

# Head Injuries in Winter Sports: Downhill Skiing, Snowboarding, Sledding, Snowmobiling, Ice Skating and Ice Hockey

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## KEYWORDS

- Skiing • Snowboarding • Sledding
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Popular winter sports and recreational activities often combine high rates of speed with the potential for collision with other participants or large, stationary objects. Head injuries in winter sports range from seemingly inconsequential minor trauma to life-threatening intracranial pathology. Factors that appear to influence head injury incidence and severity include mechanism of injury, participant skill level, age, terrain and venue conditions, helmet use, risky behaviors, and sport-specific regulations. Prevention strategies include education and helmet use programs, legislation, and sport-specific rules. Despite efforts to increase helmet use and head injury awareness, sports such as skiing and snowboarding have not yet shown wide acceptance of helmet use. Conversely, in ice hockey, where helmet use is ubiquitous, concussion remains a common diagnosis among injured players. It is important for physicians to be aware of risk factors and types of head injuries specific to particular sports in order to anticipate, help prevent, and treat these injuries.

Injuries as a result of winter sporting activities can also bring a unique set of challenges to the treating physician, including hypothermia and difficulties related to remote and often difficult-to-access locations.

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This article provides an overview of the epidemiology and treatment of injuries seen in some of the more commonly enjoyed winter sports, with a focus on the unique aspects of injuries as they relate to specific sports.

### DOWNSHILL SKIING

Downhill skiing is enjoyed by more than 200 million people worldwide.<sup>1</sup> Downhill skiers are at risk of serious head injury through falls or collisions, sometimes at high speeds, which can lead to long-term disability or death.<sup>2,3</sup> Head injury incidence is estimated to be in the range of 0.77 to 3.8/100,000 ski visits, with most cases involving beginner or intermediate-level enthusiasts.<sup>2,6</sup> Head injuries are the leading cause of death in downhill skiing accidents, with an average age of head-injured skiers of approximately 30 years,<sup>1,4</sup> but traumatic brain injury is also the leading cause of downhill skiing injury fatalities in children.<sup>5</sup> Head injury is also the most common diagnosis among child and adolescent skiers requiring admission to hospital.<sup>7,8</sup> In a study of skiing related fatalities in Colorado from 1980 to 2001, 42.5% of 174 deaths in that era resulted from head injury.<sup>9</sup>

Approximately 50% of head injuries result from falls on the slopes, whereas 42% to 47% result from collisions.<sup>1,2</sup> Collisions with other skiers and snowboarders account for 58% and 34% of collision-related head injuries respectively, whereas collisions with trees and lift towers account for only 4% and 3% respectively.<sup>2</sup> Jumping accounts for only 2.5% of head injuries among skiers.<sup>2</sup> The pattern of injury by head region is: occipital (31%), frontal (29%), diffuse (23%), temporal (14%), and parietal (3%).<sup>2</sup> Most head injuries in skiing are mild, with concussion as the most frequent diagnosis.<sup>1</sup> The most common organic head injury among skiers is skull fracture. Wearing a helmet has been shown to reduce the risk of head injuries in downhill skiers, even when other potential risk factors are considered.<sup>10,11</sup> It was once assumed that helmet use would increase the incidence of cervical spine injuries in downhill skiers, but this controversial assumption has been shown to be unlikely.<sup>12</sup>

Despite clear evidence that helmet use prevents or reduces the severity of injuries, use remains less than widely accepted.<sup>13</sup> In one study examining helmet use in child enthusiasts, only 30% of injured skiers and snowboarders wore helmets.<sup>12</sup> It has also been suggested that no suitable helmet exists to protect all skiers, and that helmet development should be based on injury data analysis and strict standards.<sup>14</sup>

There are very few published data on the risk and nature of head injury among Nordic or cross-country skiers.

### SNOWBOARDING

Snowboarding is a downhill alpine sport that was initially assumed to have injury patterns similar to those of skiing, but recent studies have shown that the incidence of head and spinal injuries in snowboarding is higher than previously documented.<sup>15</sup> Injuries to the head and face represent 25% of all snowboarding injuries, and the rate of head and neck injury among snowboarders is one and a half to three that of skiers.<sup>1,2,16,17</sup> The incidence of head injury for snowboarders is estimated to be 6.5/100,000 visits, compared with 3.8/100,000 visits for skiers.<sup>18</sup> Head-injured snowboarders tend to be an average of 3.6 to 6.3 years younger than their skiing counterparts, and are more likely to be male.<sup>2,4</sup> It is speculated that higher risk-taking behavior in younger males may be responsible for higher incidences of head injury. Most head injuries occur as a result of falls on mild to moderate slopes among beginner to intermediate-level participants.<sup>2</sup> Jumping accounts for 30% of head injury cases among snowboarders, compared with only 2.5% of cases in skiers,<sup>2</sup> reflecting the differences between the two activities. Most severe head injuries have occurred on gentle or moderate slopes resulting from the “opposite edge” phenomenon, in which the edge of the

snowboard facing upslope catches a ridge of snow during a turn at low speeds, causing the rider to lose balance and fall.<sup>18</sup> The occipital region of the head is the area most frequently affected in snowboarding head injuries, with a pattern of injury by head region being: occipital (48%), diffuse (23%), frontal (19%), temporal (9%), and parietal (1%).<sup>2</sup> Snowboarders suffer intracranial hemorrhage more than twice as often as skiers, and require a craniotomy nearly three times as often.<sup>19</sup> The reason for the difference in injury patterns in snowboarders compared with those in skiers is unclear, but may be related to the rails and jumps commonly found in snowboard parks.

The most common organic head injury among snowboarders is subdural hematoma, as opposed to skiers, who exhibit a higher frequency of skull fractures.<sup>2</sup> Acute subdural hematomas are related to falls on the slope, falling backward, and occipital impact, whereas subcortical hemorrhagic contusions are thought to be related to falling during a jump, temporal impact, and falling on a jump platform.<sup>18</sup> Mild snowboarding head injuries may rarely lead to chronic subdural hematoma, even in the absence of other predisposing factors.<sup>20,21</sup> Snowboarders suffering head injuries more frequently require longer terms of rehabilitation and ongoing care compared with skiers who have head injuries,<sup>19</sup> suggesting that the injuries themselves are more severe. Helmet use in snowboarders has shown similar efficacy as in skiers, leading to a reduction in head injury even after other risk factors have been considered.<sup>10,11</sup> As with downhill skiing, helmet use does not significantly increase the risk of cervical spine injuries in snowboarders.<sup>12</sup>

### SLEDDING/TOBOGGANING

Injuries in sledding affect a larger and younger contingent of winter sport participants than injuries in skiing or snowboarding, likely owing to its easy accessibility, high speeds of descent, limited control and stability, and dangerous venues fraught with hazards such as trees, rocks, and roadways.<sup>4,7</sup> Sledding is the winter activity most commonly associated with admission to hospital for children under 16 years of age, with head injury being the most common diagnosis.<sup>7</sup> The average age of a severely injured sledder is 18.8 plus or minus 11.9 years; 12 years younger than the average skier, and more than 5 years younger than the average snowboarder.<sup>4</sup> More than half (59%) of injured children sledders are male. Injured children sledders are almost three times as likely to require hospital admission compared with children injured in other sports.<sup>22,23</sup> Although head injuries represent 13% of all sledding injuries in general, they account for 55% of severe sledding injuries.<sup>4,22</sup> In most pediatric studies examining sledding injuries requiring emergency department assessment, head/neck injuries are the most frequent type of injury.<sup>24–26</sup> Among childhood sledding injuries, younger children ( $\leq 6$  yrs) are more likely to experience head/neck trauma compared with older children, with a relative risk of 2.60 ( $P < .001$ ).<sup>24</sup> The most serious sledding injuries were incurred after the rider struck a tree or another stationary object in 60% and 76% of injuries.<sup>25,26</sup> Although the incidence of collisions with motor vehicles is low, these often have catastrophic consequences,<sup>26,27</sup> with head injury much more common.<sup>28</sup> Although many studies advocate helmet use for sledders, the efficacy of helmet use in sledding is uncertain, and there are no specific helmets designed for sledding.. Helmet use among sledders is significantly lower than for downhill skiing or snowboarding, with only about 3% of sledders wearing some form of head protection.<sup>24</sup> In addition to helmet use, familiarity with the terrain, proper lighting conditions, and proper supervision in children may also lower the risk of injury.

### SNOWMOBILING

Snowmobiles are an increasingly popular form of winter recreation in Canada and the northern United States. Snowmobiles can weigh over 600 pounds, and reach speeds

in excess of 90 mph.<sup>29</sup> Each year in North America more than 200 people die from injuries sustained while snowmobiling, and more than 14,000 people present to hospitals with snowmobile-related injuries.<sup>29</sup> Only 15% of snowmobile accidents take place on groomed trails, where 80% of riding occurs, whereas 31% occur on roadways.<sup>29,30</sup> Head injuries represent 13% to 34% of all snowmobiling injuries, and are the leading cause of snowmobile injury fatalities in both adult and pediatric populations.<sup>30-34</sup> Snowmobile fatalities have a strong male predominance.<sup>29</sup> Collision is the most common mechanism of injury in adult population snowmobilers, and is also the most common mechanism for fatality in the pediatric population.<sup>30,33</sup> In a study of severe snowmobile injuries presenting to a level 1 trauma care center in Manitoba over 10 years, 27.6% of patients died of their injuries.<sup>30</sup> Risk factors included excessive speed (54%), suboptimal lighting conditions (86%), and blood alcohol level greater than 0.08 (70%).<sup>30</sup> Fifty-four percent of accidents in the adult population involve excessive speed, compared with 33% in the pediatric population,<sup>30,35</sup> whereas alcohol is implicated in 40% to 70% of snowmobile-related fatalities.<sup>29,30</sup> Among cases with fatality, only 35% of riders were wearing a helmet in one study,<sup>36</sup> lack of helmet use should be considered a major risk factor for snowmobile injury death. For pediatric patients who had snowmobile injuries requiring admission to a trauma center, only 68% of children were wearing a helmet at the time of injury.<sup>34</sup> Moreover, whereas older children are more likely to suffer serious snowmobile related injuries, younger children are less likely to wear a helmet while snowmobiling.<sup>34,35</sup> A review of snowmobile legislation in states where pediatric deaths have occurred revealed that few helmet laws or age restrictions exist, and children as young as 8 years may legally operate a snowmobile in some jurisdictions.<sup>33</sup> Snowmobile injuries, including head injuries, may be reduced through initiatives such as trail development and improvement, driver education about intoxication and riding, innovative helmet use programs, and mandatory snowmobile registration and driver licensure.<sup>36</sup> In Sudbury, Ontario, a significant decrease in snowmobile related injuries and fatalities was noted after the institution of a community-based snowmobile policing program.<sup>29</sup>

### ICE SKATING

Under the age of 18, head injuries compose 13.3% of ice skating injuries, compared with only 5.0% of in-line skating injuries and 4.4% of roller skating injuries. Ice skaters suffer five times as many concussions as in-line skaters, and seven times as many concussions as roller skaters.<sup>37</sup> Children injured while skating have a mean age of 10.9 years, with a male-to-female ratio of 1:1.<sup>37</sup> Most pediatric ice skating head injuries result from falls, which take place when the child is not wearing a helmet or other protective equipment.<sup>37,38</sup> Ice skating falls causing head injury are predominantly from falling forward, and involve head contact with the ice surface.<sup>39</sup> Helmet use is widely recommended as a means to reduce the risk of head injury in ice skating.<sup>38,39</sup> The observation that, during forward falls, the ice skater often attempts to brace against the ice with outstretched hands, has also led to the recommendation of a wrist-guard with a non-slip palm to protect the skater against head and wrist injury.<sup>39</sup> Although ice skating fatalities are rare, the authors recently were involved in a case of a helmetless 4-year-old female who died from a severe head injury after she fell while skating, following which she had another skater land on her.

There is a paucity of data regarding head injury in competitive speed skaters.

### ICE HOCKEY

Hockey-related injuries are covered in a separate article in this issue, but are covered briefly below.

With the exception of rare cases of intracranial hemorrhage, concussions compose the majority of head injury cases in ice hockey.<sup>40</sup> Moreover, concussion is the most common injury diagnosis overall in minor league, collegiate men's, and university women's ice hockey.<sup>41-43</sup> Because of a lack of appropriate studies and a noted trend of under-reporting of concussion throughout youth ice hockey organizations, the overall incidence of head injury in ice hockey is difficult to gauge.<sup>40,44</sup> Contact with an opposing player through body checking is the most common mechanism of concussion in hockey, followed by collision with the ice surface, or with the goal post or boards.<sup>41,45,46</sup> Smaller ice surfaces increase the risk of concussion among high level hockey players.<sup>47</sup> Ice hockey players experience 65% of their injuries during games, even though games account for only 23% of total exposures.<sup>42</sup> In addition to mandatory helmet use in organized hockey, other methods of injury prevention have been considered. In a large study examining head injuries presenting to American emergency departments,<sup>48</sup> it was noted that the rate of concussion for ice hockey players dropped significantly the same year that USA Hockey implemented stricter rules surrounding body checking. The one-time showing of a hockey-specific injury prevention video to 11- to 12-year-old Canadian minor hockey players resulted in fewer body checking related penalties, as well as an increase in the ability of players to name common mechanisms of head and spinal cord injuries in hockey.<sup>49</sup> Although controversial, some critics have advocated for the delay of the introduction of body contact in minor hockey until the age of 16 as a means of reducing the incidence of concussion in ice hockey. When the authors began playing minor hockey in the early 1970s and 1980s, full body contact was prior to 6 years of age, whereas Hockey Canada has since instituted rules that disallow body contact in hockey leagues until the age of 11.

## SUMMARY

The most common theme among head injuries related to winter sports is speed, because skiing, snowboarding, snowmobiling, sledding, ice skating and ice hockey can all be associated with high speeds. Not surprisingly, the pairing of speed with a slippery surface, be it snow or ice, commonly results in a loss of control and subsequent injury. For virtually every winter-related sporting activity in which head injury can occur, the use of a protective helmet, usually activity or sport specific, has been shown to reduce both the incidence and severity of head injury. The authors are strong advocates for legislated helmet use in high-risk activities, especially among children, who should also participate in public awareness programs demonstrating the importance of helmet use.

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