.02
Female	19	59.4%	13	40.6%	0.02
Age, mean (years)	14.89 ± 1.75		13.96 ± 1.99		<0.01
White race	87	93.6%	131	92.9%	0.75
MA resident	84	90.3%	124	87.9%	0.57
Injury year					
2005–2009	58	50.9%	56	49.1%	<0.01
2010–2017	35	29.2%	85	70.8%	
High school aged	74	79.6%	79	56.0%	<0.01
Snowsport					
Snowboard	91	97.9%	130	92.2%	0.07
Ski	2	2.15%	11	7.8%	
Injury detail					
Struck ground	10	27.0%	27	73.0%	0.11
Struck object/other person	61	41.2%	87	58.8%	0.11
Injury occurred after 4 pm	49	52.7%	88	62.4%	0.14
A jump or trick was involved	34	54.8%	57	52.8%	0.80
Injury severity score, mean	6.98 ± 4.54		6.77 ± 4.53		0.73
Type of injury					
Any head injury	58	62.4%	101	71.6%	0.14
Closed head injury	56	60.2%	94	66.7%	0.31
Loss of consciousness	44	55.0%	82	64.6%	0.17
Spine injury	*19*	*20.4%*	*16*	*11.4%*	0.06
Any abdominal injury	7	7.53%	31	22.0%	0.00
Splenic injury	5	5.38%	22	15.6%	<0.01
Any solid organ injury	5	5.38%	24	17.0%	<0.01
Pelvis/genitourinary injury	8	8.6%	12	8.5%	0.98
Upper extremity injury	20	21.5%	21	14.9%	0.19
Lower extremity injury	15	16.1%	14	9.93%	0.16
Any CT	73	78.5%	121	85.8%	0.15
Head CT	56	60.2%	91	64.5%	0.50
Abdomen/pelvis CT	30	32.3%	45	31.9%	0.96
Need for operative intervention	19	20.4%	22	15.6%	0.34
Length of stay, mean (days)	1.828 ± 1.83		1.787 ± 2.19		0.88

4. Discussion

We found a significantly lower rate of helmet use among females, and high-school aged students who participated in skiing or snowboarding. Additionally, we saw a substantial increase in helmet use in injured skiers and snowboarders overall during our study period, 49% in 2005–2009 to 71% in 2010–2017 (Table 3). This finding supports existing literature [5, 6] but we noted that the HS group fell slightly below the national averages (51.6% vs. approximately 57%). Given the nature of this study it is possible that this difference is due to non-helmeted participants suffering more injuries and diluting the rate of helmet use seen in participants presenting to the hospital.

An important finding of this study was the relationship of engaging in jumps or tricks on the number of injuries. High-school-aged participants were significantly more likely to suffer any head injury if they were participating in jumps or tricks compared to those who did not participate. Additionally, among children engaging in jumps and tricks, high-schoolers appear to be at even higher risk than the middle-school aged snow sports participants. The relationship between engaging in jumps and tricks with injuries is unclear. There are several possible answers: children trying to emulate maneuvers seen on the internet or television, variability in the difficulty of the jump or trick itself, varying weather conditions and its effect on landing a jump/trick safely, peer pressure to impress others, and the use of safety equipment emboldening children to engage in riskier behaviors. There is limited evidence investigating these higher risk behaviors within snow sports, and additional research is needed. Educational efforts on safety while engaging in tricks or jumps should be focused on the high-school age group.

The first report of 'Snowboarder Spleen' was published in 2002 [12] with the first extensive retrospective study of this specific trauma cohort becoming available in 2005 [13]. Our work has shown a considerable increase in the risk of solid organ injuries, almost five-fold, within the helmet wearing HS population as well as a trend to increased odds within the MS population, but this failed to reach significance. Our study demonstrated a significant increase in the length of stay for children suffering solid organ injury as compared to those who did not (5.42 versus 1.42 days, p-value < 0.01). Snowboarders are no longer a

minority on the slopes rising from 11% in 1996 [14] to 49% in 2011–15 [15] and the risk of solid organ injuries should not be overlooked. The high prevalence of snowboarders within this study (>94%) suggests snowboarders might suffer injuries at a high rate than skiers but without the necessary exposure information, we cannot draw that conclusion here.

There is a paucity of data on the impact of time of day on injury rates and patterns. We hypothesized that more injuries occur later in the day as the participant becomes tired or as the ambient light decreases. We found a significant increase in the odds of any head injury, closed head injury, and loss of consciousness after 4 pm among middle-schoolers but not in high schoolers. These findings suggest that increased scrutiny should be paid to the fatigue level of middle schoolers or the slope conditions to reduce the likelihood of a head injury. Further research could focus on the number of hours a participant has been skiing or snowboarding at the time of the injury.

One surprising finding in our study was the increased odds ratios of head injury, closed head injury, and loss of consciousness in MS helmeted patients. A similar finding was seen in two National Trauma Database Studies [15, 16] but in contrast to clear evidence demonstrated in both cohort studies and a systematic review [6, 17, 18]. We performed a sub-analysis of MS aged participants engaged in jumps or tricks but not wearing helmets and found a small sample ($n = 8$) of which none suffered any form of head injury. We believe this unusually small sample size influences the overall data significantly as when these participants are excluded the aOR drops to 3.42 and is no longer significant. We do not think that helmets increase the rate of these injuries, nor do we suggest participants should not wear helmets, but there may be other explanations for the high rate of head injuries seen within the helmet wearing population. There have been studies within the adult snow sports population discussing a 'risk-compensation' hypothesis by which protective equipment, such as helmets, instill a false sense of security and safety in their users potentially resulting in the user partaking in riskier behaviors. Adolescents report that the difficulty of the ski or snowboard activity, as opposed to cost, was a major factor influencing their decision to use a helmet [19]. In this study, we noted that almost two-thirds of helmeted high schools were involved in jumps or tricks at the time of their injury compared to helmeted middle schoolers. There are no data on this in the pediatric population, but in the adult population, the evidence is mixed. One study showed 8% of surveyed participants agreed that helmet use increased risk taking [20], while another study showed that helmet use was predictive of greater risk-taking behavior [21]. A review article on this topic surmised that helmets did not appear to increase the risk of compensation behavior [18]. It is possible that high schoolers while wearing helmets feel more invincible, are going at higher speeds, and engaging in riskier behaviors. These higher speeds and riskier behaviors might explain the association we found in this study with helmet use and the higher rates of solid organ injuries. Further research within the pediatric population is needed to assess the impact of helmets or protective equipment on engaging in risk-taking behaviors and the impact on injury patterns.

Strengths of this study include the wide year range for injuries allowing for assessment of temporal trends or changes within this population. In addition, the retrospective chart review performed by a single data abstractor allows for consistent data extraction in a high fidelity fashion. Additionally, being the only Level-I trauma center within a 45-mile radius ensures all significant trauma within central MA, southern NH and northern RI is directed to our facility. Thus, it is unlikely that significant trauma is not being accounted for due to presentation to a different facility.

This study is subject to the following limitations: it is a single center study, the use of a trauma registry for case identification, the small sample size, and the absence of population data. This study was a single center study in central Massachusetts, and our results may not be generalizable to other institutions or geographic settings. It is possible the slope conditions in our area are significantly different than in other regions of the country and may have influenced either the rate or patterns of injury. Also, the use of our center's trauma registry limits the case identification to those cases where a pediatric trauma consult was requested. At our institution, it is not routine to consult pediatric trauma on isolated orthopedic injuries, and thus the actual number of overall cases, as well as extremity injuries, is likely to be higher. Additionally, it is possible there were cases in which the patient self-presented to the Emergency Department with mild injuries, for which no trauma consult was obtained, and this too would inflate our case numbers and injury severity. We feel confident that all significant pediatric trauma at our institution resulted in a trauma consultation. Given the single institution nature of this study and prevalence of snow sports in central Massachusetts, our sample size is relatively small and thus creates relatively wide confidence intervals. However, all model diagnostics for the regressions suggested validly and reliability of the models. Lastly, the absence of population data limits this study in that we do not know the total number of pediatric snow sports participants in Massachusetts or the North-East. Thus the results do not represent incidence but the patterns and trends of our region.

5. Conclusions

We have demonstrated a significant difference in the rates of helmet use in middle and high school groups and defined the difference in injury patterns based on age. High schoolers are at increased risk of solid organ injury while wearing a helmet, and increased risk of head injuries while engaging in tricks of jumps. Additionally, we have identified a temporal relationship regarding late day head injuries that is strongest in middle schoolers that warrants further investigation. We recommend that additional educational efforts be focused on engaging in safe behaviors while skiing or snowboarding in addition to the use of protective equipment.

Conflict of interest and source of funding

The authors have no conflicts of interest to report, and source of funding was internal departmental support.

Meetings/conferences

This work has not been presented at any academic meetings or conferences.

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