Efficacy of Helmet Use on Head Injury Reduction in Snow Sports: A Critically Appraised Topic

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Context: Review articles published in 2010 concluded that there was strong evidence to support the use of helmets as a way to decrease the risk of sustaining a head injury during snow sport participation. However, new research published over the last decade on this relationship warrants revisiting this primary injury prevention approach. Clinical Question: What is the effect of helmet use on the occurrence of head injuries in snow sports? Clinical Bottom Line: The results from the included studies did not consistently find a reduction in head injury occurrence with helmet use in snow sports. Rather, the collective findings were more supportive of a neutral relationship between helmet use and head injuries. Therefore, these heterogeneous findings indicate there is SORT Level B evidence to support the use of helmets as a primary head injury prevention approach in snow sports. Future initiatives should acknowledge the multifaceted nature of injury occurrence and seek to educate the public more clearly on the limitations of helmet use during skiing and snowboarding.

Keywords: skiing, snowboarding, concussion, traumatic brain injury, injury prevention

Clinical Scenario

Skiing and snowboarding are popular winter sports in the United States with over 13 million people participating each season for a total of over 50 million visits to ski areas.1,2 Over 100,000 nonfatal snow sport injuries occur each year,1 and of those, head injuries account for approximately 15% of all injuries in adults and 22% in children ≤15 years old.3 Although head injuries make up only a fraction of all snow sport injuries, they account for 50%–80% of adult slope fatalities.4,5 Suffering a traumatic brain injury is the leading cause of serious injury and death in skiers and snowboarders.5 From 2002 to 2012, there were 41.5 fatal accidents in skiing and snowboarding per season on average, and approximately 87% (n = 36) of those individuals were wearing a helmet at the time of their accident.4 Other past research has found that 11 fatalities per season in snow sports could be avoided with the use of helmets, and the risk of head injuries overall can be reduced by 44% (n = 7,700 injuries per season).5

In March 2010, a meta-analysis was published that assessed the effect of helmet use on the risk of head injuries among skiers and snowboarders.6 The meta-analysis included 12 studies, and pooled odds ratio (OR) results concluded that helmeted snow sport participants were less likely to have a head injury compared to nonhelmeted individuals.6 Just 2 months later in May 2010, an additional systematic review was published to summarize the best available evidence regarding the impact of helmet use on head injuries in skiers and snowboarders.7 This review included 10 studies and found, similarly to the results of the meta-analysis, that there was strong evidence to support the use of helmets in reducing the risk of head injuries in snow sports.7 Based upon these findings, both Russell et al.8 and Cusimano and Kwok9 recommended the use of helmets for skiers and snowboarders in order to reduce the risk of sustaining a head injury. Since those recommendations over a decade ago, newer investigations8,9 have found a significant increase in helmet use among snow sport participants over time, however, the evidence regarding a change in head injury occurrence is less clear. For example, Sulheim et al.10 found a significant increase in helmet use among snow sport participants from 23.8% in 2002 to 77.1% in 2011, but the relative reduction in the proportion of head injuries was less substantial with only a decrease of 1.8% between those time points. Additionally, in an ecological study by Dickson et al.11 that captured data from 2008 to 2013, results indicated that helmet use increased from 69% to 80% over the study period, respectively, while the rate of head injuries remained relatively unchanged. Given these heterogeneous findings, the purpose of this critically appraised topic was to synthesize the latest evidence to determine the effectiveness of helmet use on the frequency of head injuries in snow sport participants. The results of this critically appraised topic could help guide future snow sport head injury prevention and awareness initiatives.

Focused Clinical Question

What is the effect of helmet use on the occurrence of head injuries in snow sports?
Search Strategy

A comprehensive search strategy was conducted in the Fall of 2021 to assess the clinical question. We executed searches on PubMed, CINAHL, and SPORTDiscus computerized databases. The primary search terms used were: skiing, snowboarding, snow sports, head injuries, concussion, traumatic brain injury, helmets, helmeted, and nonhelmeted. See Table 1 for a detailed description of the PICO components and search terms used to guide our systematic review of the literature.

Inclusion Criteria

- Studies that investigated head injuries in helmeted versus nonhelmeted snowboarders and skiers. These categories of snow sports were isolated from other winter sport activities (e.g., snowmobiling, snowshoeing, ice skating) due to their similar downhill nature and sole inclusion as the populations of interest in the previously published systematic review and meta-analyses on helmet use and head injury occurrence.6,7
- Studies that were conducted both nationally (United States) and internationally.
- Studies published from 2014 through October 2021 that had at least 50% of data collection time after 2010.
- Studies that were available in English in full-text form.

Exclusion Criteria

- Studies published prior to 2014.
- Studies that did not directly compare helmeted versus nonhelmeted head injury occurrence.
- Studies that focused solely on professional snow sport athletes. Results of articles that only included professional snow sport athletes may not be a realistic comparison of the impact of helmet use on head injuries in the general population due to the advanced skill level, engagement in higher risk skiing and snowboarding maneuvers, and financial implications of performance on this subpopulation of snow sport participants.

Results of Search, Best Evidence Appraisal, and Key Findings

The literature was searched to identify studies that investigated the use of helmets on head injury occurrences in recreational snow sport activities. The literature search yielded 143 articles initially that underwent title and abstract screening, duplicate article removal, and the application of the inclusion and exclusion criteria (Figure 1). This resulted in the inclusion of four studies8,9,12,13 in this critical appraisal that directly answered the clinical question. Overall, there were inconsistent findings among the included studies8,9,12,13 regarding the influence of helmet use on head injury occurrence in snow sport participants.

Dickson and Terwiel8 conducted an ecological study using accident data from the Canada West Ski Areas Association and found snow sport participants wearing a helmet were 8% (95% confidence interval [CI] [1.02, 1.14]) more likely to have a head injury than those not wearing a helmet, however, results of a multivariable linear regression suggested that helmet use was not a significant predictor of head injury rate (p = .312). Stuart et al.12 utilized a retrospective multicenter chart review study design and concluded that helmet use in skiing and snowboarding participants did not significantly decrease the

| Table 1 PICO Clinical Question Components and Search Terms |
|---------------------------------|---------------------------------|---------------------------------|
| Component | Data evaluated | Search terms* |
| Outcome | Head injury occurrence | |

*Terms used in PubMed search.
odds of suffering a concussion (OR = 1.28; 95% CI [0.91, 1.80]) or other moderate head injuries (OR = 1.10; 95% CI [0.75, 1.62]). Although, they did find that helmet use did significantly reduce the odds of sustaining a more serious head injury (OR = 0.47; 95% CI [0.23, 0.95]). Porte et al. completed a retrospective cohort study that concluded helmeted participants were significantly more likely to experience an intracranial hemorrhage (OR = 1.81; 95% CI [0.14, 0.64]) compared to those who were not helmeted. Lastly, Bailly et al. performed a case control study that included 1,425 total traumatic brain injuries, of which 839 (59%) were non-helmeted and 586 (41%) were helmeted injury scenarios. Additionally, results of this study indicated that helmeted snow sport participants had lower odds of sustaining a traumatic brain injury (adjusted OR = 0.65; 95% CI [0.56, 0.75]) compared to those who did not wear a helmet.

### Evidence Quality Assessment

The Physiotherapy Evidence Database (PEDro) and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist were used to assess the quality of the included studies. All four studies were found to have a 2/10 PEDro score. Additionally, two of the studies scored a 21 on the STROBE checklist, one scored a 20, and one scored a 16. According to the Oxford Centre for Evidence-Based Medicine classifications, one study had a level of evidence of 2, two studies had a level of evidence of 3, and one study had a level of evidence of 4. Characteristics of the four included studies can be seen in Table 2.

### Results of Evidence Quality Assessment

The four included studies earned PEDro scores of 2/10 as they provided results for between-group statistical comparisons and point measures and measures of variability for at least one key outcome. Given the nature of the PEDro scale, these low scores were anticipated due to the observational study designs of the included studies. To provide another quality assessment perspective, we also completed the STROBE checklist as it is more suitable to assess internal validity of observational studies. The included studies included the majority of items found on the STROBE checklist. However, the Dickson and Terwiel study did not discuss the statistical methods used, the potential sources of bias, or other analyses performed. The Bailly et al. study did not report other analyses performed, and the remaining two studies did not explain how the study size was determined. The remaining STROBE criteria were met within each respective study.

### Clinical Bottom Line

Results from the four studies evaluated show slightly varying results with the majority of the studies trending toward no difference in head injury occurrence when the snow sport participants are either helmeted or not helmeted. According to Dickson and Terwiel, head injury rates did not differ by helmet use status. Porter et al.'s study demonstrated that helmeted participants were more likely to suffer...
### Table 2 (continued)

<table>
<thead>
<tr>
<th>Inclusion/exclusion criteria</th>
<th>Dickson and Terwiel(^8)</th>
<th>Stuart et al.(^{12})</th>
<th>Porter et al.(^9)</th>
<th>Bailly et al.(^{13})</th>
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</thead>
<tbody>
<tr>
<td><strong>Inclusion</strong></td>
<td>Data for alpine skiers and snowboarders were included as long as at least eight seasons of data across the decade were recorded. There had to be a minimum of 20 injuries per year in the resort. Skier visit data had to be available. Data were excluded if the location was indoors or no ticket type was indicated. Injury data were excluded if only a facial injury was reported without an associated head injury. A final exclusion was if the data on helmet usage were incomplete.</td>
<td>All head or face related trauma which occurred from skiing and snowboarding activities treated at either study center were included. Face trauma included all impacts that may have caused head or brain related injuries. Additionally, incidents at either emergency department involving head impact that did not result in head injury were included. Skiing and snowboarding fatalities resulting from head injury were identified and included. Those who sustained injuries not associated with active participation in skiing or snowboarding were excluded.</td>
<td>Patients were included if they had an International Classification of Diseases Codes—9th or 10th Revision injury mechanism related to skiing or snowboarding. Participants were excluded if helmet status information was incomplete.</td>
<td>Any injury reported by an Alpine sport participant resulting from a skiing or snowboarding related accident who was consulted by one of the resort’s physicians associated with the Médecins de Montagne group was recorded. Patient information (age, sex, sport, and estimated skill level) and the type of injury were recorded. Helmet use, crash type (collision or not), and location (in a snow park or not) were included in the survey.</td>
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<tr>
<td><strong>Outcome measures</strong></td>
<td>The multiple linear regression was built upon previous research that has explored risk factors in snow sport injuries. This was done to further investigate the potential relationship between the head injury rate and the helmeted population who were injured.</td>
<td>Helmet use and its association with injury outcomes were examined. The MAIS was used to define the highest AIS score. Odds were compared for moderate and severe head injury (AIS ≥ 2 or 3, respectively) in helmeted versus unhelmeted snow sport participants.</td>
<td>The primary exposure was helmet use during injury, and the primary outcome was severe injury (admission ISS greater than 15). After patients were identified from the trauma registry, a manual chart review was performed. All registry data points were cross-checked with medical record data.</td>
<td>Helmet use and the risk of TBI were evaluated with a multivariate logistic regression adjusted for age, sex, sport, skill level, crash type, and crash location.</td>
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<tr>
<td><strong>Results</strong></td>
<td>The multiple linear regression indicated that there was no significant relationship between the proportion of helmeted participants and the head injury rate ((p = .312)). There has been a decrease in the head injury rate with the most notable change occurring from 2015 to 2016 when helmet usage levels in the injured population reached 90%. While helmet usage in the injured population increased from 63% to 91%, reported head injuries remained in the range of 9%–10% of all injuries across the decade, (X^2(36, n = 107,540), 203.4, p &lt; .001, \varphi = 0.04) indicating a small effect.</td>
<td>Helmet users who went to the ED are 0.47 times less likely ((p = .05; 95% \text{ CI [0.23, 0.95]})) to suffer a MAIS 3+ head injury as compared to unhelmeted participants. However, helmet users did not have a decreased risk of suffering concussion (OR = 1.28; 95% CI [0.91, 1.80]) or other MAIS 2+ head injuries (OR = 1.10; 95% CI [0.75, 1.62]).</td>
<td>Helmet use in the population doubled from 43% to 81% ((p &lt; .001)) over the study period. However, the head injury rate did not significantly change, only slightly decreasing from 49% (2010–2011) to 43% (2017–2018; (p = .499)).</td>
<td>Helmeted participants had a lower risk of sustaining TBIs (adjusted OR = 0.65) when compared with unhelmeted participants. Of the 43,099 snow sport participants injured during the 2012–2014 period, 1,425 experienced a TBI (skull fracture is included in this figure). Of the Case 1 participants, 41% were helmeted and 59% of were unhelmeted.</td>
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<tr>
<td><strong>OCEBM level of evidence</strong></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>Evidence quality scores</strong></td>
<td>PEDro: 2/10 STROBE: 16/22</td>
<td>PEDro: 2/10 STROBE: 21/22</td>
<td>PEDro: 2/10 STROBE: 21/22</td>
<td>PEDro: 2/10 STROBE: 20/22</td>
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<tr>
<td><strong>Support for the answer?</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
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*Note.* AIS = abbreviated injury scale; ED = emergency department; ISS = injury severity score; OR = odds ratio; PEDro = Physiotherapy Evidence Database; STROBE = Strengthening the Reporting of Observational Studies in Epidemiology; OCEBM = Oxford Centre for Evidence-Based Medicine; TBI = traumatic brain injury; MAIS = maximum abbreviated injury scale; CI = confidence interval.
an intracranial hemorrhage, but less likely to sustain a skull fracture or scalp laceration. This finding highlights the protection for the skull and scalp when helmeted but not for the brain itself. Stuart et al.\textsuperscript{12} showed no difference for concussion or moderate head injury between helmeted and unhelmeted participants, however there was a reduction in the severity of head injury in the participants who wore a helmet. Bailly et al.\textsuperscript{13} was the only study evaluated to show that wearing a helmet while participating in snow sports decreased the odds of sustaining a head injury. Therefore, the overall findings from the included studies\textsuperscript{8,9,12,13} highlight the lack of clear evidence for preventing head injuries through helmet use in snow sports. In reality, there are likely a dynamic array of factors that contribute to sustaining a head injury during snow sport participation beyond just wearing helmets.

In accordance with the Strength of Recommendation Taxonomy,\textsuperscript{14} the heterogeneity of results included in this critical appraisal indicate there is Grade B evidence regarding the use of helmets for reducing head injury occurrence in skiing and snowboarding. This grade is appropriate as there were inconsistent findings stemming from studies of limited quality patient-oriented evidence.

Implications for Practice, Education, and Future Research

The results of this critical appraisal suggest that helmet use may not play as large a role in head injury mitigation in snow sports as once originally thought. Although the introduction of helmets for snow sports has increased in recent years, only one of the included studies\textsuperscript{13} showed significant difference in injury occurrence between helmeted and nonhelmeted snow sport participants. These findings may suggest that a significant increase in helmet use does not directly lead to a significant decrease in head injury occurrence. Rather, it has been speculated that helmet use may give people a false sense of security and lead them to partake in riskier behaviors.\textsuperscript{9,13} It would be impractical to reverse snow sport helmet recommendations at this point, but future snow sport head injury awareness and prevention approaches should focus on educating individuals on the limitations of helmets, proper helmet use and care, as well as signs and symptoms of head injuries, rather than simply promoting them as an all-encompassing safety tool.

Risk compensation is a theory that may partially explain why the results of the included studies\textsuperscript{8,9,12,13} showed no significant difference between head injury occurrence by helmet status. The theory states that individuals who wear a protective device, such as a helmet, use that device as an excuse to act in a riskier manner or partake in riskier behaviors due to the perceived safety they believe they are receiving from the device.\textsuperscript{15} The relationship between risk taking, head injury occurrence, and helmet use is one that is typically overlooked and could be one motivating factor behind head injury occurrence in skiers and snowboarders. It may also help to explain why there has not been a significant decrease in head injury rates after the introduction of helmet requirements years ago. The increase in helmet use overtime in skiing and snowboarding has opened the door for risk compensation to exist in this setting; thus, potentially creating a new reason or mechanism for head injuries to be sustained due to the creation of a false sense of security that may not have been present before helmets became popular. This may explain why the results of our critical appraisal differ from those of the 2010 systematic review and meta-analyses\textsuperscript{6,7} that originally led to the helmet recommendations as helmet use was not as widespread during the 1991–2009 time period of their included studies. Steps to properly educate the public on risk compensation theory along with the many other contributing factors, such as proper equipment fitting and quality control, falling mechanics, limitations of helmets, terrain risk, age, experience, and skill level should be instated in ski and snowboarding resorts.

The main limitation for head injury prevention that helmets miss the mark on is the fact that a helmet will have little to do with slowing down or stopping the brain from moving in the skull when accelerations are applied to the head.\textsuperscript{13} Their primary protective mechanism is to prevent lacerations and skull fractures, not closed head injuries.\textsuperscript{9,13,16} Moving forward, skiers and snowboarders may benefit from using a more multifaceted approach to reduce head injuries rather than solely relying on helmets. From a public health perspective, this could include the introduction of a video, such as what indoor rock climbing gyms and airlines implement, before equipment rental or use of the slopes to relay important head safety information. This video segment can also introduce what someone should do if they think they or a friend have sustained a head injury and explain a potential protocol for management. Furthermore, this awareness approach should encourage participants to engage only in skiing or snowboarding maneuvers and use runs that correspond to their true level of experience and skill. Specifically, a note of caution should be provided regarding terrain park use as their obstacles and jumps have been found to increase the odds of suffering a head, neck, back, or severe injury compared to regular slopes.\textsuperscript{17} Additionally, a more widespread approach that goes beyond ski resorts could be implemented by athletic therapists and athletic trainers. As the winter months approach, infographics that include explicit messaging regarding the limitations of helmet use during snow sport participation and the concept of risk compensation could be posted in clinics and circulated via electronic communications to all patients. It may also be important to highlight that injuries sustained during recreational skiing and snowboarding activities could lead to negative consequences related to physical activity and sport engagement or impact their ability to fulfill job responsibilities.

There has not been a decline in the frequency of head injuries, even though helmet use has increased over the last 10 years.\textsuperscript{8} Therefore, there is a need for research on how to more adequately reduce the occurrence of head injuries in snow sport. For instance, Ruedl et al.\textsuperscript{18} has postulated that factors, such as skill level, age, and sex may lead to injuries beyond the personality trait of risky behavior and helmet use. Future research is needed to assess these variables and their influence on head injuries in snow sports. Additionally, we need to promote and educate the public on safe skiing/snowboarding practices including proper equipment fitting, falling mechanics, limitations of helmets, terrain park risk, age, experience, and skill level.\textsuperscript{9,18}

CAT Kill Date: July 2025

CATs have limited life and should be revisited approximately 2 years after publication (see 10.1123/ijatt.2018-0093).

References


