An Evidence-based Review: Efficacy of Safety Helmets in the Reduction of Head Injuries in Recreational Skiers and Snowboarders

Adil H. Haider MD, MPH
Johns Hopkins School of Medicine - Baltimore

Taimur Saleem MD
Johns Hopkins School of Medicine

Jaroslaw W. Bilaniuk MD
Morristown Memorial Hospital

Robert D. Barraco MD
Lehigh Valley Health Network, robert_d.barraco@lvhn.org

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An Evidence Based Review: Efficacy of Safety Helmets in Reduction of Head Injuries in Recreational Skiers and Snowboarders

Adil H Haider, MD, MPH[1], **Taimur Saleem, MD**[1], **Jaroslaw W Bilaniuk, MD**[2], and **Robert D Barraco, MD, MPH**[3] **on behalf of On behalf of the Eastern Association for the Surgery of Trauma Injury control / Violence Prevention Committee**

[1]Center for Surgery Trials and Outcomes Research (CSTOR) Johns Hopkins School of Medicine, Baltimore MD

[2]Morristown Memorial Hospital, Morristown NJ

[3]Department of Surgery, Lehigh Valley Health Network, Allentown PA

Introduction

Alpine skiing and snowboarding are immensely popular winter sports across North and South America, Europe, Japan and Australia. Snowboarding is the relatively newer sport which started in the United States (U.S.) in the 1960-70s and debuted in the 1998 Winter Olympics in Nagano, Japan.[1] Skiing, on the other hand, was introduced in the U.S. in the mid-1800s and has been a part of the Olympics since 1936.[2] It is estimated that there are more than 200 million skiers globally and children account for 13–27% of these participants.[3] According to the National Sporting Goods Association (NSGA), there were 6.5 million skiers and 5.9 million snowboarders in the U.S. in 2008. Additionally, about 20% of snowboarders also engage in skiing and vice versa. Thus, the total number of on-slope participants in 2008 was approximately 10 million.[4] According to the 2009/10 Kottke National End of Season Survey, 471 ski areas were operational during the season in the United States. [4]

Injuries from Skiing and Snowboarding

Recreational skiing and snowboarding are not without their share of risks. According to data from National Ski Areas Association (NSAA), a representative body of the majority of ski areas in North America, about 40 people have died per year on average during these activities in the past decade.[4] According to the NSGA, the per-participant skier/snowboarder fatality rate was 3.9 per 1 million on-slope participants in 2008.[4] Estimates have shown that the overall rate of reported alpine ski injuries declined slightly from 2.66 injuries per 1,000 skier visits in 1990 to 2.63 injuries per 1,000 skier visits in 2000-01. However, for snowboarding, the rate of injuries doubled from 3.37 injuries per 1,000 visits in 1990 to 6.97 per 1,000 visits in 2000-01.[4] The incidence of significant injuries has been reported to be

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higher in males, children and teens under 17 years of age.[5] While some studies have reported that skiers and snowboarders are equally prone to injuries[6], other studies have reported that snowboarders are almost twice as likely to sustain injuries as compared to skiers[7,8]. In children, the mean injury severity score has been reported to be significantly higher for snowboard injuries than skiing.[9] Similar trends have also been observed in adults.[10]

Economic Burden

A study from Canada evaluated the per-patient cost of snow sport related injuries in children from 1991 to 1997 and reported it in terms of "hospital treatment, outpatient services and lost parental income" at $27,936, $15,243 and $1,500 respectively.[9] Another study from the U.S. in children in 1996 reported the average cost of in-patient treatment of skiing injuries at $22,000 per patient.[11] Therefore, primary interventions targeted at decreasing the incidence of these injuries can be expected to have far reaching impacts on health care expenditures, rehabilitative services, family resources, society and overall economy.[9,11]

Types of Injuries

Among the injuries incurred by skiers and snowboarders, head injuries constitute an important and common burden. They account for up to 20% of the 600,000 ski and snowboarding-related injuries in North America annually.[12] In children, head and face injuries account for up to 22% of the total injuries.[5] Most of these head injuries result when participants hit inanimate objects and experience linear deceleration impact.[13] The rates of head and neck injuries among skiers and snowboarders vary between 0.09 – 0.46 per 1000 outings; snowboarders have a 50% higher rate of head and neck injury as compared to skiers.[14] Overall, 22% of head injuries are severe enough to cause loss of consciousness or clinical signs of concussion.[5] Snowboarders experience more severe head injuries as compared to skiers.[15] In one study, skiers had concussion 60% of the time while snowboarders had a concussion 21% of the time, with the remaining individuals sustaining a more severe degree of head injuries.[16] Traumatic brain injury (TBI) is fatal among skiers and snowboarders of all ages, contributing to 42.5 – 88% of all injury related deaths in different studies.[7,17,18,19] Often these individuals were not wearing safety helmets.[6,20] TBI accounted for 29% of all injuries requiring admission to the hospital in one study.[7]

Helmet Use in Skiing and Snowboarding

In 1955, Haid in Austria was the first person to broach the issue of helmet use in skiing.[21] A few decades later, in 1983, Oh advocated mandatory helmet use for children up to 17 years of age during skiing to prevent head injuries.[22] Although the high-profile deaths of Michael Kennedy and Sonny Bono in skiing related accidents in 1998 highlighted the need for consideration of mandatory helmet wear during skiing/snowboarding,[23,24] it is the more recent death of actress Natasha Richardson that has rekindled fervent debate on the issue.[25] She sustained a "helmetless" head injury on a slope at Mont Tremblant's ski resort in Quebec. The seemingly minor fall on a slightly inclined beginner slope ultimately culminated into a fatal epidural hematoma. In 2009, a German politician also collided with a woman on an Austrian slope. The woman, who didn’t have a helmet on, died while the politician, who was wearing a helmet, survived the incident.[26]

Currently no unequivocal recommendations exist with regards to mandatory helmet use during skiing and snowboarding activities. This status quo may stem from a few reports about the possible increase in risk compensation behavior and neck injuries associated with helmet use during skiing and snowboarding. These may also represent a potential barrier in the widespread adoption of helmet usage by participants and form the basis of arguments put forward by detractors of helmet usage. A survey among ski patrollers demonstrated that the perception that helmets encourage recklessness predicted helmet non-use.[27] One study also reported findings suggestive of the possible detrimental effect of helmets on reducing or altering the sounds of danger on slopes.[28] In contrast, a recent study by Ruedl et al. has shown that helmets do not increase mean reaction time to peripheral stimuli.[29] However, the latter study is limited by its laboratory setting.

Many states including Michigan, New Jersey, New York, Massachusetts and California have contemplated the passage of laws regarding compulsory helmet usage for children and adolescents; however, such legislation is yet to materialize in a concrete fashion.[30] Although the American Medical Association (AMA) found insufficient evidence to endorse mandatory helmet use in 1997, it supported the voluntary use of helmets for children and adolescents during recreational skiing and snowboarding.[31] Among the European countries, Italy and Crotia introduced mandatory use of helmets for children ≤ 14 years of age in 2005, while Austria introduced the same for children ≤15 years of age in 2010.[32] According to a report on skiing and snowboarding injuries from U.S. Consumer Product Safety Commission (CPSC) in 1999, 44% of head injuries in adults (~ 7,700 injuries annually) and 53% of head injuries in children under 15 years of age (~2,600 injuries annually) are "potentially preventable" by the use of a safety helmet.[33]

Despite the above mentioned reservations regarding helmets and winter sports, data from the 2009/10 National Demographic Study of NSAA, encompassing more than 130,000 interviews across the United States, showed that helmet usage is progressively increasing among participants. Overall, about 57% of skiers and snowboarders wore helmets during the 2009/10 season as compared to 25% during the 2002/03 season.[4] As with any injury prevention intervention, the morality of beneficence must be advocated while remaining mindful of the principle of non-malficence.[26] Evidence regarding helmet efficacy in reducing or moderating injuries in skiing and snowboarding must, therefore, be scientifically evaluated and any potential risks of wearing helmets must be balanced against their verifiable benefits. The purpose of this review is to evaluate current medical literature for evidence regarding the efficacy of safety helmets during skiing and snowboarding with particular reference to head injuries and their severity, neck and cervical spine injuries and risk compensation behaviors.

Statement of Problem

Injuries sustained during recreational skiing and snowboarding can cause significant morbidity and mortality among snow sport enthusiasts. Traumatic head injuries from skiing and snowboarding crashes are an especially important cause of hospitalization, fatality and long term disability and also contribute significantly to healthcare expenditures. These injuries are potentially preventable through the use of safety helmets. However, evidence regarding the efficacy of helmets in the reduction of head injuries and head injury-related mortality in skiers and snowboarders is counteracted by reports of the possibly deleterious effects of helmets on risk compensation behavior and neck injuries. As a result of this evidentiary contention, thus far, no legislation in the U.S. exists with regards to the mandatory helmet usage for recreational skiers and snowboarders.

Questions to be addressed

A. Does helmet use increase or decrease the rate of fatal and non-fatal head injury among skiers and snowboarders?

B. Does helmet use increase or decrease the rates of neck or cervical spine injury in skiers and snowboarders?

C. Is helmet use associated with higher or lower risk compensation behavior among skiers and snowboarders?

Methods and Process

A comprehensive search of published medical literature was conducted using Pubmed, Cochrane Library and EMBASE databases using the following key words in different combinations with Boolean operators: 'equipment', 'helmet', 'helmet use', 'head protective devices', 'skiing', 'skiers', 'snowboarders', 'snowboarding', 'snow sports', 'injury', 'head injury', 'head trauma', 'traumatic brain injury', 'craniocerebral trauma', 'neck injury', 'cervical spine injury', 'winter sports' and 'risk compensation behavior'. Only published citations involving human participants (all ages, both genders) between January, 1980 and April, 2011 were selected for initial review. As no study analyzed the impact of any legislation for safety helmets, reports from other countries were also included. The keyword combination "helmet OR head protective devices OR equipment AND (skiing OR snowboarding OR skier OR snowboarder)" yielded 554, zero and 2,646 articles in Pubmed, Cochrane Library and EMBASE respectively. The search was considerably coned down by eliminating the word 'equipment' from the keyword phrase as it was felt to have very broad connotations and the search yield using it included a large proportion of articles evaluating other protective gear such as wrist-guards, mouth-guards, spine-boards and ski-boots etc. The alternative approach resulted in 83, zero and 96 hits in Pubmed, Cochrane Library and EMBASE respectively. Only one article in Cochrane Library was retrieved when the specific keyword combination "skiing OR snowboarding" was used. After the exclusion of duplicates, the titles and abstracts of 91 articles were examined to exclude reports in a language other than English, reports which were not available for review in their entirety, review articles, commentaries, letters to the editor, technical or engineering or biomechanical reports, retrospective studies of poor quality and single case reports. Studies describing analysis of original data on helmet usage in relation to death, head, neck or cervical spine injury and risk compensation behavior were selected.

A total of 16 published studies eventually met inclusion criteria for this evidence based review and careful consideration was given to the methodology section of each paper to ensure that it strictly fulfilled the criteria for inclusion. These selected manuscripts were then reviewed in detail by the authors. As is the case with motorcycle or bicycle helmets, no randomized controlled trials (RCTs) can be conducted on helmet usage in recreational skiers and snowboarders due to the ethical concerns involved. As discussed above, earlier descriptive studies have shown that the most of the fatal injuries in skiers and snowboarders were seen in individuals without helmets. In the absence of Class I studies on helmet usage in these sports, we have to completely rely on retrospective cohort, cross-sectional, case-control/case-cross over and case-control studies for evidence of helmet efficacy[d] in recreational skiing and snowboarding. It is also interesting to note that most of the better designed and more robustly analyzed studies on the subject in literature have been conducted only in the past decade.

Recommendations

Level I Recommendations

1. All recreational skiers and snowboarders should wear safety helmets to reduce the incidence and severity of head injury during these sports.

Note: As with evidence regarding helmet efficacy in the reduction of head injury and mortality in motorcycle crashes,[34] Class I evidence on helmet efficacy in recreational skiing and snowboarding is lacking. However, the above statement has been designated as a Level I recommendation because in our review of evidence, a preponderance of Class II data regarding helmet efficacy in head injuries in skiers and snowboarders with significant construct validity was observed. This was further coupled with the acknowledgement of the inability to ethically perform a RCT in this arena.

Level II Recommendations / Observations

The following observations were also made during the review of literature on the subject:

1. Helmets do not appear to increase the risk compensation behavior among skiers and snowboarders.

2. Helmets do not appear to increase the risk of neck and cervical spine injuries among skiers and snowboarders.

3. Policies and interventions directed towards increasing and promoting helmet use should be promoted to reduce mortality and head injury in recreational skiers and snowboarders.

Scientific Foundation

The following 16 studies were reviewed in the preparation of this evidence based review. The outcomes of interest were head injury, severity of head injury, neck or cervical spine injury and risk compensation behavior.

1. Case control, case-cross over study of effectiveness of helmets in skiers and snowboarders (1)

2. Case-control studies of skiers and snowboarders (7)

3. Cross-sectional studies of skiers and snowboarders (3)

4. Retrospective cohort studies (2)
5. Retrospective case series of skiers and snowboarders (3)

A. Does helmet use increase or decrease the overall rate of head injury and severe head injury among skiers and snowboarders?

A case series study from Japan investigated the effect of helmets or knit caps on serious head injuries. While no significant association was observed between helmet or knit cap usage and serious head injuries overall (p=0.056), a significant negative association of helmet or knit cap usage and occurrence of serious head injury on jumping was observed (p=0.036). However, after adjusting for jumping, the odds ratio (OR) for the effect of helmet and knit cap (as compared to no cap) on serious head injuries was non-significant at 0.661 (CI: 0.323 – 1.35) and 0.770 (CI: 0.495 – 1.20) respectively.[35] Another case-control study from Switzerland didn't show a significant association between helmet usage and injuries (p=0.331; odds ratio: 1.44 (CI: 0.69 – 3.02)). The authors used conditional inference trees to identify the following group at risk of injuries: visual analogue scale speed (VAS_{speed}) 4 – 7, icy slopes and not wearing a helmet. However, interpretation of this study is limited as there was no mention of the body region injured or the severity of the injury incurred.[36] In a similar, more recent analysis from the same author and associates,[37] a trend to an association with injury was observed for not wearing a helmet (OR: 4.65, (CI: 0.94 to 23.05), p = 0.0595) in snowboarders. Using conditional inference trees, the following group was also found to be at risk of injury while snowboarding: not wearing a helmet and riding on icy slopes. However, associations with body site of injury and severity of injury were not computed.

A case-control, case-cross over study from Canada[38] showed a 29% reduction in the risk of any head injury with helmet usage (adjusted OR: 0.71 (CI: 0.55 – 0.92)). For participants with more severe head injuries, the protective effect of helmet usage was even greater (adjusted OR: 0.44 (CI: 0.24 – 0.81), 56% reduction in risk). However, one of the critiques of this study has been the use of patients with other injury types as controls.[39] In a case-control study from Norway,[39] helmet use reduced the risk of any head injury by 60% (adjusted OR: 0.40 (CI: 0.30 – 0.55)), of head contusions and fractures by 53% (adjusted OR: 0.47 (CI: 0.33 – 0.66)), and of severe head injury by 57% (adjusted OR: 0.43 (CI: 0.25 – 0.77)). This study used a non-injured control group to minimize the effect of potential confounders.

A case-control study from United States[12] showed a 15% reduction in head injury with the use of helmets (adjusted OR: 0.85 (CI: 0.76 – 0.95)). However, this study didn't analyze outcomes with regards to the severity of head injury. Another case-control study from Canada[5] in children < 13 years of age showed that failure to wear a helmet increased the risk of head, neck or face injury (relative risk (RR): 2.24 (CI: 1.23 – 4.12), corrected RR for activity: 1.77 (CI: 0.98 – 3.19)). However, this study had a low statistical power because of its small sample size (n=70), and the analysis didn't control for confounding factors. A retrospective cohort study from United States[40] showed a decreased incidence of loss of consciousness in case of striking a fixed object while wearing a safety helmet ((χ^2: 5.8; $p < 0.05$).

Results of a cross-sectional study in Austria[41] were suggestive of the protective effect of helmets in head injury; 196 snowboarders (7.6%) wore a helmet and had no head injury, while 0.7% of snowboarders without a helmet suffered a head injury. However, the study didn't report any OR for the association. A recent meta-analysis added 0.5 to the cells of the 2x2 table with data from Machold et al and reported an unadjusted odds ratio of 0.34 (CI: 0.02 – 5.74) for the effect of helmets on head injury for this study.[42] In a retrospective study in children presenting to the hospital with head injuries incurred during skiing or snowboarding,[43] more non-helmeted participants had a skull fracture as compared to helmeted participants (36.8% vs. 5.3%, p = 0.009). Children not wearing a helmet also had a higher incidence of overall craniofacial fractures ((44.7% vs. 15.8%, p = 0.03). The OR of a skull fracture in non-helmeted skiers and snowboarders presenting to the hospital was 10.5 (95% CI 1.26 – 87.4) as compared to helmet users. However, more children wearing helmets experienced loss of consciousness as compared to non-helmeted children, although the association was not significant (68.4% vs. 57.9%, p = 0.32).

B. Does helmet use increase or decrease the rates of neck or cervical spine injury in skiers and snowboarders?

A case-control study from Canada showed that helmets do not increase the risk of neck or cervical spine injuries in skiers and snowboarders.[44] The adjusted OR was 1.09 (CI: 0.95 – 1.25) for any neck injury, 1.28 (CI: 0.96 – 1.71) for isolated ambulance evacuated neck injuries and 1.02 (CI: 0.79 – 1.31) for cervical spine fractures or dislocations. This study's large sample size ensured adequate power to detect statistical differences. An earlier case-control, case-cross over study from the same authors[38] had shown a statistically non-significant increase in potentially severe neck injuries with helmet use when sensitivity analysis was performed (odds ratio: 2.37 (CI: 0.89 – 6.32)). However, the small number of severe neck injuries in that study[38] precluded any meaningful conclusions to be derived from the sensitivity analysis.

Two other case-control studies[12,39] have also not shown evidence of increased neck injury with helmet use (adjusted OR: 0.91 (CI: 0.72 – 1.14) and 0.68 (CI: 0.34 – 1.35)). A third case-control study[5] showed the trend of the risk of cervical spine injury to be on the higher side when not wearing a helmet (RR: 2.0 (CI: 0.8 – 5.65; p=0.15)). However, the sample size of the study was too small to reach any statistical significance. A case series from Canada showed no increased incidence of neck injuries in injured participants wearing a helmet, even when adjusted for age and activity.[45] However, the actual magnitude of the protective effect and OR were not mentioned in the study.

In a recent retrospective study in children with head injuries in New England,[43] the incidence of cervical spine injury was not significant (p=0.74) between helmeted and non-helmeted skiers and snowboarders. However, this study had a small sample size (n=57) with only 3 patients sustaining cervical spine injuries.

C. Is helmet use associated with higher or lower risk compensation behavior among skiers and snowboarders?

The theoretical framework of risk compensation rests on the basic hypothesis by G.J.S Wilde that all individuals have a "target level of risk" and a "risk thermostat" that are regulated in tandem. Behaviors are modified due to changes in perceived injury risk. If the perceived level of risk has been reduced by any intervention, there exists a possibility that the individual will subsequently indulge in riskier behaviors to restore the overall homeostasis; the "risk thermostat" will endeavor to increase the risk of the individual back to the "baseline or target level." In short, there will be a "compensation" for the perceived lowered risk by indulgence in riskier activities.[46] Convincing evidence in support of the risk compensation hypothesis has not been seen with the use of the face-shield in ice-hockey, motor vehicle seat belt use and motorcycle helmet use.[47]

An extrapolation of the risk compensation theory to skiing and snowboarding would make helmets seemingly counter-productive by giving their wearers a "false sense of security." However, a few studies have now shown that helmet use is not associated with higher risk compensation behavior among skiers and snowboarders. A recent retrospective case series showed that helmet use was more likely in those who felt that helmets reduce their chance of severe injury (OR: 3.6 (CI: 2.1 – 6.4)) and among those who thought that helmet use should be mandatory (OR: 4.8 (CI: 2.7 – 8.5)).[48] One case-control study from Canada[47] showed no evidence of an increase in the severity of non-head-face-neck injury with helmet use in terms of the requirement of evacuation by ambulance (adjusted OR: 1.17 (CI: 0.79 – 1.73)), need for admission to hospital (adjusted matched OR: 0.79 (CI: 0.53 – 1.18)) or having restriction of normal daily activities for $\geq$ 1 week (adjusted OR: 0.93 (CI: 0.65 – 1.34)). Similarly, no evidence was seen regarding the association of helmet use and non-helmet equipment damage (adjusted OR: 1.20 (CI: 0.71 – 2.04)), fast self-reported speed (adjusted OR: 1.06 (CI: 0.68 – 1.66)), participation on a more difficult run (adjusted OR: 1.28 (CI: 0.79 – 20.8)) and jumping as a mechanism of injury (adjusted OR: 1.19 (CI: 0.77 – 1.83)).

Another cross-sectional study[49] showed that helmet wearers skied and snowboarded at lower speeds (adjusted OR: 0.51 (CI: 0.38 – 0.68)), and challenged themselves less than non-helmet wearers (adjusted OR: 0.67 (CI: 0.50 – 0.88)). A cross-sectional study from Austria[50] allowed the participants to subjectively classify themselves as cautious (n=369) or risk-taking (n=168), while also objectively measuring maximum speed attained on the slope by a radar speed gun. The two groups were not significantly different with regards to helmet use ($p > 0.1$). Instead, riskier behavior on the slopes was related with the higher skill level of the participants (OR: 2.09 (CI: 1.25–3.5), p=0.005). In contrast, one case-control study showed that risk taking skiers and snowboarders were more likely to wear a helmet (OR: 1.48 (CI: 1.21 – 1.81)). However, the latter study is limited by its assessment of risk-taking behavior with a formally "non-validated question."[39]

Study Limitations

A comprehensive review of the selected studies showed that no RCT has been conducted on the subject to date. It should be noted that the absence of randomization in the studies created potential for selection bias and inability to control for all the potential confounding factors. However, it must also be acknowledged that the conduct of a RCT on this subject is not a practically and ethically feasible prospect.[34] Almost 50% of the studies included in this review were, therefore, case-control studies.

Although some authors adjusted for the known extrinsic and intrinsic factors that could have affected outcomes such as consumption of drugs and alcohol, skill level and experience, type of equipment, fit of helmets used, age and gender of skiers and snowboarders, innate proclivity towards risk-taking etc, there were studies that did not adjust for many of these factors in their analysis. Other factors such as the weather conditions and the slope features on that particular day may also be involved in creating an atmosphere conducive to injuries but were not explored in all studies. In studies relying solely on data from hospitalized patients, the potential for Berkson's bias existed. Missing values and limited number of parameters assessed in the data sets, heterogeneity in response rates, methods of assessment, statistical analysis and the samples themselves was seen in many studies; all of these factors cumulatively limit a meaningful comparison between the different studies. These studies also rarely adjusted for the variation in individual skiing distance or protective equipment exposure.[51] Nevertheless, the trends in the associations between helmet use and different parameters can be appreciated.

Consensus among the studies on the definition of head, neck and cervical spine injury was also variable at best. Serious head injury has been defined in different studies as the occurrence of either traumatic amnesia,[35] loss of consciousness,[35] craniofacial fracture or intracranial lesion,[35] head injury requiring evacuation via ambulance,[38] head injury requiring referral to an emergency physician or to a hospital for treatment.[39] One study used three definitions of neck injury "a) any neck or cervical spine injury, b) an isolated neck injury that necessitated ambulance evacuation from the ski area and c) recorded neck or cervical spine fracture (simple or compound) or dislocation."[44] A recent systematic review on the utility of protective equipment in the prevention of concussion in sports has also pointed out this difficulty in the interpretation of the definition of the outcome of interest which can be based on symptoms, need for medical attention or self-reporting etc.[51] Similarly, the qualifications, experience and clinical acumen of the personnel assessing the injury and making the diagnosis also varied between the studies.[42] This, in turn, raises the possibility of misclassification, ascertainment and reporting bias. Although Hagel BE and associates have reported "moderate to almost perfect" agreement between ski patrol's report forms and follow-up data,[52] there was a wide variation in the kappa values reported depending on the risk factor being studied (range: 0.45 – 0.98). Some studies didn’t address the protective effect of helmets on attenuating the severity of the head injury sustained, and the severity of the head injury was not routinely graded in many studies. Authors also cited difficulties in reporting follow-ups for their samples. In addition, sample size of some studies was too small to achieve adequate statistical power to ascertain the true magnitude of the effects observed.

Studies that were conducted in temporal proximity to the high-profile deaths of celebrities on the ski slopes may also be fraught with "awareness" or "publicity" bias due to the widespread media coverage given to these events. Google News found > 1,100 mentions of Natasha Richardson's death in international press just in the two months following the event.[53] It is possible that this coverage generated anxiety and subsequently modified treatment-seeking and other subjective behaviors.[26] There is at least one study available which showed a 60% increase in the pediatric injury visits to the emergency room during the week following the death of Natasha Richardson in Canada.[53] Also, 15% of neurosurgeons in various European countries bought a ski helmet after the German politician's slope incident mentioned earlier.[26]

It is difficult to ascertain the precise magnitude of the protective effect of helmets in reducing the overall mortality from skiing and snowboarding because of the small number of fatalities reported in different studies and the allowance for only rudimentary analysis on such small sample sizes.[6,7,17,19,43] In the study by Sacco DE and associates,[6] none of the individuals sustaining head injuries (n=19) or fatalities (n=26) were wearing helmets. In Levy's sample,[7] only 3 of the total 1,214 patients admitted for ski-related injuries were wearing a helmet. Head injury was the cause of death in 14 of the 16 deaths reported in this study; none of these patients were wearing a helmet. In the study by Rughani et al.,[43] one skier died and was not wearing a helmet at the time of the collision.

Summary

The use of safety helmets clearly decreases the risk and severity of head injuries as compared to non-helmeted participants in skiing and snowboarding. The beneficial effects of helmets are not negated by unintended risks as their use does not appear to increase the risk of neck or cervical spine injury as compared to non-helmeted participants in skiing and snowboarding. The use of safety helmets also does not appear to increase the risk of compensation behavior as compared to non-helmeted participants in skiing and snowboarding. Therefore, helmets are strongly recommended during recreational skiing and snowboarding. Limitations in current studies have been highlighted and need to be appropriately addressed in future investigations on the subject.

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Table 1

Summary of Class II studies included in evidence-based review on the efficacy of safety helmets in recreational skiing and snowboarding (1980 – 2011)

Authors	Title	Citation	Summary
Case-control, case-cross over studies			
Authors	**Title**	**Citation**	**Summary**
Hagel BE, Pless IB, Goulet C, et al.	Effectiveness of helmets in skiers and snowboarders: Case-control and case crossover study.	*BMJ*. 2005;330:281	A study including 4,377 participants was conducted between 2001 and 2002. Helmets reduced the risk of any head injury (adjusted OR: 0.71 (CI: 0.55 – 0.92), 29% risk reduction) and head injury requiring evacuation via ambulance (adjusted OR: 0.44 (CI: 0.24 – 0.81), 56% reduction in risk).
Case-control studies			
Authors	**Title**	**Citation**	**Summary**
Hagel BE, Russell K, Goulet C, et al.	Helmet use and risk of neck injury in skiers and snowboarders.	*Am J Epidemiol*. 2010;171:1134-43.	Data from 100,394 participants between 1995 – 2005 was analyzed. Helmets didn't increase the risk of neck or cervical spine injuries in skiers and snowboarders (adjusted OR: 1.09 (CI: 0.95 – 1.25) for any neck injury, 1.28 (CI: 0.96 – 1.71) for isolated ambulance evacuated neck injuries and 1.02 (CI: 0.79 – 1.31) for cervical spine fractures or dislocations).
Hasler RM, Berov S, Benneker L, et al.	Are there risk factors for snowboard injuries? A case-control multicentre study of 559 snowboarders.	*Br J Sports Med*. 2010;44:816-21.	A survey of 559 snowboarders was conducted using a questionnaire in 2007 – 2008. A trend to an association with injury was observed for not wearing a helmet (OR: 4.65, (CI: 0.94 to 23.05), p = 0.0595). Using conditional inference trees, the following group was found to be at risk of injury: not wearing a helmet and riding on icy slopes.
Hasler RM, Dubler S, Benneker LM, et al.	Are there risk factors in alpine skiing? A controlled multicentre survey of 1278 skiers.	*Br J Sports Med*. 2009;43:1020-5.	A survey of 1,278 skiers was conducted using a questionnaire in 2007 – 2008. Use of helmet didn't emerge as a significant parameter for the patient group (OR: 1.44 (0.69 – 3.02), p= 0.331). Using conditional inference tree, following group was identified to be at risk for injury: VASspeed 4–7, icy slopes and not wearing a helmet.
Mueller BA, Cummings P, Rivara FP, et al.	Injuries of the head, face, and neck in relation to ski helmet use.	*Epidemiology*. 2008;19:270-6.	A study including 21,898 skiers and snowboarders at 3 ski resorts over 6 seasons was conducted. Helmets had a protective effect with regards to head injury (adjusted OR: 0.85 (CI: 0.76 – 0.95), 15% reduction in risk).
Sulheim S, Holme I, Ekeland A, et al.	Helmet use and risk of head injuries in alpine skiers and snowboarders.	*JAMA*. 2006;295:919-24.	A study with 6,269 participants was conducted in 2002. Helmet use reduced the risk of any head injury by 60% (adjusted odds ratio: 0.40 (CI: 0.30 – 0.55)), of head contusions and fractures by 53% (adjusted odds ratio: 0.47 (CI: 0.33 – 0.66)), and of severe head injury by 57% (adjusted odds ratio: 0.43 (CI: 0.25 – 0.77)). Risk taking skiers and snowboarders were more likely to wear a helmet (odds ratio: 1.48 (CI: 1.21 – 1.81)).
Hagel B, Pless IB, Goulet C, et al.	The effect of helmet use on injury severity and crash circumstances in skiers and snowboarders.	*Accid Anal Prev*. 2005;37:103-8.	A study including 3,295 participants from 19 areas of Quebec was conducted in 2001 – 2002. The study found no evidence of an increase in the severity of non-head-face-neck injury with helmet use in terms of the requirement of evacuation by ambulance (adjusted OR: 1.17 (CI: 0.79 – 1.73)) and need for admission to hospital [adjusted OR: 0.79 (CI: 0.53 – 1.18)). Similarly, no evidence was seen regarding the association of helmet use and fast self-reported speed (adjusted OR: 1.06 (CI: 0.68 – 1.66)) and participation on a more difficult run (adjusted OR: 1.28 (CI: 0.79 – 20.8)).
Macnab AJ, Smith T, Gagnon FA, et al.	Effect of helmet wear on the incidence of head/face and cervical spine injuries in young	*Inj Prev*. 2002;8:324-7.	A study in children < 13 years of age (n=70) between 1998 and 1999 showed that failure to wear a helmet increased the risk of head, neck or face injury (relative risk: 2.24 (CI: 1.23 – 4.12), corrected RR for activity:

Case-control, case-cross over studies			
Authors	**Title**	**Citation**	**Summary**
	skiers and snowboarders.		1.77 (CI: 0.98 – 3.19)) during skiing and snowboarding. The trend of the risk of cervical spine injury was seen to be towards the higher side when not wearing a helmet (relative risk: 2.0 (CI: 0.8 – 5.65); p=0.15).
Cross-sectional studies			
Authors	**Title**	**Citation**	**Summary**
Ruedl G, Pocecco E, Sommersacher R, et al.	Factors associated with self-reported risk-taking behaviour on ski slopes.	*Br J Sports Med*. 2010;44:204-6.	527 skiers and snowboarders in 2008 – 2009 subjectively classified themselves as cautious (n=369) or risk-taking (n=168). Objective measurements of maximum speed attained on the slope by a radar speed gun were also made. The two groups were not significantly different with regards to helmet use (p>0.1).
Scott MD, Buller DB, Andersen PA, et al.	Testing the risk compensation hypothesis for safety helmets in alpine skiing and snowboarding.	*Inj Prev*. 2007;13:173-7	1,779 participants were interviewed at 34 ski resorts in the western U.S. and Canada in 2003. Helmet wearers skied/snowboarded at lower speeds (adjusted OR: 0.51 (CI: 0.38 – 0.68)), and challenged themselves less than non-helmet wearers (adjusted OR: 0.67 (CI: 0.50 – 0.88)).
Machold W, Kwasny O, Gässler P, et al.	Risk of injury through snowboarding.	*J Trauma*. 2000;48:1109-14.	2,579 students in 1996 – 1997 in Austria, who engaged in snowboarding, filled out questionnaires. Results were suggestive of the protective effect of helmets in head injury (196 snowboarders (7.6%) wore a helmet and had no head injury while 0.7% of snowboarders without a helmet suffered a head injury). No ORs were reported.
Retrospective Cohort studies			
Authors	**Title**	**Citation**	**Summary**
Rughani AI, Lin CT, Ares WJ, et al.	Helmet use and reduction in skull fractures in skiers and snowboarders admitted to the hospital.	*J Neurosurg Pediatr*. 2011;7:268-71.	In a sample of 57 children with head injuries sustained during skiing or snowboarding, helmet use was associated with lower incidence of skull fractures (5.3% vs 36.8%, p =0.009) and overall craniofacial fractures (15.8 vs. 44.7%, p 0.03). The OR of a skull fracture in non-helmeted skiers and snowboarders presenting to the hospital was 10.5 (95% CI 1.26 – 87.4) as compared to helmet users. There was no significant difference in the incidence of cervical spine injury among helmeted and non-helmeted patients (p = 0.74).
Greve MW, Young DJ, Goss AL, et al.	Skiing and snowboarding head injuries in 2 areas of the United States.	*Wilderness Environ Med*. 2009;20:234-8.	A study between 2002 – 2004 including 1,013 participants from 9 medical facilities in Colorado, New York and Vermont was conducted. There was a decreased incidence of loss of consciousness in case of striking a fixed object while wearing a safety helmet ((χ2: 5.8; p < 0.05).
Case series			
Authors	**Title**	**Citation**	**Summary**
Cundy TP, Systermans BJ, Cundy WJ, et al.	Helmets for snow sports: prevalence, trends, predictors and attitudes to use.	*J Trauma*. 2010;69:1486-90.	A retrospective case series of 3,984 ski patrol accident reports from 2003 to 2008 was carried out in Australia. Helmet use was more likely in those who felt that helmets reduce their chance of severe injury (OR: 3.6 (CI: 2.1 – 6.4)) and amongst those who thought that helmet use should be mandatory (OR: 4.8 (CI: 2.7 – 8.5)).
Fukuda O, Hirashima Y, Origasa H, et al.	Characteristics of helmet or knit cap use in head injury of snowboarders.	*Neurol Med Chir (Tokyo)*. 2007;47:491-4	Questionnaire based data was collected from 1,190 snowboarders between 1999 – 2003. Patients were divided into three groups: helmet group (n=92), knit cap group (n=913), and no cap group (n=185). Serious head injury was overall observed in 46.1% patients (549/1,190). 59 serious head injuries occurred in the helmet group (64.1%; 59/92), 421 in knit cap group (46.1%; 421/913)) and 69 in the no cap group (37.3%;

Case-control, case-cross over studies			
Authors	**Title**	**Citation**	**Summary**
			69/185). After adjusting for jumping, a non-significant protective effect of helmet use on severe head injuries was seen (OR: 0.66, CI 0.32–1.35).
Bridges EJ, Rouah F, Johnston KM.	Snowblading injuries in Eastern Canada.	*Br J Sports Med*. 2003;37:511-5.	A prospective case series was conducted in 1999 – 2000 including 1,332 participants with traumatic injury related to winter sports. There was no increased incidence of neck injuries in injured participants wearing a helmet, even when adjusted for age and activity.