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The effect of helmet use on injury severity and crash circumstances in skiers and snowboarders

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Abstract

The aim of this study was to examine the effect of helmet use on non-head–neck injury severity and crash circumstances in skiers and snowboarders. We used a matched case-control study over the November 2001 to April 2002 winter season. 3295 of 4667 injured skiers and snowboarders reporting to the ski patrol at 19 areas in Quebec with non-head, non-neck injuries agreed to participate. Cases included those evacuated by ambulance, admitted to hospital, with restriction of normal daily activities (NDAs) >6 days, with non-helmet equipment damage, fast self-reported speed, participating on a more difficult run than usual, and jumping-related injury. Controls were injured participants without severe injuries or high-energy crash circumstances and were matched to cases on ski area, activity, day, age, and sex. Conditional logistic regression was used to relate each outcome to helmet use. There was no evidence that helmet use increased the risk of severe injury or high-energy crash circumstances. The results suggest that helmet use in skiing and snowboarding is not associated with riskier activities that lead to non-head–neck injuries.

Keywords: Risk compensation; Ski; Snowboard; Injury

1. Introduction

Helmets have been shown to prevent head injuries in bicyclists (Attwell et al., 2001). A number of investigations (Sandegård et al., 1991; Ekeland and Rødven, 2000; Machold et al., 2000; Macnab et al., 2002) including the results of our own work (Hagel, 2003) provide evidence that helmets also prevent head injuries in skiers and snowboarders. However, much less attention has been paid to the issue of whether helmets might actually lead to injuries to other unprotected body regions by encouraging skiers and snowboarders to engage in riskier behaviors.

This theory of compensating behavior or risk compensation suggests that each person has a target level of risk they are willing to accept (Hedlund, 2000). If a person perceives an intervention (e.g., ski helmet use) has lowered their level of risk, proponents of the theory argue users will change their behavior to bring them back to their desired risk level (e.g., ski faster or more aggressively, on more difficult runs). Most of the evidence for risk homeostasis is conflicting and related to road safety measures (e.g., antilock brakes and driving behavior) (Hedlund, 2000). In the context of skiing and snowboarding, although some claim the existence of risk compensation

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with ski helmet use (Hirschfeld, 2000), there is no empirical evidence on the subject.

Therefore, the objective of this investigation was to determine whether helmet use results in greater non-head–neck injury severity and more frequent high-energy crash circumstances in skiers and snowboarders.

2. Methods

This investigation was conducted at 19 of the largest ski areas in Quebec from November 2001 to April 2002. Skiers and snowboarders who reported to the ski patrol and had an accident report form (ARF) completed for an upper extremity, lower extremity or trunk injury were asked to participate (i.e., injuries presumably unrelated to helmet use). These individuals formed one control group for a larger case-control study on helmet effectiveness in skiers and snowboarders (Hagel, 2003).

2.1. Cases

Among this non-head, non-neck injured group, there were two broad categories of cases. The first category related to injury severity. This included individuals evacuated by ambulance, admitted to hospital, or with restriction of normal daily activities 7 or more days, a time-loss criterion for severe injuries consistent with other investigations (Meeuwisse et al., 2000). The second category of cases involved high-energy crash circumstances. Cases in this category had non-helmet equipment damage, fast self-reported speed, a jumping-related injury, and were participating on a more difficult run than usual at the time of the crash.

2.2. Controls

Controls were those (non-head, non-neck) injured skiers and snowboarders who did not have severe injuries or severe crash circumstances, as defined above, and were matched to cases on ski area, activity, day of injury, age, and sex, in that order.

2.3. Data collection procedures

The participating ski areas were informed of the study and asked to send their ARFs every 2–3 weeks. An employee of the Quebec Secrétariat au loisir et au sport (SLS) then photocopied the reports and sent them to the project coordinator at the Montreal Children's Hospital.

The coordinator abstracted name, address, telephone number, participation, and injury information. Many addresses and telephone numbers were not found making follow-up impossible.

Questionnaires were then sent to all cases and to injured controls matched for ski area, activity (skiing or snowboarding), date of injury, age, and sex. Because the subjects for this investigation were part of a larger study on helmet effectiveness at preventing head injuries (cases being head or neck injured individuals originally matched to three non-head, non-neck injured controls), the number of matched controls varied from 0 to 2, depending on the set. Similarly, there could be more than one case in a matched set due to the re-coding of the original controls as cases according to whether they were ambulance evacuated, etc.

A post card was sent within 2 weeks of the initial mailing to remind those who had not returned their questionnaire to do so. The questionnaire was in both French and English and was skier or snowboarder specific.

Parents were asked to answer the questionnaire for children under 15. A maximum of five follow-up telephone calls were made on different days of the week and at different times of the day to non-responders.

For those cases who did not list (or the ski patrol did not record) a correct telephone number, a mail follow-up was attempted (Dillman, 1978). For ski patrol ARFs that had only a telephone number without an address, a telephone interview was conducted if consent was provided, as above, to obtain the same information as the mailed questionnaire.

For skiers and snowboarders from other countries (mostly European) only a telephone interview was attempted due to the substantial mail delay anticipated.

In addition to helmet use at the time of injury, we considered a number of intrinsic characteristics including: age group (<15, 15 to 25, 26+), sex, activity (ski, snowboard), self-reported ability (beginner-intermediate, intermediate, intermediate-expert), days of participation that season to the day of injury (first day, 2–10 days, 11+ days), lessons (yes, no), education or mother's level of education if under age 26 (high school or less, college or professional diploma, university or graduate school), seasons of experience (first, 2–5, 6+), and history of head or neck injury (yes, no).

2.4. Analysis

The frequency of hospital admission, mode of leaving the hill as reported on the ARF, along with follow-up care as reported on the questionnaire, non-helmet equipment damage, self-reported speed and reported jumping-related injury, were used as indicators for risk compensation. Comparisons were made between helmet users and non-users among those with upper extremity, lower extremity or trunk injuries. Comparisons were restricted to this group because head and neck injuries may be related to helmet use. Discrepancies between the hill level of difficulty where the control was injured (based on concordant questionnaire and ski patrol ARF information) and the type of runs usually skied were compared between helmeted and non-helmeted skiers and snowboarders.

These analyses were conducted using conditional logistic regression because injured controls of the same matched set were not independent in terms of ski area, activity, day of injury, age, and sex. Only intrinsic characteristics (age, sex, activity, self-reported ability, experience, lessons, education, history of head or neck injury) were controlled for in this analysis as some environmental conditions (e.g., hill difficulty at the time of injury) represent intermediates in the helmet use-outcome pathway. Stated another way, excess control of factors that would be influenced by helmet use and related to outcome would bias the associations toward the null (i.e., no association).

Harrell Jr. et al. suggest that for logistic regression models with good prognostic properties, the number of potential independent variables should be less than 10% of the minimum of the number of cases or the number of controls (Harrell, 1996). However, when dealing with a matched study, only discordant sets contribute to estimation of the odds ratio. Therefore, we used the 10% or fewer 'rule of thumb' for the number of discordant matched sets and not simply the minimum of the cases or controls. This is consistent with the recommendations of Greenland et al. (2000). We deemed this a prudent approach to avoid over-fitting a model that can result in thin strata leading to extreme estimates (Greenland et al., 2000).

A forward selection strategy was used when the number of independent variables considered exceeded 10% of the number of discordant matched sets. Potential confounders (i.e., age, sex, etc.) were added one at a time and those that had the largest influence on the point estimate of the helmet effect were retained in an iterative process until no additional variables changed the estimate by more than 10%. Addition of variates was stopped before exceeding 10% of the number of discordant matched sets.

To be certain there were no influential observations distorting the estimates, a delta-beta (i.e., dfbeta) analysis was conducted. A dfbeta for an observation measures standardized differences in regression estimates after deletion of the observation. Stated otherwise, dfbetas indicate how much *influence* a single observation (a particular skier or snowboarder) has on the final estimated odds ratio. The three observations producing the largest dfbetas were deleted along with their matched sets, and the model re-fitted with the same variables to determine how much influence these observations had on the final estimated odds ratio.

3. Results

To evaluate the hypothesis that helmet use increases an individual's willingness to take risks, we related helmet use to both injury severity indicators and characteristics of the injury event among those *without* a head, face, or neck injury (i.e., injuries presumably unrelated to helmet use). The response rate for the non-head, non-neck injured group was 71% (3295/4667).

3.1. Injury severity related to helmet use

There were over 150 matched sets discordant for helmet use for the outcomes of hospital admission (151 discordant sets) and restriction of normal daily activities greater than 6 days (303 discordant sets). Therefore, the conditional logistic regression model included all 15 intrinsic variables. There were only 127 discordant sets for ambulance evacuation and therefore the forward selection modeling strategy was used.

Table 1 indicates that there is no evidence to suggest that helmet use influences the severity of injury. Specifically, helmet use among *non-head–face–neck injured* individuals, after adjusting for other risk factors, had no effect on the likelihood of requiring evacuation by ambulance, being admitted to hospital, or having restriction of normal daily activities for 7 or more days.

Table 1
Injury severity by helmet use for non-head, non-face, and non-neck injured skiers and snowboarders

Outcome	Wearing helmet	
	No	Yes
Evacuated by ambulance[a]		
Yes		
#	250	103
%	70.8	29.2
No		
#	2030	789
%	72.0	28.0
Matched[b] OR (95% CI)	1.0	1.14 (0.79–1.63)
Adjusted Matched OR (95% CI)	1.0	1.17[c] (0.79–1.73)
Admitted to hospital[d]		
Yes		
#	475	165
%	74.2	25.8
No		
#	1870	750
%	71.4	28.6
Matched[b] OR (95% CI)	1.0	0.70 (0.53–0.94)
Adjusted Matched OR (95% CI)	1.0	0.79[e] (0.53–1.18)
Normal daily activities restricted =7 days[f]		
Yes		
#	1525	488
%	75.8	24.2
No		
#	735	391
%	65.3	34.7
Matched[b] OR (95% CI)	1.0	0.61 (0.48–0.78)
Adjusted Matched OR (95% CI)	1.0	0.93[e] (0.65–1.34)

[a] Missing evacuation information on 37 helmet users and 86 non-users.
[b] Model with helmet use but no other predictors.
[c] Adjusted for age (<15, 15 to 25, 26+), sex; age and sex forced into model; forward modeling selection strategy.
[d] Missing hospital admission information on 14 helmet users and 21 non-users.
[e] Adjusted for age (<15, 15 to 25, 26+), sex, activity (ski, snowboard), self-reported ability (beginner-intermediate, intermediate, intermediate-expert), days of participation this season (first day, 2–10 days, 11+ days), lessons (yes, no), education or mother's level of education if under age 26 (high school or less, college or professional diploma, university or graduate school), seasons of experience (first, 2–5, 6+), history of head or neck injury (yes, no).
[f] Missing duration of convalescence information on 50 helmet users and 106 non-users.

Table 2
Injury characteristics by helmet use for non-head, non-face, and non-neck injured skiers and snowboarders

Outcome	Wearing helmet	
	No	Yes
Non-helmet equipment damage[a]		
Yes		
#	118	71
%	62.4	37.6
No		
#	2211	851
%	72.2	27.8
Matched[b] OR (95% CI)	1.0	1.38 (0.88–2.16)
Adjusted Matched OR (95% CI)	1.0	1.20[c] (0.71–2.04)
Fast self-reported speed[d]		
Yes		
#	527	212
%	71.3	28.7
No		
#	1610	566
%	74.0	26.0
Matched[b] OR (95% CI)	1.0	1.28 (0.96–1.70)
Adjusted Matched OR (95% CI)	1.0	1.06[e] (0.68–1.66)
Participation on a more difficult run[f]		
Yes		
#	438	111
%	79.8	20.2
No		
#	1786	753
%	70.3	29.7
Matched[b] OR (95% CI)	1.0	0.74 (0.54–1.03)
Adjusted Matched OR (95% CI)	1.0	1.28[e] (0.79–20.8)
Jumping cause of injury[g]		
Yes		
#	447	276
%	61.8	38.2
No		
#	1901	646
%	74.0	25.4
Matched[b] OR (95% CI)	1.0	1.86 (1.42–2.43)
Adjusted Matched OR (95% CI)	1.0	1.19[e] (0.77–1.83)

[a] Missing non-helmet equipment damage information on 7 helmet users and 37 non-users.
[b] Model with helmet use but no other predictors.
[c] Adjusted for age (<15, 15 to 25, 26+), sex, and seasons of experience (first, 2–5, 6+); age and sex forced into model; forward modeling selection strategy.
[d] Missing self-reported speed information on 143 helmet users and 218 non-users; not applicable (e.g., injured using lift) in 8 helmet users and 11 non-users.
[e] Adjusted for age (<15, 15 to 25, 26+), sex, activity (ski, snowboard – by matching if coefficient or confidence limits not inestimable), self-reported ability (beginner-intermediate, intermediate, intermediate-expert), days of participation that season to day of injury (first day, 2–10 days, 11+ days), lessons (yes, no), education or mother's level of education if under age 26 (high school or less, college or professional diploma, university or graduate school), seasons of experience (first, 2–5, 6+), history of head or neck injury (yes, no).
[f] This variable constructed by comparing the hill difficulty skied-snowboarded at least often (on a scale of never, sometimes, often, always) with the hill they were injured on. In cases where individuals indicated they skied or snowboarded any runs only sometimes, the highest level of difficulty the individual indicated for sometimes was used as the usual hill skied. Missing hill difficulty at time of injury or hill difficulty usually skied-snowboarded for 32 helmet users and 70 non-users; not applicable (e.g., injured using lift) in 33 helmet users and 72 non-users.
[g] Missing mechanism of injury information on 3 helmet users and 3 non-users; not applicable (e.g., injured using lift) in 4 helmet users and 15 non-users.

To check on how robust the effect estimates were, for each model, the three most influential matched sets (i.e., those with the largest absolute values of the dfbetas) were deleted and the model was refit. The resulting estimates from this refitting process had little influence on the relation between helmet use and ambulance evacuation (adjusted odds ratio {AOR}: 1.12; 95% CI: 0.66–1.91), hospital admission (AOR: 0.73; 95% CI: 0.48–1.09), and restriction of normal daily activities greater than 6 days (AOR: 0.97; 95% CI: 0.68–1.39).

3.2. Injury characteristics related to helmet use

There were over 150 matched sets discordant for helmet use for self-reported fast speed at the time of injury (167 discordant sets), participation on a more difficult run compared with the difficulty of runs usually skied or snowboarded (163 discordant sets), and jumping as a mechanism of injury (163 discordant sets). This made it possible to adjust for all 15 variables in the conditional logistic regression analysis. There were only 82 matched sets discordant for helmet use for the outcome non-helmet equipment damage and so the forward modeling selection strategy was used.

Table 2 indicates there is no evidence of an association between helmet use and non-helmet equipment damage, fast self-reported speed at the time of injury, participation on a more difficult run, and jumping as a mechanism of injury, once other relevant intrinsic factors were controlled.

To determine the robustness of the fit, the models concerning the relation between helmet use and injury circumstances were again refit after deletion of the three most influential matched sets. The resulting estimates for non-helmet equipment damage (AOR: 1.03; 95% CI: 0.55–1.92), fast self-reported speed (AOR: 1.0; 95% CI: 0.63–1.59), participation on a more difficult run (AOR: 1.26; 95% CI: 0.77–2.05), and jumping as a mechanism of injury (AOR: 1.18; 95% CI: 0.76–1.83), changed little with the deletion of the three matched sets.

4. Discussion

There was no evidence that wearing a helmet predisposed skiers or snowboarders to more severe non-head–neck injuries or that helmet use was related to more high-energy crash circumstances. To our knowledge, this is the first study to examine helmet use on behavior change in skiing and snowboarding. Our results are consistent with the findings of Spaite et al. who found *greater* injury severity among non-head, non-neck injured cyclists *not* wearing helmets reporting to an emergency department (Spaite et al., 1991). A recent study by Lardelli-Claret et al. provides further evidence against risk compensation demonstrating that, among cyclists involved in a traffic crash with victims, committing certain traffic violations while cycling were either less likely among helmet users compared with non-users or showed no relation to helmet use (Lardelli-Claret et al., 2003). Similar conclusions have been reached in examining face-shield use in ice-hockey (Benson et al., 1999; Stuart et al., 2002) motor-vehicle seat belt use (Dinh-Zarr et al., 2001) and motorcycle helmet use (Hedlund, 2000).

4.1. Limitations

The lack of support for risk compensation found in our investigation rests on the assumption that our case definitions provides solid, acceptable proxies for behavior change. If helmets have little relation to non-head or non-neck injuries after controlling for other relevant factors, it is reasonable to believe that, in the absence of behavior change with helmet use, there should be no difference in crash circumstances or injury severity between helmet users and non-users.

Selection bias would be an issue if participation in the study were related to both helmet use status and outcome status (crash or injury severity), and not captured by any of the covariates in the analysis. This dual association seems unlikely as we documented information on many known risk factors in the ski and snowboard injury literature and controlled for their effects in the analysis.

Non-differential misclassification of helmet use status or outcome status would bias the results to the null. However, there was substantial consistency of reported helmet use between the ski patrol ARF and our mail questionnaire or telephone interview. It also seems unlikely that objective measures such as ambulance evacuation, hospital admission, or jumping as a mechanism of injury would be reported with substantial error.

We did not control participation at the time of injury in terms of competition versus recreation. Those competing may be more likely to use a helmet and have a higher risk of non-head–neck injuries independent of any risk compensation effect. Control for this factor may have produced estimates even closer to the null and may explain those instances where the odds ratios were above one.

Our results may be confounded if more cautious people tend to wear helmets. That is, risk compensation may still operate among these individuals, but the effect may not be substantial enough to increase their risk above the level of the non-user. Although we did adjust for many intrinsic risk factors that likely reflect differences in baseline risk taking propensity (e.g., age, sex, ability) and used a matched study design, confounding by cautious personality cannot be ruled out entirely.

This also brings up a philosophical argument about who would be influenced by risk compensation. A possible argument against mandating helmet use in skiing and snowboarding, or in other activities, is that if legislation is implemented requiring people to wear helmets, injury rates may increase because of compensating behavior. For risk compensation to occur, however, there must be a belief by the helmet user that helmets confer some protective effect. If we assume that voluntary users believe in a protective effect and non-users do not, then implementing legislation requiring helmet use should result in no net increase in risk taking behavior because non-users will perceive no change in risk. This argument has been made by other investigators (Lardelli-Claret et al., 2003).

5. Conclusions

Our results do not support a compensatory effect for helmet use in skiers and snowboarders in terms of increasing injury severity or high-energy crash circumstances. These findings are consistent with those in the bicycling, ice-hockey, motor-vehicle and motorcycling literature. Whether it is the case that helmet users indeed do not take more risks or that cautious people wear helmets but do not increase their risk over other slope users, requires further research.

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