Concussion Among Youth Skiers and Snowboarders
A Review of the National Trauma Data Bank From 2009 to 2010

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Objective: There are limited data regarding concussion among youth skiers and snowboarders. The objective of this study was to examine the frequency of concussion among helmeted and unhelmeted youth skiers and snowboarders presenting to trauma centers.

Methods: Subjects 18 years or younger with a ski- or snowboard-related injury were studied using data from the National Trauma Data Bank from 2009 to 2010. We further selected those with head/neck injuries and stratified based on helmet status. Concussive injuries were identified from International Classification of Diseases, 9th Revision codes. Severity analysis was based on the Glasgow Coma Scale and Injury Severity Score.

Results: A total of 1001 subjects met inclusion criteria with 678 subjects having documented helmet status. Subjects 12 years or younger were more likely to use helmets compared to 13–18 year-olds (odds ratio, 2.21; 95% confidence interval [95% CI], 1.52–3.21). Skiers were more likely to use helmets compared to snowboarders (odds ratios, 1.60; 95% CI, 1.16–2.19). Snowboarders had a greater likelihood of concussion (estimated-β, 2.1; 95% CI, 1.48–2.85) after adjusting for helmet status and age. There was no significant difference in the frequency of concussion among helmeted compared to unhelmeted subjects. Imputing missing values for helmets status had no effect on outcome for concussion. We found no difference in injury severity among helmeted compared to unhelmeted subjects.

Conclusions: Among youth skiers and snowboarders who present to trauma centers with a head injury, the likelihood of that injury involving a concussion was not associated with helmet use.

Key Words: concussion, traumatic brain injury, skiing, snowboarding, trauma

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Concussion is a distinct form of mild traumatic brain injury (TBI) sustained when an abrupt acceleration-deceleration injury produces rotational forces around the fixed fulcrum of the brainstem, leading to shearing forces at the junction of gray-white matter and subsequent axonal injury.[1–3] Approximately 1 out of every 220 pediatric patients are evaluated for concussion in the emergency department (ED), with sports-related mechanisms accounting for up to 40% of all cases.[4] Although skiing and snowboarding continue to be popular among youth, there is currently limited data regarding concussive injury specifically among youth participants. This is despite evidence showing that the incidence of overall TBI has been increasing among youth skiers and snowboarders, particularly among adolescents compared to children.[5]

It is unclear whether the increase in overall TBI among youth skiers and snowboarders is attributable to increased rates of concussion or possibly differential use of protective helmets. Currently, available data suggest that helmet use among youth skiers and snowboarders may be associated with a reduction in TBI,[6,7] and reports from the U.S. Consumer Product Safety Commission estimate that 53% of ski-related head injuries in children could be prevented by helmet use.[8] However, the likelihood of overall TBI among child and adolescent participants has increased 111% and 250%, respectively, from 1996 to 2010[5] despite a concurrent increase in helmet use over this time.[9,10] This suggests that other factors, such as concussive injury, may contribute to the increase in TBI.

To our knowledge, no studies have investigated concussion specifically in relation to helmet use among youth skiers and snowboarders. Therefore, the primary aim of this study was to describe the frequency of concussion among helmeted and unhelmeted youth skiers and snowboarders presenting to U.S. trauma centers.

METHODS

Study Design

We conducted a retrospective, cross-sectional analysis of head trauma and helmet use among children and adolescents presenting to trauma centers after skiing or snowboarding accidents. The Institutional Review Board at the Children's Hospitals and Clinics of Minnesota approved this study.

Study Setting and Population

We used the data from the National Trauma Data Bank (NTDB, version 7.0, 2010) for the calendar years of 2009 and 2010. The NTDB is the largest repository of trauma data in the United States and is maintained by the American College of Surgeons Committee on Trauma. Data submitted to the NTDB from participating trauma centers across the United States is cleaned, standardized, and aggregated on an annual basis.[11]

Study Protocol

Criteria for inclusion consisted of age 18 years or younger and either International Classification of Diseases, 9th Revision E-Code E885.3 or E885.4, which correspond to injuries related to skiing or snowboarding, respectively. From among these subjects, we further selected those with injuries to the head/neck or face based on Abbreviated Injury Scale (AIS) codes. The primary exposure variable was reported use of a helmet in the database. We excluded subjects from the primary analysis if helmet status was not available or missing. However, it was unclear whether helmet status was in fact not known in these subjects, or if they were incorrectly labeled due to failure to observe or ask of helmet status by clinical personnel. A missing value for helmet status may have been the result of failure to make a positive report of being unhelmeted, whereas a positive identification of helmet use may be less likely to include many false-positive results. For this reason, a sensitivity analysis was performed to test assumptions related to the meaning of a missing value for helmet status.

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TABLE 1. Demographic and Injury Characteristics of Youth Skiers and Snowboarders Presenting to U.S. Trauma Centers*

Variable	Helmeted (%)	Unhelmeted (%)	$P^{\dagger}$
Number of subjects	354	324	
Mean age (years ± SD)	13.7 ± 2.9	14.5 ± 3.0	<0.001
Age range, y			
≤12	105 (29.7)	52 (16.0)	<0.001
13-18	249 (70.3)	272 (84.0)	
Sex			
Male	283 (80.0)	248 (76.5)	0.28
Skiers	146 (41.2)	99 (30.6)	0.004
Snowboarders	208 (58.8)	225 (69.4)	
Mean length of stay (days ± SD)	2.4 ± 3.2	2.3 ± 2.4	0.84
Discharge from ED‡	60 (18.2)	61 (19.9)	0.59
General admission‡	183 (55.6)	151 (49.3)	0.11
Operating room admission‡	31 (9.4)	25 (9.2)	0.58
ICU admission‡	55 (16.7)	69 (22.5)	0.06
Mean ICU length of stay (days ± SD)	13.5 ± 9.0	13.8 ± 8.5	0.85
Mean GCS (± SD)§	14.1 ± 2.7	14.0 ± 2.9	0.95
Mean ISS (± SD)§	7.5 ± 6.8	8.1 ± 6.8	0.24

*Values are reported as counts or mean values where indicated.

†χ^2 was used for categorical variables and the *t* test for continuous variables.

‡Subjects with discharge status coded as Not Applicable (N = 11), Unknown (N = 10), or Transferred to Another Hospital (N = 22) were excluded from analysis.

§Subjects missing GCS (N = 27) and ISS (N = 9) status were excluded.

Measurements

Demographic characteristics including age, race, sex, and sport (skiing or snowboarding) were examined as potential effect modifiers. Age was stratified by children 12 years or younger and adolescents aged 13 to 18 years. We also examined length of hospital stay, admission to a general floor (floor bed, observation unit, telemetry unit, or step-down unit), admission to the operating room, intensive care unit (ICU) admission, length of ICU stay, and discharge status from the ED as binary variables. The diagnosis of concussion was based on International Classification of Diseases, 9th Revision coding for concussion with or without loss of consciousness (850.0–9).

Measures of injury severity were used to assess the impact of helmet use on severity of concussive injury sustained during skiing and snowboarding accidents. Injury severity was assessed by the Glasgow Coma Scale (GCS) and Injury Severity Score (ISS), where ISS = $A^2 + B^2 + C^2$, and A, B, C correspond to the three most injured body regions scored by AIS.[12] The GCS scores were included if they were documented in the ED. Glasgow Coma Scale ≤ 13 and ISS scores ≥ 15 were considered severe.

Data Analysis

SPSS Statistics Version 20.0 (IBM, Inc., Somers, NY) was used to perform all statistical analyses. We compared demographic and clinical features between helmeted and nonhelmeted subjects using χ^2 for categorical variables and the Student *t* test for continuous variables. A binary logistic regression model was used to determine interaction effects with concussion as the dependent variable and age (continuous), helmet use, and type of sport (skiing or snowboarding) as independent variables. Sensitivity analysis for helmet use was performed using the monotone multiple imputation method[13] using age, sports, and helmet status in the model. The pooled values of 5 imputations were used to determine the potential impact of alternate assumptions regarding the true values for subjects with missing helmet values.

RESULTS

Demographics

A total of 256,528 subjects with age 18 years or younger were initially identified in the NTDB. Of these, 2291 subjects sustained a ski- or snowboard-related injury, with 1001 of these subjects sustaining an injury to the head/neck or face based on AIS codes. Of these, 323 were missing data for helmet status and were thus excluded from our primary analysis, resulting in a sample of 678 subjects. Of the 678 subjects identified, men accounted for 78.3% and women for 21.7% of the sample. The mean age was 14.1 ± 3.0 years. The most common age group

TABLE 2. Concussion and Injury Severity by Helmet Status Among Youth Skiers and Snowboarders

Variable	Total N	Helmeted (%)	Total N	Unhelmeted (%)	*P*
Concussion	354	188 (53.1)	324	162 (50.0)	0.42
GCS* ≤13	185	13 (7.0)	157	19 (12.1)	0.11
ISS† ≥15	186	13 (7.0)	162	11 (6.8)	0.94

*Missing GCS status for concussion: helmeted (N = 3) and unhelmeted (N = 5).

†Missing ISS status for concussion: helmeted (N = 2).

TABLE 3. Binary Logistic Regression Model Parameters

Variables	Coefficient ± SE	Estimated-β	95% CI
Age	−0.32 ± 0.03	0.97	0.92–1.02
Helmet status	−0.18 ± 0.16	0.84	0.61–1.14
Skiing or snowboarding	0.72 ± 0.17	2.10	1.48–2.85

was adolescents between 13 and 18 years, accounting for 76.8% of subjects, whereas children 12 years or younger accounted for 23.2% of subjects. Skiers accounted for 36.1% of subjects and snowboarders for 63.9%.

Injury Characteristics and Helmet Use

We identified 354 helmeted and 324 unhelmeted subjects (Table 1). The mean age for helmeted subjects (years) was 13.7 ± 2.9 and 14.5 ± 3.0 for unhelmeted subjects ($P < 0.001$). Children 12 years or younger were more likely to be helmeted compared to adolescents aged 13 to 18 years (odds ratios [OR], 2.21; 95% confidence interval [95% CI], 1.52–3.21). Men were more likely to be helmeted compared to females, although the difference was not significant (OR, 1.22; 95% CI, 0.85–1.76). When evaluating each sport, we found that skiers were more likely to be helmeted compared to snowboarders (OR, 1.60; 95% CI, 1.16–2.19). The majority of subjects had minor injuries, with 89.9% of helmeted subjects having a GCS score greater than 13 and 87.9% having an ISS score less than 15, and 88.8% of unhelmeted subjects having a GCS score greater than 13 and 85.7% having an ISS score less than 15. The proportion of subjects with minor injuries was similar for helmeted and unhelmeted subjects based on GCS and ISS. Subjects missing GCS or ISS were excluded from this analysis. The mean length of stay, discharge rates from the ED, and admission rates were similar between helmeted and unhelmeted subjects. Subjects that were admitted to an ICU were more likely to be unhelmeted compared to helmeted subjects, although the difference was not significant (OR, 1.45; 95% CI, 0.98–2.15).

Concussion and Helmet Use

We found no statistical difference in the proportion of subjects with concussion (Table 2). Injury severity analysis as assessed by GCS revealed no statistical difference in proportion of severe injuries (GCS ≤13 or ISS ≥15) in helmeted compared to unhelmeted subjects. Subjects' missing values for GCS or ISS were not included in the analysis. Using binary logistic regression, our model indicated that snowboarders had a greater likelihood of concussion (estimated-β, 2.1; 95% CI, 1.48–2.85) after controlling for age and helmet status. Goodness of fit was assessed using the Hosmer-Lemeshow test ($P = 0.88$). Coefficients, odds ratios, and confidence intervals of the model parameters are shown in Table 3.

Sensitivity Analysis

Our study sample included 323 subjects (32.3%) with no information regarding helmet status, which were initially excluded from our primary analysis (Table 4). Those with missing helmet status were noted to have lower mean age compared to those with known helmet status ($P = 0.05$). Additionally, there were significantly more children 12 years or younger among those with missing helmet status compared to those with known helmet status ($P = 0.008$). Those with missing helmet status were of similar sex, race, and type of sport (skiing or snowboarding). Imputing missing values for helmet status had no effect on the proportion of subjects with concussion (Table 5).

DISCUSSION

Using a cross-sectional analysis of a large national trauma registry, this study examines the frequency of concussion among helmeted and unhelmeted youth skiers and snowboarders presenting to trauma centers. We found no difference in the frequency of concussion among helmeted compared to unhelmeted subjects. Our results indicate that, among youth skiers and snowboarders who are evaluated at a trauma center, helmet use is not associated with a reduction in concussion.

Although recent studies have investigated intracranial injuries (ICIs), such as intracranial hemorrhage and cerebral contusion, there have been limited data regarding concussive injury specifically among youth skiers and snowboarders.[14,15] Moreover, the results of currently available studies focusing on youth participants have been conflicting.[6,7] Macnab et al[6] reported an increased risk of combined head, neck, or face injury among unhelmeted youth skiers and snowboarders (RR, 2.24; 95% CI, 1.23–4.12). However, their study was limited in that multiple types of head injuries, including concussion, were grouped into 1 category and analyzed in aggregate as "head, neck, or face injury." In contrast, Rughani et al[7] investigated specific head injuries among helmeted compared to unhelmeted youth skiers and snowboarders and showed no difference in the rates of various ICIs. However, the authors did not specifically investigate concussive injury. One explanation for these disparate findings is the effect of helmet use on concussion. Indeed,

TABLE 4. Demographics of Youth Skiers and Snowboarders by Known and Missing Helmet Status*

Variable	Known Helmet Status (%)	Missing Helmet Status (%)	$P^{\dagger}$
No. subjects	678	323	
Mean age (±SD)	14.1 ± 3.0	13.7 ± 3.3	0.05
Age range, y			
≤12	157 (23.2)	100 (31.0)	0.008
13-18	521 (76.8)	223 (69.0)	
Sex			
Male	531 (78.3)	247 (76.5)	0.51
Skiers	245 (36.1)	114 (35.3)	0.80
Snowboarders	433 (63.9)	209 (64.7)	

*Values are reported as counts or mean values where indicated.

†χ^2 was used for categorical variables and the *t* test for continuous variables.

TABLE 5. Concussion by Helmet Status After Multiple Imputation

Variable	Imputed N	Helmeted (%)	Imputed N	Unhelmeted (%)	*P**
Concussion	512	228 (44.5)	489	219 (44.8)	0.94

*Fisher exact test used when cell count was less than 5.

the majority of head injuries among youth skiers and snowboarders result from an impact that produces abrupt deceleration.[16] In contrast, ICIs and skull fractures are typically produced by higher velocity blunt forces and penetrating injuries. Although this fundamental difference has led to improved helmet designs in other sports, such as competitive and professional football,[17,18] only recently has this been addressed among skiers and snowboarders.

Recent investigation has demonstrated an increasing rate of TBI among youth skiers and snowboarders,[19] particularly among adolescents compared to children,[5] despite a concurrent increase in helmet use.[10,20] This discrepancy has been further illustrated by recent media reports highlighting the considerable TBI frequency among helmeted skiers and snowboarders[21,22] and has led to improved concussion guidelines by the United States Ski and Snowboard Association.[23] It is currently unclear what accounts for the increased TBI rates in the pediatric population, although a number of factors likely contribute including increased awareness of sports-related concussion,[24] variation in risk-taking behavior,[25–27] the proliferation of terrain parks, which may promote more aggressive skiing or snowboarding practices,[19,21,28,29] age differences in protective helmet use,[6,10,20,30] and increased rates of snowboarding.[31] Our results indicate that snowboarders have a greater likelihood of concussion after adjusting for age and helmet status, which is supported by previous data showing increased rates of injures among snowboarders.[10,32,33] Adolescent participants may be particularly prone to TBI because they are more likely to attempt more difficult terrain beyond their ability, use excessive speed, and are subsequently more likely to sustain more severe injuries.[34] Indeed, it has been previously shown that the effectiveness of ski helmets decreases with higher speeds.[19,20,35] Although we did not specifically assess differences in concussion among adolescents compared to children, we found no difference in concussion among helmeted compared to unhelmeted youth skiers and snowboarders younger than 18 years. Notably, the majority of injuries in our study sample were minor, with GCS of 13 or higher and ISS of 15 or lower, which is consistent with previous studies.[16,36]

Limitations

Our study is subject to limitations. Within our sample, 32.3% of subjects were missing information regarding helmet status and of those with known helmet status, there was no distinction between various types of helmets used. It was unclear whether a missing value for helmet status was the result of failure to make a positive report of being un-helmeted rather than a true negative. However, imputing missing helmet values did not change outcome for concussion, further suggesting that helmet use is not associated with a reduction in the frequency of concussive injuries among youth skiers and snowboarders.

Our study is retrospective and uses data compiled from multiple trauma centers. Although the NTDB cleans and standardizes data, the quality of data is dependent on each individual participating center. Additionally, the NTDB is not a population-based data set and is therefore not a nationally representative sample of trauma centers. In particular, the NTDB contains a disproportionately larger number of younger and more severely injured subjects that may not have been fully examined for concussion symptoms. However, in this context, we did identify a large number of subjects with a concussion diagnosis. Our study was also limited by selection bias. Subjects who sustained minor head injuries not severe enough to warrant ski patrol or local hospital evaluation were not included in analysis. Moreover, helmeted subjects may have had to incur greater trauma to achieve similar injury as less traumatized unhelmeted subjects. It is notable that, in this context, we found the majority of head injuries in both helmeted and unhelmeted subjects to be minor (GCS >13 and ISS <15), with no difference in mean GCS or mean ISS, whereas one may have expected such a difference with a data set containing more severely injured subjects. We acknowledge that the application of severity based on GCS and ISS may be not be as pertinent to concussive injury because severity may not be fully elucidated until follow-up care.

CONCLUSIONS

Our results show that, among children and adolescents with a ski or snowboard accident presenting to a trauma center, helmet use is not associated with a difference in frequency of concussion. Adolescent participants are more likely to be unhelmeted compared to younger children, and snowboarders have a greater likelihood of concussion after controlling for age and helmet status. The frequency of concussion among youth skiers and snowboarders is likely influenced by a number of factors, including variations in helmet use, risk-taking behaviors, and increased access to more advanced terrain. The authors do not advocate that youth skiers and snowboards avoid helmet use or that helmets do not help to prevent concussion. Rather, the authors point out that more research is needed to address the issue of concussion among youth skiers and snowboarders, and that better helmets specifically designed to prevent the rotational forces that produce concussive symptoms are needed.

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