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Papers

Effectiveness of helmets in skiers and snowboarders: case-control and case crossover study

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Abstract

Objective To determine the effect of helmets on the risk of head and neck injuries in skiers and snowboarders.
Design Matched case-control and case crossover study.
Setting 19 ski areas in Quebec, Canada, November 2001 to April 2002.
Participants 1082 skiers and snowboarders (cases) with head and neck injuries reported by the ski patrol and 3295 skiers and snowboarders (controls) with non-head or non-neck injuries matched to cases at each hill.
Main outcome measures Estimates of matched odds ratios for the effect of helmet use on the risk of any head or neck injury and for people requiring evacuation by ambulance.
Results The adjusted odds ratio for helmet use in participants with any head injury was 0.71 (95% confidence interval 0.55 to 0.92), indicating a 29% reduction in the risk of head injury. For participants who required evacuation by ambulance for head injuries, the adjusted odds ratio for helmet use was 0.44 (0.24 to 0.81). Similar results occurred with the case crossover design (odds ratio 0.43, 0.09 to 1.83). The adjusted odds ratio for helmet use for participants with any neck injury was 0.62 (0.33 to 1.19) and for participants who required evacuation by ambulance for neck injuries it was 1.29 (0.41 to 4.04).
Conclusions Helmets protect skiers and snowboarders against head injuries. We cannot rule out the possibility of an increased risk of neck injury with helmet use, but the estimates on which this assumption is based are imprecise.

Introduction

In 1983, Oh and Schmid argued that helmet use should be mandatory in skiers up to the age of 17 owing to the risk of severe head injuries.[1] Guided by compelling evidence that helmets are effective at preventing head, brain, and facial injuries in bicyclists, helmet use would seem to be reasonable.[2] Helmets are not yet widely recommended in skiers and snowboarders because of the paucity of information on their effectiveness. The best evidence suggests they are protective, but this was based on a study that was restricted to participants aged less than 13 years, had a small sample size, and lacked control for potential confounders.[3] Helmets may increase the risk of spinal injury owing to the biomechanics of the association between the helmet and the head and neck[4 5]—a particular concern for children, who have a greater head to body ratio. A helmet may exert large bending or twisting forces on the neck in the event of an otherwise "routine" fall. We determined the effect of helmet use on the risk of head and neck injuries in skiers and snowboarders.

Methods

We invited 20 of the largest ski areas in Quebec, Canada, to take part in our study over the 2001-2 ski season (November to April) through initial contact with the director and chief ski patrol member.

Cases

Cases were those people with an accident report form completed by the ski patrol for a head (including face) or neck injury while skiing or snowboarding, as indicated by the body region recorded (head, face and neck or cervical spine).

We defined potentially severe cases as people with isolated (one body region) head or neck injuries who needed to be evacuated by ambulance. This subset ensured that no other injury was responsible for the evacuation.

The accident report form provided details for three injury types and three body regions. We considered people as cases when several injuries were recorded and one was of the head or neck.

Controls

Controls were people with non-head or non-neck injuries who were reported by ski patrols at the same ski areas as for cases. We used a case crossover approach, with cases acting as their own controls by self reporting on their participation in skiing or snowboarding before the day of injury.

Data collection

We asked the ski patrols to send us their accident report forms every two or three weeks. Photocopies of these were sent by the Quebec secretariat of leisure and sport to the Montreal Children's Hospital, where we abstracted the details on address, phone number, activity (skiing or snowboarding), date of injury, age, sex, and type of injury.

We sent questionnaires by post or scheduled a telephone call (to those with no address listed) to all the cases, and to controls matched for ski area, activity (skiing or snowboarding), date of injury, age (< 15, 15-25, and ≥ 26), and sex. Parents responded for participants aged less than 15 years. We attempted to contact non-responders by telephone (if phone number was available) up to five times or we sent out another questionnaire (if no phone number was available).

In addition to helmet use, we asked about potential determinants of head and neck injury: general characteristics (age, sex, ability, experience, lessons, education, and previous head or neck injury) and circumstances at the time of the injury (hours of participation in the activity, damage to non-helmet equipment, self reported speed in relation to average, participation type, mechanism of injury (collision or jump, fall), protective equipment other than a helmet, run difficulty (easy, difficult, very difficult to extreme), visibility (good, average to fair), snow conditions (groomed to hard pack ice, other), and temperature (≤10°C, −10°C to −1°C, ≥0°C).

Case crossover methods

For the case crossover approach we used information from cases with head injuries only. We chose the day the individual was injured as the case period of time, and we considered as the control period that same person's previous outing for skiing or snowboarding when they were not injured. This method provided matched case-controls.

Statistical analysis

We used conditional logistic regression to analyse cases matched to controls. To assess for confounding we examined changes in the estimates for helmet effect and the confidence intervals.[6] When appropriate, we used a backward elimination approach.[6 7] Briefly, we fit the full model with all covariates, representing the ideal. We then removed the covariate with the smallest influence on the helmet effect and repeated the procedure. When two covariates had an equal effect, we omitted the one which, after being removed, produced the smallest standard error for the helmet effect. For substantive reasons, we retained the variables for age and sex.

To avoid over-fitting we used the 10% or fewer guideline for the number of discordant matched sets.[8 9] When the number of independent variables exceeded 10%, we used a forward selection strategy, adding the covariates individually and retaining those that had the largest influence on the point estimate. This was done until the estimate was not changed by more than 10%, or before 10% of the number of discordant matched sets was exceeded.

Sensitivity analysis

We used information from the accident report form to examine the effect of non-responders on the analysis of each outcome. To assess influential observations, we measured the standardised differences in regression estimates after deletion of each observation. We omitted the three observations, along with their matched sets, that produced the largest influence on the final estimated odds ratio for each outcome, and refitted the model. Regression analyses were carried out in SAS version 8.02.

Results

Of the 20 ski areas invited to participate in our study, one failed to return its accident report forms in time and was excluded from analysis. We sent out a questionnaire or scheduled a call to 1576 cases with head, face, or neck injuries and 4667 controls. The overall response rate was 70.1% (68.7% (1082 participants) for cases with head, face, and neck injuries and 70.6% (3295 participants) for controls), similar to snowboarders (71.9%, 2041 participants) and skiers (68.7%, 2335 participants), and age group (67.0%, 1582 participants to 73.0%, 1726 participants). Response rates varied between ski areas (55.1%, 27 participants to 84.7%, 133 participants).

Overall, 693 people had head injuries, with 69.7% (483) assessed as concussion. Of the 469 participants with isolated head injuries, 32.4% (152) were evacuated by ambulance; this proportion increased to 43.2% (107) when we considered only isolated head injuries assessed as concussion. In total, 44% (58) of the neck injuries were assessed as sprains, 16.0% (21) were assessed as fractures, and 6.9% (9) were assessed as muscle or nerve strains. Of the participants with isolated neck injuries, 56.1% (23) were evacuated by ambulance.

Table 1 Characteristics of cases and controls and event around injury. Values are numbers (percentages)

Characteristic	Cases with head injuries (n=693)	Cases with neck injuries (n=131)	Controls (n=3295)
Age (years):			
<15	257 (37.1)	65 (49.6)	1277 (38.7)
15-25	287 (41.4)	49 (37.4)	1185 (36.0)
≥26	149 (21.5)	17 (13.0)	832 (25.3)
Missing data	—	—	1 (0.03)
Sex:			
Male	421 (60.8)	55 (42.0)	1457 (55.8)
Female	272 (39.3)	76 (58.0)	1837 (44.2)
Missing data	—	—	1 (0.03)
No of days participated in activity in season:			
1	160 (23.1)	31 (23.7)	929 (28.2)
2-10	333 (48.1)	49 (37.4)	1690 (51.3)
≥11	168 (24.2)	41 (31.3)	591 (17.9)
Missing data	32 (4.6)	10 (7.6)	85 (2.6)
Previous head or neck injury:			
No	515 (74.3)	96 (73.3)	2643 (80.2)
Yes	171 (24.7)	35 (26.7)	631 (19.2)
Missing data	7 (1.0)	—	21 (0.6)
Hours of participation in activity before injury:			
<2	239 (34.5)	50 (38.2)	1322 (40.1)
2-5	396 (57.1)	80 (61.1)	1688 (51.2)
≥6	57 (8.2)	1 (0.8)	284 (8.6)
Missing data	1 (0.1)	—	1 (0.03)
Damage to non-helmet equipment:			
No	626 (90.3)	119 (90.8)	3062 (92.9)
Yes	53* (7.7)	9 (6.9)	189† (5.7)
Missing data	14 (2.0)	3 (2.3)	44 (1.3)
Self reported speed:			
Slow	155 (22.4)	33 (25.2)	1005 (30.5)
Average	206 (29.7)	46 (35.1)	1171 (35.5)
Fast	231 (33.3)	41 (31.3)	739 (22.4)
Missing (and other‡)	101 (14.6)	11 (8.4)	380 (11.5)
Mechanism of injury:			
Collision or jump	344 (49.6)	56 (42.8)	1321 (40.1)
Fall	346 (50.0)	75 (57.3)	1949 (59.2)
Missing	3 (0.4)	—	25 (0.8)
Non-helmet protective equipment:			
No	652 (94.1)	122 (93.1)	3159 (95.9)
Yes§	41 (5.9)	9 (6.9)	136 (4.1)

*Excludes 28 individuals who had damaged either their goggles or sunglasses. These individuals were considered not to have had equipment damage.
†Excludes 5 individuals who had damaged either their goggles or sunglasses. These individuals were considered not to have had equipment damage.
‡For example, injured on lift.
§Excludes all yes answers with only "goggles" or "sunglasses" specified.

Table 1 lists the characteristics of the cases and controls at the time of injury. Cases with head injuries reported a collision or jump related injury more often than controls. Compared with controls, cases with neck injuries were more likely to be younger, to be female, to have participated for 11 or more days and for fewer hours before the injury, and to have had a previous head or neck injury.

The proportion of participants with head injuries or potentially severe head injuries who wore a helmet was similar to that of controls but was higher among those with neck injuries (table 2). The prevalence of helmet use decreased with increasing

Table 2 Frequency of helmet use in cases with head and neck injuries and controls. Values are numbers (percentages)

	Head injuries*		Neck injuries		
Characteristic	All injuries	Potentially severe injuries†	All injuries	Potentially severe injuries†	Controls
Wore helmet					
No	518 (74.8)	115 (75.7)	87 (66.4)	14 (60.9)	2366 (71.8)
Yes	175 (25.3)	37 (24.3)	44 (33.6)	9 (39.1)	929 (28.2)
Helmet use by age (years)					
<15:					
No	110 (42.8)	46 (67.7)	33 (50.8)	8 (57.1)	665 (52.1)
Yes	147 (57.2)	22 (32.4)	32 (49.2)	6 (42.9)	612 (47.9)
15-25:					
No	243 (84.7)	45 (80.4)	38 (77.6)	5 (62.5)	983 (83.0)
Yes	44 (15.3)	11 (19.6)	11 (22.5)	3 (37.5)	202 (17.0)
≥26:					
No	129 (86.6)	26 (86.7)	16 (94.1)	1 (100.0)	718 (86.3)
Yes	20 (13.4)	4 (13.3)	1 (5.9)	—	114 (13.7)

*Includes any head injury accompanied by facial injury.
†Required evacuation by ambulance.

age for all groups. Cases aged less than 15 years with head injuries had a higher prevalence of helmet use than controls whereas cases aged less than 15 years with potentially severe head injuries had a lower prevalence of helmet use than controls. The proportion of helmet users among cases aged 15 to 25 with potentially severe neck injuries (37.5%; three participants) was greater than among controls (17.0%; 202 participants), although this result is based on only eight cases.

All case-control sets among responders were well matched for ski area. Of the 1044 sets with one case and at least one control, 1026 (98.3%) were well matched for activity, and 428 (41%) were well matched for date of injury. Overall, 389 (37.3%) sets were well matched for age category and 329 (31.5%) were well matched for sex. We therefore considered age, sex, and environmental conditions for our conditional logistic regression model.

Table 3 shows the results of the conditional logistic regression analyses for the matched cases and controls. We found no evidence of effect modification by age either statistically ($\chi^2 = 0.01$) or practically (odds ratio for age groups: ≥26, 0.75; 15-25, 0.71; <15, 0.73). The ideal model with the 27 covariates produced a helmet effect estimate of 0.73 (95% confidence interval 0.49 to 1.08).[7] A backward deletion strategy produced a final adjusted helmet effect estimate of 0.71 (0.55 to 0.92). A forward selection strategy produced an adjusted helmet effect estimate for potentially severe head injuries of 0.44 (0.24 to 0.81).[6 7]

We found no evidence of effect modification by age for neck injuries when we fit a model with helmet use, age, sex, and two product terms for age by helmet use (<15 and 15-25; $\chi^2 = 0.01$). For those aged less than 15 years the estimate of the helmet effect was 0.92. After removal of the product terms from the model and using a forward selection strategy starting with helmet use, age and sex, our final model for any neck injury included age, sex, and days of participation that season. This gave a helmet effect of 0.62 (0.33 to 1.19).

We carried out no adjustments beyond matching due to the limited number (n = 13) of discordant sets for those sustaining neck injuries who were evacuated by ambulance. The conditional logistic regression estimate was 1.29 (0.41 to 4.04).

For the case crossover analysis we focused on 35 participants with head injuries who had discordant helmet use on the day of injury compared with their previous outing (estimated odds ratio for helmet use 0.6, 0.28 to 1.22). The odds ratio decreased to 0.43 (0.09 to 1.83) when we restricted the analysis to those injured during recreational participation.

Sensitivity analysis

After we included information on non-responders based on the accident report form and after adjusting for age, sex, and days of participation, we obtained a helmet effect estimate for any head injury of 0.73 (0.59 to 0.89).

Table 3 Effect of helmet use

Outcome variable compared with control	Matched odds ratio (95% CI)*	Partially adjusted matched odds ratio (95% CI)†	Ideal matched odds ratio (95% CI)‡	Final adjusted matched odds ratio (95% CI)
Any head injury	0.81 (0.64 to 1.02)	0.78 (0.61 to 1.0)	0.73 (0.49 to 1.08)	0.71§ (0.55 to 0.92)
Potentially severe head injury¶	0.67 (0.40 to 1.11)	0.59 (0.34 to 1.0)	—	0.44** (0.24 to 0.81)
Any neck injury	1.11 (0.67 to 1.83)	0.96 (0.56 to 1.66)	—	0.62†† (0.33 to 1.19)
Potentially severe neck injury¶	1.29 (0.41 to 4.04)	—	—	—

Age=<15, 15-25, ≥26; days of participation that season to day of injury=1, 2-10, ≥11)
*Helmet use only.
†Helmet use, age, and sex; adjusted for activity through matching.
‡Adjusted for age, sex, ability, seasons of participation, days of participation that season to day of injury, lessons (yes, no), education (high school or less, college or professional diploma, university or graduate degree), previous head or neck injury, hours of participation on day of injury (1, 2-5, ≥6), damage to non-helmet equipment (yes, no), self reported speed in relation to average (slower, average, faster), mechanism of injury (collision or jump, fall), type of participation on day of injury (recreation, lessons, or school outing), run difficulty (easy, difficult, very difficult to extreme), other protective equipment besides helmet (yes, no), visibility (good, average to fair), snow conditions (groomed to hard pack ice, other), temperature (≤10°C, –10°C to –1°C, ≥0°C); adjusted for activity through matching; interaction of age and helmet use (<15 and 15-25) initially tested in full model; age and sex forced into model.
§Adjusted for age, sex, days of participation that season to day of injury adjusted for activity through matching; age and sex forced into model; backward deletion modeling strategy.
¶Evacuated by ambulance.
**Adjusted for age, sex, days of participation that season to day of injury, and wearing other protective equipment besides helmet at time of injury (yes, no); age and sex forced into model; forward selection modeling strategy.
††Adjusted for age, sex, and days of participation that season to day of injury; age and sex forced into model; forward selection modeling strategy.

The estimates for potentially severe head injuries (0.58, 0.36 to 0.94) and any neck injuries (0.94, 0.24 to 0.81) moved closer to the null after we included non-responders and after adjusting for age, sex, and days of participation. The helmet effect increased to 2.37 (0.89 to 6.32) when we added non-responders to the analysis of potentially severe neck injuries and after adjustment for age only (20 discordant sets).

When we omitted the three observations that produced the largest influence on the final estimated odds ratio (with their matched sets) for the outcome of any head injuries and refitted the model with the same variables, the estimate changed to 0.68 (0.52 to 0.88). The odds ratio changed to 0.34 for potentially severe head injuries, 0.43 for any neck injuries, and 1.66 for potentially severe neck injuries.

Discussion

Wearing a helmet while skiing or snowboarding may reduce the risk of head injury by 29% to 56%—that is, for every 10 people who wear helmets, three to six may avoid head injuries. This may even be an underestimate if, as in cycling, the helmets were worn incorrectly or were in poor condition,[10] or were not designed for skiing or snowboarding. The effect of helmet use on neck injuries is less clear. Although we found no statistically significant estimates for neck injury and no evidence of effect modification by age, our sensitivity analysis suggests an increased risk of neck injuries with helmet use.

Limitations

When we included non-responders in the analyses, we found few differences for all outcomes except potentially severe neck injuries, where the estimate increased. This suggests possible under-response in helmet users. Few of these injuries, however, produced considerable random error and precluded the addition of potential confounders.

We would have overestimated the protective effect of helmets if those who sustained a head injury while wearing a helmet were less likely than those who did not wear a helmet to report their injury to the ski patrol. This may have occurred if the individual believed that the helmet should have prevented any serious injury, but this effect would have to be independent of injury severity.

We concede that bias could have played a part in the comparisons with injured controls. We did not include in our series of injured controls those who fell and hit their heads but did not sustain an injury because they were wearing a helmet. Including these individuals would have increased the protective effect of helmets.

Where appropriate we adjusted for personal characteristics and events at the time of injury. The small number of neck injuries, however, precluded control for more than a few covariates. As 13 of the participants with neck injuries who required evacuation by ambulance were in discordant matched sets, we did not consider further adjustment beyond that provided by the matching.

It has been noted that ski patrols may not distinguish between fractures and sprains but do accurately report the body regions affected.[11] We were able to use a classification for severity of injuries similar to that used in other studies on the basis of mode of leaving the ski area (for example, by ambulance, with parents).[12 13]

We found few differences in consistency of reporting between the postal questionnaire or phone interview and accident report form.[14] The most plausible mechanism for differential misclassification would be if cases who had not worn a helmet were more confused than controls about whether they had worn a helmet, but this would lead to underestimation of a protective effect.

Recall on the day of injury of a participant with head injuries was confined to a specific event for the case crossover analysis,[15] whereas recall on the previous outing may have been less accurate. If cases had over-reported previous helmet use then the protective effect of helmets would have been overestimated, but we found a consistent helmet effect between the matched case-control and case crossover analyses.

Comparison with previous research

To our knowledge only one other case-control study has been carried out to determine whether helmets protect skiers and snowboarders against head injuries.[3] Those investigators evaluated combined head, face, and neck injuries in participants aged less than 13 years. After adjustment for activity, helmets were associated with a 43% reduction in the risk of head, face, and neck injuries, and no serious neck injury occurred in those using helmets. Our estimates for all age groups confirm the protective effect of helmets on head injuries found by this previous study.[3] Although other investigators have examined the relation between helmet use and risk of neck injury in skiers and snowboarders, unlike us they did not examine this in isolation or did not report an effect estimate.[3 16]

What is already known on this topic

Helmets protect bicyclists against head injuries

Evidence is limited on the effectiveness of helmets against head and neck injuries in skiers and snowboarders

What this study adds

Helmets may reduce the risk of head injuries in skiers and snowboarders by 29% to 56%

Evidence is limited on the relation between helmet use and the risk of neck injury

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