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Original Contribution

Helmet Use and Risk of Neck Injury in Skiers and Snowboarders

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In a case-control study, the authors examined the relation between helmet use and neck injury among Québec, Canada, skiers and snowboarders using 10 years of ski patrol data (1995–1996 to 2004–2005). Cases were defined as persons with any neck injury (n = 2,986), an isolated neck injury requiring ambulance evacuation (n = 522), or a cervical spine fracture or dislocation (n = 318). The control group included persons with non-head, non-neck injuries (n = 97,408) in an unmatched analysis. The authors also matched cases with controls injured at the same ski area, during the same activity (skiing vs. snowboarding), and during the same season. Helmet use was the primary exposure variable. For the unmatched analysis, the authors used unconditional logistic regression and adjusted for clustering by ski area and other covariates. They used conditional logistic regression for the matched analysis. Multiple imputation was used to address missing values. The adjusted odds ratio was 1.09 (95% confidence interval (CI): 0.95, 1.25) for any neck injury, 1.28 (95% CI: 0.96, 1.71) for isolated ambulance-evacuated neck injuries, and 1.02 (95% CI: 0.79, 1.31) for cervical spine fractures or dislocations. Similar results were found in the conditional logistic regression analysis and in analyses restricted to children under age 11 years. These results do not suggest that helmets increase the risk of neck injuries among skiers and snowboarders.

head protective devices; neck; skiing; sports; wounds and injuries

Abbreviations: CI, confidence interval; OR, odds ratio.

Recent studies have indicated that ski and snowboard helmets protect against head injuries (1–7). There is concern, however, that head-neck-helmet biomechanics (8) may increase spinal injury risk, and this is of particular concern for children because of their greater head-to-body ratio. It has been hypothesized that in the event of an otherwise ‘‘routine’’ fall, the weight of the helmet may exert large bending or twisting forces on the neck. Because spinal injuries account for 1%–13% of skiing and snowboarding injuries (9), it is important to examine this more closely.

There is limited research regarding helmet use and neck injuries in skiers and snowboarders, but there is some evidence from cyclists and motorcyclists. An extensive systematic review by Liu et al. (10) examined the use of helmets for preventing injury among motorcyclists and concluded that there was insufficient evidence to determine what relation, if any, was present. However, the relevance of this literature is questionable because of differences in helmet design and weight in comparison with skiing and snowboarding helmets. A better comparison might be bicycle helmets. In a meta-analysis on bicycle helmet efficacy, Attewell et al. (11) found 3 studies that observed an association between helmet use and neck injury (odds ratio (OR) = 1.36, 95% confidence interval (CI): 1.00, 1.86).

The skiing and snowboarding literature has been largely inconclusive about the effect of helmets on neck injuries. Data from a number of studies indicate no evidence of an association between helmet use and neck injuries (1, 5, 6, 12, 13). Point estimates of neck injury–helmet use odds ratios, when available, range from 0.62 (95% CI: 0.33, 1.19) (14) to 1.08 (95% CI: 0.98, 1.20) (13). Sulheim et al. (7) concluded that helmets may actually provide skiers and snowboarders with some protection from neck injuries (OR = 0.68, 95% CI: 0.34, 1.35), but this association was not statistically significant. However, the relation between helmet use and neck injuries has not been clarified, primarily because prior studies have not used sufficiently large samples. An exception is a recent, well-conducted investigation by Mueller et al. (6) that found no evidence of a relation between helmets and neck injuries (OR = 0.91, 95% CI: 0.72, 1.14). Although it was much larger than previous studies (565 neck injuries), it used a single definition of neck injury, and the authors did not analyze the effect of helmets separately for younger children (6). Therefore, we conducted a case-control study to examine the association using a much larger database involving 10 seasons of Québec, Canada, ski patrol data, allowing for the use of several definitions of neck injury in different age groups.

MATERIALS AND METHODS

Definition of cases and controls

In this matched case-control study, we used data from the Québec Secrétariat au Loisir et au Sport covering the period from 1995–1996 to 2004–2005. Cases were skiers and snowboarders at a Québec ski area who reported an injury to a ski patrol member and for whom an Accident Report Form for a neck injury (including cervical spine injuries) was completed. When a person had several injuries recorded on the Accident Report Form, 1 of which was a neck injury, he or she was considered a case. We used 2 definitions of severe neck injury: 1) an isolated neck injury that required ambulance evacuation from the ski hill and 2) any recorded neck or cervical spine fracture (simple or compound) or dislocation.

Controls were skiers and snowboarders who reported a non-neck injury (i.e., arm, leg, or trunk) to a ski patrol member at the same ski area in the same year. We excluded skiers and snowboarders who had a face or head injury without a neck injury, to ensure that our main determinant of interest, helmet use, would not be related to any of the control "outcomes" (i.e., head injuries in the control group would underestimate the prevalence of helmet use in the source population).

Data source and collection

The Direction de la Promotion de la Sécurité of the Secrétariat au Loisir et au Sport is responsible for enforcing the Act Respecting Safety in Sports (15). According to the Act, each ski area operator in Québec must ensure that first-aid responders (i.e., ski patrollers) who meet the standards set by the regulations are present in the ski area during all hours of operation (16). Accident Report Form data were obtained from all 91 Québec ski areas in operation at any time from 1995–1996 to 2004–2005.

The Accident Report Forms include information on the location and type of injury for up to 3 injuries. Age, sex, ability, participation, contributing factor, environment, type of hill (snow park vs. other), equipment use, and mode of leaving the hill are also recorded on each form. Ski patrol members are required by law to send these reports to the Secrétariat (16). Secrétariat personnel enter the information into a database after excluding personal identifiers.

Matching injured controls

We matched cases and controls in the following order: ski area, activity (skiing vs. snowboarding), and date of injury. The number of cases and controls in a set depended simply on the number of skiers or snowboarders who had a case or control injury at a particular ski area on a particular date; therefore, matched sets contained a variable number of cases and controls.

Because we did not match a case to a control from another ski area or from a different season, our findings were controlled for subjective characteristics of the hill, such as difficulty of run. In addition, we did not match skiers to snowboarders, since prior work has demonstrated substantial differences in injury risk between the 2 activities (14).

Variable coding

Coding of variables required consistency within years because of changes in the Accident Report Forms. The greatest changes in the forms occurred between the 1998–1999 and 1999–2000 seasons, in which 2 or more categories were created from 1 preexisting category, names of categories were changed, coding changed, and the format of the forms changed. Thus, for a number of categories, the only option was to code them in a less detailed manner.

The Accident Report Forms were used to code the characteristics of the injured person as follows: age ($<$11, 11–14, 15–18, 19–24, or $\geq$25 years), activity (skiing or snowboarding), sex, ability (beginner, intermediate, or expert), number of days of participation in skiing or snowboarding that season (first day, 2–10 days, or $\geq$11 days), hours of participation on the day of injury ($<$5 or $\geq$5), whether the individual had had lessons (yes or no), and type of participation (recreation, competition/training, lesson, school outing). Helmet use was coded yes/no and ownership of equipment as owned versus rented/borrowed. The mechanism of injury was based on whether the injury involved a collision with another person or object or a noncollision. Environmental characteristics at the time of injury included: run difficulty (easy, difficult, very difficult, or extreme), visibility (fair, average, or good), temperature (<-10°C, -10°C to -1°C, or >-1°C), weather conditions (clear/sunny, snowing/raining/blowing snow/foggy/windy, or cloudy), type of light (natural or artificial), and snow conditions (groomed, powder, corn/crud/crusty, ice, or wet). Finally, season was coded biennially as 1995–1997, 1997–1999, 1999–2001, 2001–2003, or 2003–2005.

Ethical approval for the study was obtained through the Office of Medical Bioethics, Faculty of Medicine, University of Calgary, Calgary, Alberta, Canada.

Analysis

We tabulated helmet use and individual and environmental characteristics with 3 outcomes: 1) any neck or cervical spine injury, 2) an isolated neck or cervical spine injury requiring ambulance evacuation, and 3) a neck or cervical spine fracture or dislocation.

For unconditional logistic regression models, Harrell et al. (17) suggest that the number of independent variables

Table 1. Personal Characteristics of 2,986 Skiers and Snowboarders With Neck Injuries and 97,408 Injured Controls Without Neck Injuries, Québec, Canada, 1995–2005

Characteristic	Cases						Controls (No Head or Face Injury)	
	Any Neck Injury		Isolated Neck Injury With Ambulance Evacuation		Neck or Cervical Spine Fracture/ Dislocation			
	No.	%	No.	%	No.	%	No.	%
Equipment details								
Helmet use								
Yes	763	25.6	151	28.9	84	26.4	20,259	20.8
No	2,223	74.5	371	71.1	234	73.6	77,149	79.2
Total	2,986	100	522	100	318	100	97,408	100
Activity								
Snowboarding	1,468	49.2	256	49.0	159	50.0	54,923	56.4
Skiing (skis, miniskis, freestyle)	1,518	50.8	266	51.0	159	50.0	42,485	43.6
Missing data	0	0.00		0.00		0.00		0.00
Total	2,986	100	522	100	318	100	97,408	100
Ownership of equipment								
Own equipment	2,156	72.2	369	70.7	220	69.2	67,435	69.2
Rented or borrowed equipment	757	25.4	145	27.8	92	28.9	28,276	29.0
Missing data	73	2.4	8	1.5	6	1.9	1,697	1.7
Total	2,986	100	522	100	318	100	97,408	100
Demographic factors								
Age, years								
1–10	449	15.0	83	15.9	36	11.3	12,814	13.2
11–14	978	32.8	188	36.0	96	30.2	29,074	29.9
15–18	695	23.3	113	21.7	86	27.0	20,013	20.6
19–25	297	10.0	46	8.8	37	11.6	10,842	11.1
>25	528	17.7	83	15.9	60	18.9	23,465	24.1
Missing data	39	1.3	9	1.7	3	0.9	1,200	1.2
Total	2,986	100	522	100	318	100	97,408	100
Sex								
Male	1,508	50.5	243	46.6	163	51.3	53,166	54.6
Female	1,455	48.7	276	52.9	151	47.5	43,529	44.7
Missing data	23	0.8	3	0.6	4	1.3	713	0.7
Total	2,986	100	522	100	318	100	97,408	100
Experience								
Ability								
Beginner	968	32.4	184	35.3	97	30.5	35,911	36.9
Intermediate	1,245	41.7	216	41.4	134	42.1	40,441	41.5
Advanced	633	21.2	99	19.0	65	20.4	18,582	19.1
Missing data	140	4.7	23	4.4	22	6.9	2,474	2.5
Total	2,986	100	522	100	318	100	97,408	100

Table continues

should be less than 10% of the minimum of the number of cases or controls, to guard against overfitting the model. When this condition was met, we entered all variables into the model to obtain the helmet effect estimate (i.e., odds ratio). When the number of variables exceeded the 10% rule of thumb, we used a forward selection process. That is,

Table 1. Continued

Characteristic	Cases						Controls (No Head or Face Injury)	
	Any Neck Injury		Isolated Neck Injury With Ambulance Evacuation		Neck or Cervical Spine Fracture/ Dislocation			
	No.	%	No.	%	No.	%	No.	%
No. of days of having skied/snowboarded in that year								
1 (first day)	614	20.6	127	24.3	67	21.1	27,571	28.3
2–10	1,367	45.8	224	42.9	145	45.6	46,645	47.9
≥11	797	26.7	137	26.3	78	24.5	20,630	21.2
Missing data	208	7.0	34	6.5	28	8.8	2,562	2.6
Total	2,986	100	522	100	318	100	97,408	100
Receipt of lessons								
Yes	986	33.0	161	30.8	101	31.8	36,124	37.1
No	1,714	57.4	312	59.8	178	56.0	56,442	57.9
Missing data	286	9.6	49	9.4	39	12.3	4,842	5.0
Total	2,986	100	522	100	318	100	97,408	100
No. of hours of participation before injury								
<5	2,469	82.7	439	84.1	261	82.1	85,235	87.5
≥5	328	11.0	60	11.5	37	11.6	9,326	9.6
Missing data	189	6.3	23	4.4	20	6.3	2,847	2.9
Total	2,986	100	522	100	318	100	97,408	100
Circumstances of injury								
Type of participation at time of injury								
Recreation	2,223	74.5	394	75.5	233	73.3	76,903	79.0
Competition/training	144	4.8	20	3.8	11	3.5	2,842	2.9
Lesson	239	8.0	47	9.0	23	7.2	7,963	8.2
School outing	230	7.7	41	7.9	38	12.0	5,578	5.7
Missing data	150	5.0	20	3.8	13	4.1	4,122	4.2
Total	2,986	100	522	100	318	100	97,408	100
Mechanism of injury								
Collision with another person	261	8.7	49	9.4	31	9.8	4,880	5.0
Collision with an object	112	3.8	11	2.1	19	6.0	2,099	2.2
Noncollision	2,323	77.8	423	81.0	241	75.8	83,557	85.8
Missing data	290	9.7	39	7.5	27	8.5	6,872	7.1
Total	2,986	100	522	100	318	100	97,408	100

variables were entered one at a time, and the variable that resulted in the largest change in the helmet effect estimate was retained. This process was repeated until no additional variables changed the effect estimate more than 10% or until the number of variables equaled 10% of the minimum of the number of cases or controls. We based the maximum number of variables to be added to the model on the number of cases or controls with nonmissing data for all variables. When a sufficient number of cases were available for a particular analysis based on the above rule of thumb, for substantive reasons we included, in order, helmet use, age, sex, activity, ability, and season in the models. This approach was used for all 3 case definitions. We also conducted a subanalysis among children under the age of 11 years, whose risk of neck injury may be most affected by helmet use.

Table 2. Environmental Characteristics of 2,986 Skiers and Snowboarders With Neck Injuries and 97,408 Injured Controls Without Neck Injuries, Québec, Canada, 1995–2005

Characteristic	Cases						Controls (No Head or Face Injury)	
	Any Neck Injury		Isolated Neck Injury With Ambulance Evacuation		Neck or Cervical Spine Fracture/ Dislocation			
	No.	%	No.	%	No.	%	No.	%
Hill characteristics								
Run difficulty at time of injury								
Extremely difficult	201	6.7	22	4.2	18	5.7	6,216	6.4
Very difficult	541	18.1	89	17.1	67	21.1	16,897	17.4
Difficult	906	30.3	173	33.1	96	30.2	27,546	28.3
Easy	892	29.9	178	34.1	103	32.4	31,596	32.4
Missing data	446	14.9	60	11.5	34	10.7	15,153	15.6
Total	2,986	100	522	100	318	100	97,408	100
Snow conditions								
Groomed	1,640	54.9	275	52.7	183	57.6	56,870	58.4
Powder	613	20.5	116	22.2	62	19.5	19,089	19.6
Corn, crud, or crusty	169	5.7	27	5.2	11	3.5	5,190	5.3
Ice	53	1.8	9	1.7	6	1.9	2,025	2.1
Wet	254	8.5	53	10.2	18	5.7	7,036	7.2
Missing data	257	8.6	42	8.1	38	12.0	7,198	7.4
Total	2,986	100	522	100	318	100	97,408	100
Weather conditions								
Visibility								
Fair	74	2.5	15	2.9	6	1.9	2,270	2.3
Average	383	12.8	77	14.8	42	13.2	11,789	12.1
Good	2,403	80.5	412	78.9	260	81.8	79,904	82.0
Missing data	126	4.2	18	3.5	10	3.1	3,445	3.5
Total	2,986	100	522	100	318	100	97,408	100
Temperature								

Table continues

For the conditional logistic regression analysis, we first created matched sets based on cases and controls injured at the same ski area who were participating in the same activity (skiing vs. snowboarding) on the same day. We used the same modeling approach as we used for the unconditional logistic regression analysis. However, because only discordant sets contribute to estimation in a matched study, we used the 10%-or-fewer rule of thumb for the number of discordant matched sets to avoid overfitting. Because of missing data or concordance among variables within a matched set, we based the 10%-or-fewer rule of thumb on the actual number of discordant sets used in the analysis. When a sufficient number of discordant sets were available for a particular analysis, we included, in order, helmet use, age, sex, and ability in the models for substantive reasons and used this as the starting model. As we did for the unconditional logistic regression analysis, we conducted a subanalysis in children under age 11 years.

To address the problem of missing data, we used multiple imputation by chained equations with 5 imputed data sets (18) and then repeated each of the unconditional and conditional logistic regression analyses. For the imputation of all variables, we used injury location (head, face, neck, trunk, upper extremity, or lower extremity) helmet use, age, sex, activity, ability, and biennium (1995–1997, 1997–1999, 1999–2001, 2001–2003, or 2003–2005) as predictors. All analyses were conducted in Stata/SE, version 10 (19).

RESULTS

Over 10 seasons in Québec, there were 133,263 ski patrol reports completed, of which 25,320 records for head and facial injuries were excluded (n = 107,943). Data were missing on body region of injury for 1,265 records, on activity for 3,596 records, and on both for 297 records. After restriction to only skiers and snowboarders with complete

Table 2. Continued

Characteristic	Cases: Any Neck Injury		Cases: Isolated Neck Injury With Ambulance Evacuation		Cases: Neck or Cervical Spine Fracture/ Dislocation		Controls (No Head or Face Injury)	
	No.	%	No.	%	No.	%	No.	%
Below −10°C	610	20.4	104	19.9	81	25.5	20,359	20.9
−10°C to −1°C	1,658	55.5	296	56.7	176	55.4	55,948	57.4
Above −1°C	613	20.5	112	21.5	50	15.7	18,153	18.6
Missing data	105	3.5	10	1.9	11	3.5	2,948	3.0
Total	2,986	100	522	100	318	100	97,408	100
Weather								
Clear, sunny	1,657	55.5	281	53.8	165	51.9	55,134	56.6
Snowing, raining, blowing snow, foggy, or windy	543	18.2	95	18.2	48	15.1	17,922	18.4
Cloudy	385	12.9	73	14.0	53	16.7	12,190	12.5
Missing data	401	13.4	73	14.0	52	16.4	12,162	12.5
Total	2,986	100	522	100	318	100	97,408	100
Type of light								
Natural	2,168	72.6	394	75.5	224	70.4	70,684	72.6
Artificial	569	19.1	97	18.6	73	23.0	18,858	19.4
Missing data	249	8.3	31	5.9	21	6.6	7,866	8.1
Total	2,986	100	522	100	318	100	97,408	100
Biennium								
1995–1997	375	12.6	51	9.8	36	11.3	14,291	14.7
1997–1999	407	13.6	62	11.9	40	12.6	15,536	16.0
1999–2001	588	19.7	87	16.7	57	17.9	18,838	19.3
2001–2003	802	26.9	147	28.2	85	26.7	24,102	24.7
2003–2005	814	27.3	175	33.5	100	31.5	24,641	25.3
Total	2,986	100	522	100	318	100	97,408	100

data on outcome and activity, there were 2,986 neck injuries (3% of all injuries), 522 (0.5%) isolated neck injuries requiring ambulance evacuation, and 318 (0.3%) neck or cervical spine fractures or dislocations among skiers and snowboarders.

Table 1 shows the personal characteristics of the cases and controls at the time of injury. Compared with controls, cases with any neck injury were more likely to be wearing a helmet, to be skiing versus snowboarding, and to have participated in the activity for more than 10 days that season. Those with a non-neck injury tended to be older (>25 years), male, and involved in a noncollision injury. There were no noteworthy differences in environmental characteristics at the time of injury (Table 2).

Because there were substantial missing data (only 64,208 of the eligible 133,263 reports (48%) had complete data for all variables considered, including outcome), we repeated the analyses after imputing missing data. Comparison of the multiple-imputation analysis with the complete-case analysis indicated little difference in results between the 2 approaches. Therefore, we elected to present the results based on multiple imputation, since these results were less subject to bias.

Table 3 shows the relation between helmet use and neck injuries. In the unconditional logistic regression analysis, regardless of the severity of the neck injury, the crude odds ratios all indicated that there were statistically significantly increased odds of neck injury among skiers and snowboarders who wore a helmet compared with skiers and snowboarders who did not. However, after adjustment, the odds ratios were not significant, being 1.09 (95% CI: 0.95, 1.25) for any neck injury, 1.28 (95% CI: 0.96, 1.71) for neck injury requiring ambulance evacuation, and 1.02 (95% CI: 0.79, 1.31) for neck or cervical spine fracture or dislocation.

Similarly, in the conditional logistic regression analysis, cases and controls were matched on injury day, ski area, and activity. The crude analysis showed that there were significantly higher odds of neck injury among persons wearing a helmet compared with those not wearing a helmet (OR = 1.20, 95% CI: 1.06, 1.36); however, the strength of the

Table 3. Odds Ratios From Multiple Imputation Analysis of the Relation Between Helmet Use and Neck Injury, Québec, Canada, 1995–2005

Age Group, Analysis, and Adjustment Factor(s)	Any Neck Injury		Isolated Neck Injury With Ambulance Evacuation		Neck or Cervical Spine Fracture/ Dislocation	
	OR	95% CI	OR	95% CI	OR	95% CI
All ages						
Unconditional logistic regression[a]						
Crude	1.30	1.18, 1.43	1.59	1.30, 1.93	1.29	1.00, 1.65
Age, sex, activity, ability, and season	1.10	0.98, 1.24	1.23	0.99, 1.53	1.14	0.87, 1.50
Age, sex, activity, ability, biennium, and no. of skier days					1.02[b]	0.79, 1.31
All covariates	1.09	0.95, 1.25	1.28	0.96, 1.71		
Conditional logistic regression[c]						
Matched set	1.20	1.06, 1.36	1.17	0.88, 1.57	1.05	0.74, 1.50
Age			1.11[d]	0.81, 1.52		
Age and sex					1.13[e]	0.78, 1.64
Age, sex, and ability	1.07[f]	0.93, 1.22				
Children aged <11 years						
Unconditional logistic regression[a]						
Crude	1.26	1.02, 1.57	2.12	1.39, 3.23	1.19	0.61, 2.29
Sex, activity, and ability					1.03[g]	0.53, 1.99
Sex, activity, ability, and biennium	0.98	0.74, 1.29	1.56[h]	0.98, 2.48		
All covariates	0.94	0.60, 1.48				
Conditional logistic regression[c]						
Matched set	1.11	0.68, 1.81	0.77[i]	0.26, 2.24	0.36[j]	0.04, 3.10
Sex	1.11[k]	0.69, 1.81				

Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Cluster adjustment for ski area.
[b] There were 346 cases, so no more than 34 variables were included in the analysis.
[c] Sets were matched on ski area, activity, and date of injury.
[d] Only age was retained in the model, since the addition of sex or ability exceeded the allowable number of variables for the number of discordant sets.
[e] Only age and sex were retained in the model, since the addition of ability exceeded the allowable number of variables for the number of discordant sets.
[f] No additional variables changed the effect estimates more than 10% without exceeding the allowable number of variables for discordant sets.
[g] Adjusted for sex, activity, and ability, since there were only 55 cases.
[h] Season was coded as 1995–1997, 1997–1999, or 1999–2001 to ensure that there were only 8 variables in the model, given that there were 86 cases.
[i] Total of 15 discordant sets.
[j] Total of 5 discordant sets.
[k] Adjusted for sex, since there were only 36 discordant sets.

association decreased and was not statistically significant after controlling for potential confounders (OR = 1.07, 95% CI: 0.93, 1.22). Moreover, both the crude and adjusted estimates revealed no statistically significant associations between helmet use and more severe neck injuries, with adjusted point estimates of 1.11 for isolated, ambulance-evacuated injuries and 1.13 for neck-cervical spine fractures or dislocations.

Because young children are thought to be at increased risk for a neck injury due to the added weight of the helmet, we conducted a subanalysis restricted to children under age 11 years. The crude analysis from unconditional logistic regression showed that children had increased odds of any neck injury and neck injury requiring ambulance evacuation when wearing a helmet. After controlling for all covariates, however, this association was no longer significant for any neck injury (OR = 0.94, 95% CI: 0.60, 1.48). The odds ratio for the relation between helmet use and neck injury requiring ambulance evacuation was 1.56 (95% CI: 0.98, 2.48) after adjustment for sex, activity, ability, and season. Neither the crude analysis nor the adjusted (sex, activity, ability) analysis showed a statistically significant association between helmet use and neck or cervical spine fracture or dislocation (OR = 1.03, 95% CI: 0.53, 1.99). In addition, none of the odds ratios generated from the conditional logistic regression model were statistically significant when matched on activity, ski area, and date of injury, with estimates ranging from 0.36 for neck-cervical spine fractures/ dislocations to 1.11 for any neck injury.

When we evaluated interaction terms for age and helmet use in the full unconditional logistic regression model for any neck injury, the interaction terms were not statistically significant in an omnibus test based on differences in model log likelihoods ($P = 0.2768$). The effect estimates ranged from 0.95 for children aged 11–14 years (95% CI: 0.78, 1.15) to 1.39 for persons aged 26 years or older (95% CI: 0.94, 2.05). The estimate for children under age 11 years was 1.26 (95% CI: 0.90, 1.77), and none of the estimates excluded the null value of 1.0.

The interaction terms for age and helmet use in the full, unconditional logistic regression model for isolated neck injuries requiring ambulance evacuation were not statistically significant in an omnibus test based on differences in model log likelihoods ($P = 0.2137$). The effect estimates ranged from 0.59 for youths aged 15–18 years (95% CI: 0.25, 1.42) to 2.04 for children under age 11 years (95% CI: 0.95, 4.40). The confidence intervals for the estimate among persons aged 26 years or older excluded the null value of 1.0 (OR = 1.86, 95% CI: 1.05, 3.33).

We could not evaluate interaction terms in any of the other models, since there were insufficient numbers of cases to allow the addition of more variables.

DISCUSSION

To our knowledge, this is the largest study to have examined the effect of helmet use on neck injuries in skiers and snowboarders. It involved 10 years of data and more than 100,000 participants and used several definitions of neck injury. We also conducted an analysis among children under age 11 years, who are thought to be at greatest risk because of the weight of the helmet. After adjusting for confounding factors, we did not find evidence of a relation between neck injuries and helmet use. We found similar results after accounting for missing values using multiple imputation. Although the effect estimate for children under age 11 years in the unconditional logistic regression analysis of ambulance-evacuated, isolated neck injuries was 2.04, the confidence intervals included the null value of 1.0 and the overall test for interaction in the model was not statistically significant, arguably precluding the interpretation of age-specific estimates. Further, we would argue that the original analysis restricted to children under age 11 years would have provided a more reasonable estimate of the relation between helmet use and neck injury in that the model was based on a single, homogeneous age group.

Our results are similar to those of other investigations (20). Although many of the other studies that have examined the association have been limited by small numbers of neck injury events, they also found no increased risk of neck injuries among persons wearing helmets. For example, the number of neck injuries available for analysis in studies reporting odds ratios for the neck injury–helmet use relation ranged from 22 in the study by Macnab et al. (5) to 131 in the study by Hagel et al. (14). In one of the largest and most methodologically robust recent studies conducted on the issue, Mueller et al. (6) reported an adjusted odds ratio for helmet use of 0.91 (95% CI: 0.72, 1.14) based on 565 neck injuries accrued over 5 seasons, using a ski patrol reported injury definition comparable to our "any neck injury" outcome. However, the authors did not examine the subset of potentially more severe injuries, and they did not focus on the youngest age group.

Limitations

Selection bias would be an issue if the relation between neck injuries and helmet use differed for persons who were seen by the ski patrol and those who were not. For minor injuries, it is likely that the ski patrol missed some cases and controls who, if they sought care at all, proceeded directly to a health-care provider. This is much less likely for the more "severe" definitions of neck injury, because few such victims would be able to proceed to a hospital without the assistance of the ski patrol. In addition, both cases and controls were injured, so the factors that resulted in the cases' presenting to the ski patrol would also have existed for controls.

Some potential misclassification bias probably exists in our study, and it is possible that it is differential. For example, it is likely that controls with upper- or lower-extremity injuries would be less likely to have helmet use recorded than those with neck injuries. If this occurred, it would have decreased the prevalence of helmet use among controls, thus increasing the likelihood of finding a link between helmets and neck injury risk. However, since we did not find any such significant association, the effect of this bias, if present, was negligible.

The ski patrol recorded injuries on a standard data collection form but did not have access to diagnostic equipment (e.g., an x-ray machine) to confirm their assessment of injuries such as fractures. Thus, the assessment of neck or cervical spine fracture or dislocation was based only on the ski patrol member's considered assessment of the injured individual. Although it is likely that some of these persons would have gone on to be diagnosed by a physician as not having a neck or cervical fracture, it is highly unlikely that the ski patrol would indicate a neck injury when a skier or snowboarder had an injury to another body region.

In terms of potentially confounding factors for the helmet use–neck injury relation, we adjusted for many variables captured by the ski patrol reports, including demographic factors and crash circumstances. We could not adjust for all potentially confounding variables in all analyses, as there were simply too few neck injury outcomes, even with 10 years of data. However, in the strongest comparisons for children, using conditional logistic regression with multiple imputation of missing values, odds ratios ranged from 0.36 for severe neck injuries adjusted for matched set to 1.11 for all neck injuries adjusted for matched set and sex.

There has been speculation that wearing a helmet may give the user a false sense of security, resulting in greater risk-taking—the ''risk compensation'' hypothesis (21). Although we failed to find a risk compensation effect with helmet use in our previous work on skiing and snowboarding (22), if persons who wore helmets took more risks than those who did not, helmet users would increase their risks of both neck injury and other injuries. Related to this, if risk-takers were more likely to sustain a neck injury because of the way they participated and were less likely to wear a helmet, this would bias our results toward the null. However, given that all subjects in this study went through an injury-producing event (i.e., injured controls) and we adjusted for potential ''behavior''-related variables such as injury mechanism and related factors such as skill level, it is unlikely that risk-taking behavior confounded our results.

Conclusions

We did not find evidence of a relation between helmet use and the risk of neck injuries among skiers and snowboarders, regardless of the severity of the neck injury. Among children, who have a larger head-to-body ratio than adults, there was also no statistically significant association. Regardless of the results, reductions in the weight of ski and snowboard helmets that offer adequate protection should remain a goal for manufacturers. Our study provides additional evidence that helmets do not significantly increase the risk of neck injuries among skiers and snowboarders, and their use should be encouraged.

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