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[TABLE OF CONTENTS >](#)

Original Contribution

## Helmet Use and Risk of Head Injuries in Alpine Skiers and Snowboarders

Steinar Sulheim, MD; Ingar Holme, PhD; Arne Ekeland, MD, PhD; Roald Bahr, MD, PhD

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### ABSTRACT

**Context** Although using a helmet is assumed to reduce the risk of head injuries in alpine sports, this effect is questioned. In contrast to bicycling or inline skating, there is no policy of mandatory helmet use for recreational alpine skiers and snowboarders.

**Objective** To determine the effect of wearing a helmet on the risk of head injury among skiers and snowboarders while correcting for other potential risk factors.

**Design, Setting, and Participants** Case-control study at 8 major Norwegian alpine resorts during the 2002 winter season, involving 3277 injured skiers and snowboarders reported by the ski patrol and 2992 noninjured controls who were interviewed on Wednesdays and Saturdays. The controls comprised every 10th person entering the bottom main ski lift at each resort during peak hours. The number of participants interviewed corresponded with each resort's anticipated injury count based on earlier years.

**Main Outcome Measure** Injury type, helmet use, and other risk factors (age, sex, nationality, skill level, equipment used, ski school attendance, rented or own equipment) were recorded. A multivariate logistic regression analysis was used to assess the relationship between individual risk factors (including helmet wear) and risk of head injury by comparing skiers with head injuries with uninjured controls, as well as to skiers with injuries other than head injuries.

**Results** Head injuries accounted for 578 injuries (17.6%). Using a helmet was associated with a 60% reduction in the risk for head injury (odds ratio [OR], 0.40; 95% confidence interval [CI], 0.30-0.55; adjusted for other risk factors) when comparing skiers with head injuries with uninjured controls. The effect was slightly reduced (OR, 0.45; 95% CI, 0.34-0.59) when skiers with other injuries were used as controls. For the 147 potentially severe head injuries, those who were referred to an emergency physician or for hospital treatment, the adjusted OR was 0.43 (95% CI, 0.25-0.77). The risk for head injury was higher among snowboarders than for alpine skiers (adjusted OR, 1.53; 95% CI, 1.22-1.91).

**Conclusion** Wearing a helmet is associated with reduced risk of head injury among snowboarders and alpine skiers.

### INTRODUCTION

Alpine skiing and snowboarding are increasingly popular winter sports and are enjoyed by several hundred million people worldwide. However, the injury risk is high,<sup>1</sup> and head injuries are common in alpine skiers and snowboarders.<sup>2-4</sup> Head injury is the most frequent reason for hospital admission<sup>5-8</sup> and the most common cause of death among skiers and snowboarders with an 8% fatality rate among those admitted to hospital with head injuries.<sup>9</sup> In bicycling, case-control studies indicate that helmets reduce the risk of head injury,<sup>10-11</sup> and helmets are strongly advocated to prevent head

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### Jump to Section

- [Top](#)
- [Introduction](#)
- [Methods](#)
- [Results](#)
- [Comment](#)
- [Author information](#)
- [References](#)

injuries in bicycling and in-line skating. Helmets are also mandatory for competitive skiers in the Fédération Internationale de Ski (FIS) World Cup events in all disciplines.<sup>14</sup> In contrast, ski resorts do not typically require helmet use. In the absence of recommendations, helmet use is generally low among recreational skiers and snowboarders<sup>15-16</sup> although their use is higher among children.<sup>17</sup> Opponents of mandatory helmet use even claim that helmets may increase the risk because they may lead to a reduced field of vision, impaired hearing, or increased speed through a false feeling of security and thus increase the incidence of collisions, the cause of many severe injuries.<sup>18</sup> Another argument against helmet use is the uncertainty about whether it might cause higher risk of cervical spine injuries, through a guillotine effect of the heavy helmet, especially in children.<sup>19-20</sup> Two recent epidemiological studies have assessed the effect of helmet use on the risk of head and neck injuries among skiers and snowboarders, but one study did not control for potentially important confounding factors,<sup>16</sup> and the other used patients without head injuries as their control group.<sup>19</sup>

The purpose of our study was to examine the effects of helmet use on the risk of head injury among skiers and snowboarders using an uninjured, representative group of skiers and snowboarders as controls while adjusting for risk factors and potential confounders, such as age, equipment, ability, and sex. Also, we wanted to assess the effect of helmet wear on the risk of neck injuries.

## METHODS

Ski patrols at 8 major Norwegian ski resorts registered injuries during the 2002 winter season (Geilo, Hafjell, Trysil, Norefjell, Hovden, Oppdal, Hemsedal, and Ålsheia). These 8 ski resorts account for about 55% of the ski lift transports in Norway, based on the number of tickets sold (Andreas Rødven, Norwegian Ski Lift Association, written communication, November 11, 2006). Our study was based on anonymized data from the Norwegian Ski Lift Association injury and marketing research databases. According to the mandate of the Regional Committees for Medical Research Ethics, projects that are based on records from regular treatment procedures are exempt from review. For this study, the chair of the Regional Committee for Medical Research Ethics of Southern Norway reviewed the study retrospectively and confirmed that the project would have been approved, had it been submitted for formal review at an earlier stage (Kristian Hagestad, written communication, January 30, 2006).

An injury was recorded when a skier or snowboarder was treated by or consulted with the ski patrol or first aid room staff after an accident in the skiing area during skiing or lift transport. To qualify for the ski patrol, the personnel are required to undergo a structured program of first aid education. A standard form was used to record personal data (age, sex, nationality), as well as information on the type of equipment used (alpine skis; Telemark skis, which permits a turning technique with free heel lift; snowboard, sleigh; or other), use of helmet (yes/no), previous ski school attendance (yes/no), rented or own equipment (yes/no), and skiing ability. Skiing ability was classified into 4 categories (beginner, intermediate, good, or expert) based on self-reported performance of turns.<sup>21</sup> In addition, the ski patrol recorded whether the injury occurred in prepared runs, in the snowboard park, off-piste (outside groomed runs), while taking the ski lift, or getting on or off the ski lift. The anatomical location (head, neck, shoulder, etc) and injury type was recorded (classified as fracture, dislocation, sprain, contusion, skin wound, or illness), as well as whether the patient needed transportation to a physician or hospital for further evaluation and treatment. Such patients were defined as potentially severe cases. For patients with multiple injuries, each injury was recorded separately.

As a control group, 2992 noninjured skiers and snowboarders were interviewed in the same 8 ski resorts during the same season. The target number interviewed corresponded to the expected injury count from each resort, estimated from injury surveillance data from previous years.<sup>17</sup> The interviews were conducted at the entry of the bottom main ski lift at each resort. Every 10th skier or snowboarder waiting in line was interviewed to achieve a systematic sample of the population. The interviews were done every Wednesday and Saturday during the 4 winter months of 2002 by personnel who were not told the purpose of the study. The registration was done when lifts opened in the morning and after lunch (ie, 10-11 AM and 1-2 PM). This is when most users enter the area, and the main lifts serve to feed a number of other lifts that take the skiers further into the mountain area to ski the runs available. Except for the injury-related information, the questions asked were the same as those for the injured skiers (ie, age, sex, nationality, equipment type, use of helmet, previous ski school attendance, rented or own equipment, and skiing ability).

In addition, a second systematic sample of 700 noninjured skiers and snowboarders was interviewed about risk-taking behavior, using the same approach as that used to select noninjured controls as described above. Skiers or snowboarders entering the bottom main ski lift in the same ski resorts were asked if they considered themselves to be a cautious or risk-taking skier or snowboarder. Helmet use, age, sex, nationality, equipment type, and skiing ability were also recorded in this

### Jump to Section

- [\\* Top](#)
- [\\* Introduction](#)
- [\\* Methods](#)
- [\\* Results](#)
- [\\* Comment](#)
- [\\* Author information](#)
- [\\* References](#)

group.

Fisher exact tests were used to compare characteristics between groups. We used logistic regression analysis to estimate the relationship between helmet use and head injuries. To select potential confounders, we performed univariate analyses of the relationships, first between head injuries and risk factors and then between helmet use and risk factors. Risk factors with significant relationships to both head injuries and helmet use with  $P < .20$  were used as adjustment factors for potential confounding in the logistic models. The factors found were age, sex, nationality, skiing ability, and type of equipment. Factors such as skiing instructions and ski rental did not qualify as a confounder. Analyses of the protective effect of helmet wear were done using uninjured skiers or snowboarders and skiers or snowboarders with other injuries than head injuries as controls. Tests of interaction between helmet use and risk factors for head injuries were done by adding cross-product terms of helmet use and dummy variables for categorized variables. Two-way interactions were also performed by adding cross-product terms of 3 factors, such as age, equipment and helmet use, including all 3 2-factor cross-product terms, as well. If significant 2-way interactions were not identified, the term was eliminated and 1-way interactions with helmet use were tested collectively and thereafter singly. Likelihood ratio tests were used to detect interaction effects. Odds ratios (ORs) are presented with 95% confidence intervals (CIs). An  $\alpha$  level of .05 was considered to be statistically significant. All  $P$  values are 2-tailed. All statistical analyses were performed using SPSS for Windows, version 11.5 (SPSS, Chicago, Ill).

## RESULTS

Of the 3277 patients with injuries recorded, 578 patients (17.6%) had head injuries. Head injuries accounted for 288 (17.9%) of 1607 alpine skiing injuries, 248 (17.8%) of 1391 snowboard injuries, and 32 (17.9%) of 179 of Telemark skiing injuries. Ten head injuries occurred among those whose equipment was unknown. Patients with head injuries and controls differed on a number of descriptive characteristics (Table 1). Of the 578 patients with head injury, 147 were referred to a physician or hospital by the ski patrol for further assessment or treatment (potentially severe injuries), and the characteristics of this subgroup did not differ from individuals with less severe head injuries (Table 1). Table 2 compares the same characteristics with respect to helmet use or not within the control group. It shows that many of the same risk factors were associated with head injuries as well as with helmet use, thus representing potential confounding factors for the relationship between head injuries and helmet use.

### Jump to Section

- [• Top](#)
- [• Introduction](#)
- [• Methods](#)
- [• Results](#)
- [• Comment](#)
- [• Author information](#)
- [• References](#)

**View this table:**  
[\[in this window\]](#)  
[\[in a new window\]](#)

**Table 1.** Comparison Between Skiers and Snowboarders With Head Injuries or Potentially Severe Head Injuries and Controls\*

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[\[in this window\]](#)  
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**Table 2.** Comparison of Helmet Use Frequency in Various Subgroups of Skiers and Snowboarders in the Uninjured Control Group\*

The OR for head injuries vs helmet use was fairly consistent across subgroups of age and equipment, adjusting for sex, skiing ability, and nationality. Among alpine skiers, the OR was 0.40 (95% CI, 0.20-0.96) for skiers younger than 13 years, 0.52 (95% CI, 0.23-1.19) for those aged 13 to 20 years, and 0.43 (95% CI, 0.18-1.02) for skiers older than 20 years. For snowboarders the corresponding ORs were 0.18 (95% CI, 0.04-0.74; <13 years), 0.56 (95% CI, 0.32-0.95; 13-20 years), and 0.18 (95% CI, 0.03-0.39; >20 years), respectively. Even if snowboarders seemed to be better protected by helmet use than alpine skiers in the younger and older age groups, this 2-way interaction was not significant ( $P = .64$ ). After elimination of the second-order term in the model, no 1-way interaction remained significant ( $P$  ranging from .12-.46). Table 3 shows the relationship between participant characteristics and risk of head injuries analyzed using multiple logistic regression analyses. Helmet use was associated with a lower risk of head injuries (OR, 0.40; 95% CI, 0.30-0.55), adjusted for potential confounders (age, sex, skiing ability, equipment, nationality). The crude OR for helmet use was 0.71 (95% CI, 0.56-0.90). When adjusted for age, the OR was reduced to 0.44 (95% CI, 0.32-0.59), then when adjusted for age and equipment to 0.41 (95% CI, 0.30-0.55), and when adjusted for ability to 0.40 (95% CI, 0.30-0.55). For 393 head contusions and fractures, the OR for helmet users vs nonusers was 0.47 (95% CI, 0.33-0.66), and for 147 potentially severe head injuries (referred for emergency physician or hospital treatment), the odds ratio was 0.43 (95% CI, 0.25-0.77), both adjusted for the same set of risk factors. When considering subgroups of injuries occurring in different ski locations,

the OR was 0.45 (95% CI, 0.31-0.64) for 396 injuries occurring in prepared runs, 0.26 (95% CI, 0.14-0.50) for 123 injuries occurring in the snowboard park or off-piste, and 0.52 (95% CI, 0.19-1.38) for the 39 with remaining categories, injuries occurring while getting on or off or taking the ski lift (information on injury location was missing in 20 cases). An additional analysis using skiers with other injuries than head injuries as controls vs all skiers with head-injuries revealed an OR for helmet wear of 0.45 (95% CI, 0.34-0.59). Similarly, when 523 skiers with head injuries only were compared with skiers with other injuries than head injuries as controls, the effect of helmet wear was 0.46 (95% CI, 0.35-0.61).

**View this table:**  
[\[in this window\]](#)  
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**Table 3.** Multiple Logistic Regression Analyses of Relationship Between Head Injury and Potential Confounding Risk Factors\*

There were 62 neck injuries, 27 in alpine skiing (0.8% of the total number of alpine skiing injuries), 29 in snowboarding (1.3%), 4 in Telemark skiing (0.8%), and 1 with other equipment (3.1%). Of the 62 neck injuries, 14 wore a helmet and 46 did not (2 unknown). After adjustment for age, sex, skiing ability, equipment, and nationality, the use of helmets was also associated with a lower risk of neck injuries, but this association was not statistically significant (OR, 0.68; 95% CI, 0.34-1.35).

Among the subgroup of 700 controls who were interviewed about risk-taking behavior, 242 wore a helmet and 458 did not. A total of 116 (43.3%) of 268 who classified themselves as risk takers wore a helmet, and 126 (29.2%) of 432 who viewed themselves as cautious skiers or snowboarders wore a helmet. Risk takers were more likely to wear a helmet (OR, 1.48; 95% CI, 1.21-1.81), and this difference was consistent across sex, equipment type, age groups, and skiing ability.

## COMMENT

Two recent case-control studies suggest that helmets can protect skiers and snowboarders against head injuries. The first study by Macnab et al,<sup>16</sup> which was based on a group of patients younger than 13 years with injury to their head, face, or neck, compared a simple count of the proportion of helmet users in this group with random skiers and snowboarders at the same resort. They reported that children who did not wear a helmet experienced an increased risk of head, neck, or face injury combined. However, the study was too small for conclusive statements regarding the effect on head injury alone and did not control for potentially important confounding factors.<sup>16</sup> Recently, Hagel et al<sup>19</sup> reported on a group of patients recorded by ski patrols. They compared patients with head injuries (cases) to patients with other injury types (controls). Thus, they addressed the question of whether helmets protected the head when skiers experienced any type of serious injury and concluded that helmets may reduce the risk of head injuries among skiers and snowboarders by 29% to 56%. This result was replicated in our study when we used patients with other injury types as controls. Moreover, by using a noninjured, representative control group to correct for potential confounders, the current study also addressed the more general question of whether helmets were protective for all skiers and snowboarders, irrespective of whether they experienced other injuries. Overall, we observed a 60% reduction in head injury risk. Our analysis identified beginners, male sex, youth, and snowboarders as groups with increased risk of head injuries but also showed that the protective effect of helmet use is consistent across groups.

That cautious people tend to wear helmets and that it is caution that confers the protective effect is an issue of concern when interpreting the results from case-control studies on the protective effect of helmet use. The question used to assess risk-taking behavior has not been formally validated but appears to have face validity. Our data show that risk takers were more likely to use a helmet within all disciplines, age groups, and skill levels. This means that the true helmet effect may be greater than our estimate and strengthens the conclusion that helmet use is associated with a reduced risk of head injury. It should also be noted that the helmet effect was as great in the presumably wildest activity areas—the snowboard park and off-piste—as it was for injuries in groomed runs, where the more cautious skiers and snowboarders are more likely to be.

One concern raised with helmets is whether they lead to an increased risk of neck injuries, especially among children due to the relatively higher mass added to the head. In our study, there was a trend toward a lower risk of neck injuries with helmet wear. Hagel et al,<sup>19</sup> again using a population of skiers and snowboarders with other injuries as their control group, suggested that the risk of cervical spine injuries may be increased.<sup>19</sup> Nevertheless, neither study has sufficient power to provide conclusive evidence regarding the relationship between neck injuries and helmet use.

## Jump to Section

- [Top](#)
- [Introduction](#)
- [Methods](#)
- [Results](#)
- [Comment](#)
- [Author information](#)
- [References](#)

## Limitations

Obtaining a control group representative of all skiers and snowboarders at risk is difficult. The controls were registered during "rush hours" in the morning and after lunch, when most users were entering the area through the bottom main ski lift. All users entered there, and many users would end up there after a run, even after going off-piste or in the snowboard park. We selected Wednesdays and Saturdays to sample the control group to compensate for differences in user characteristics between weekdays and weekends, and matched the number of controls to the expected injury count in each ski area. However, even this elaborate approach does not take skiing distance into account, and if helmeted skiers ski less, the helmet effect will have been overestimated. Potential confounding by type of run or weekday of injury may have been accounted for, at least in part, by the factors already adjusted for.

This would also be the case if helmeted skiers who sustained a head injury were less likely to report their injury than those not wearing a helmet. We have not assessed the number of injured skiers and snowboarders that bypass the ski patrol for their injuries. Studies have shown that self-reported injuries may be up to 10 times higher than injuries recorded by ski patrols, but those missed by ski patrols were minor.<sup>22-23</sup> Our results showed that the helmet effect was consistent between less and potentially more severe cases, which means that a reporting bias with respect to helmet status was unlikely.

Recall bias is not likely to have been a significant factor because interviews were conducted on the spot, usually within a few minutes after the injury. Although we do not know how a stressful injury situation may have affected how skiers report their skiing ability or ski instruction, most other factors (including helmet status) could be observed directly by the ski patrol.

## Conclusions

Helmet use is associated with reduced risk of head injury among snowboarders and alpine skiers. There was a trend toward a lower risk for neck injuries with helmet wear.

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**Author Contributions:** Drs Sulheim, Holme, and Bahr had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

*Study concept and design:* Sulheim, Ekeland, Bahr.

*Acquisition of data:* Sulheim, Ekeland, Bahr.

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*Critical revision of the manuscript for important intellectual content:* Sulheim, Holme, Ekeland, Bahr.

*Statistical analysis:* Sulheim, Holme, Bahr.

*Obtained funding:* Ekeland, Bahr.

*Study supervision:* Ekeland, Bahr.

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### Jump to Section

- [Top](#)
- [Introduction](#)
- [Methods](#)
- [Results](#)
- [Comment](#)
- [Author information](#)
- [References](#)

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### Jump to Section

- [Top](#)
- [Introduction](#)
- [Methods](#)
- [Results](#)
- [Comment](#)
- [Author information](#)
- [References](#)

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