Skiing and snowboarding injury prevention

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Abstract
Skiing and snowboarding are popular recreational and competitive sport activities for children and youth. Injuries associated with both activities are frequent and can be serious. There is new evidence documenting the benefit of wearing helmets while skiing and snowboarding, as well as data refuting suggestions that helmet use may increase the risk of neck injury. There is also evidence to support using wrist guards while snowboarding. There is poor uptake of effective preventive measures such as protective equipment use and related policy. Physicians should have the information required to counsel children, youth and families regarding safer snow sport participation, including helmet use, wearing wrist guards for snowboarding, training and supervision, the importance of proper equipment fitting and binding adjustment, sun safety and avoiding substance use while on the slopes.

Key Words: Helmet; Injury; Skiing; Snowboarding; Wrist guard

Epidemiology
An estimated 77,300 skiing and 62,000 snowboarding injuries were treated in US emergency departments in 2002 alone, including 10,700 traumatic brain injuries [4]. Snowboarding is responsible for an estimated 25% of nonfatal outdoor recreational injuries requiring emergency care [5], In an analysis of Canadian children presenting to emergency departments with injuries related to snow and ice activities, snowboarding and alpine skiing were the second- and third-leading causes, after hockey. However, both skiing (12.6%) and snowboarding (11.3%) had higher rates of hospitalization when compared to hockey (3.6%) [6]. Skiing and snowboarding combined are the second-leading cause of sport- and recreation-related injury hospitalizations in the winter (18%) and spring months (10%) in Ontario, surpassed only by snowmobile injuries [7].

The risk of injury for skiers and snowboarders is approximately 2 to 4 per 1000 participant days, with the highest risk in snowboarders [5][6][9][10]-[12]. Children and teens seven to 17 years of age have higher rates of injury than younger and older participants [3]. Injuries requiring referral to a tertiary trauma center have been estimated at 0.06 to 0.07 per 1000 participant days (13). Deaths have been estimated to occur at a rate of 0.5 to 1.9 per 1 million participant days [14][15]. In the 2009/10 season there were 38 deaths in the US (0.64 deaths per million visits) [16]. There is recent evidence that the incidence of traumatic brain injury and spinal cord injury in skiing and snowboarding is increasing worldwide. This increase in serious injuries may be related to increased risk-taking, such as jumping and acrobatic activities, both on new terrain and in snow parks specifically designed for snowboarding [17].

Snow sports participation
There are more than 78 million annual visits to North American ski areas by skiers and snowboarders of all ages [1][2]. Approximately 20% to 30% of participants are children and youth [3]. An estimated 15% of Canadians over the age of 12, and 4% of the US population over the age of seven, report participating in alpine skiing, cross-country skiing or snowboarding at least once in 2008-2009 [1].
Head injuries account for the majority of deaths, serious injuries and significant disabilities sustained while skiing and snowboarding [18]. Most fatalities and serious injuries are due to collisions with stationary objects such as trees and lift poles [18][19][20]. Skiers are more likely to be injured due to collisions, whereas snowboarders are more likely to be injured by falling [13][21][25].

Several reviews have been published that summarize the epidemiology of skiing and snowboarding injuries in children and youth [26][27]. In alpine skiing, the most common injury site is the lower extremity (40% to 60%); knee injuries (eg, fractures and sprains) are common and observed more frequently in younger children. Other typical injuries are to the head and neck (10% to 20%), upper extremity (15% to 25%), and thumb (10% to 20%). In snowboarding, the most common site injured is the wrist (22%), with upper-extremity injuries (including wrist injuries) in approximately 50% of cases. Head injuries are more common in snowboarders than skiers, with rates of 10% (emergency department series) to 30% to 40% (trauma admissions). Ski patrol injury reports document head and face injuries in 10% to 50% of cases [28].

Risk/protective factors

A number of individual-level risk factors have been identified for skiing and snowboarding injuries in children, including age, sex, experience and skill level, and deficient binding adjustment.

Age and sex

Children and youth are at higher risk for ski and snowboarding injuries, including lower-extremity injuries, head and neck injuries, and more severe (predominantly head) injuries [3][10][11][14][26][30]. The majority (70% to 90%) of injured snowboarders are male [9][21][31][33]. Males appear to be at higher risk for more severe injuries, head and neck injuries, and fatal injuries, than their female counterparts [14][18][26][34].

Experience and skill

Among young skiers, 40% to 50% of injuries occur among beginners, often on the first day of skiing [11][28][27]. While injury rates have been shown to be lower for expert skiers and snowboarders compared with beginners [11][26][35], experts may be at risk for more severe injuries. In a recent case control study, expert skiers and snowboarders were more likely to sustain a severe injury and to be evacuated by ambulance [36]. Several studies of snowboarder injuries have found mean injury severity scores (ISS) increase with greater skill level [33][34].

Ski equipment

Injury incidence among skiers has declined over several decades, largely due to improvements in ski equipment, particularly boots and bindings [37][38]. Binding technology has been influential in reducing lower extremity-, equipment-related (LEER) injuries in skiers; however, knee sprains and upper-extremity injuries continue to be common [37]. LEER injuries (sprains and fractures) are found in 40% of all injured skiers, with the most common injury-type being knee sprains (56%) [29]. Young skiers are at higher risk for LEER injuries related to skeletal immaturity, boot design, and their inability to activate self-release bindings [27].

Modern bindings reduce the incidence of foot, ankle and lower tibial injuries providing they are properly mounted, adjusted and maintained [39][38]. Strategies to better protect the knee have not been identified [39][40]. Many injuries are the result of poorly adjusted bindings [39]. In one study of adult LEER injuries it was determined that in 96% of cases the ski bindings did not release when the injury occurred [41]. Non-release of bindings has also been reported as an injury contributor in other studies of youth and adults [29][42]. In one study, skiers younger than 13 years of age with poorly adjusted bindings were more likely to be injured than children with properly adjusted bindings (adjusted odds ratio 2.11, 95% CI 1.02 to 4.33) [43]. Release bindings, which are adjusted by weight and skiing ability, have contributed to reducing the incidence of lower-extremity injuries [44]. Research suggests that a professional should adjust children's ski bindings at the start of each lesson and that children need to be taught to check their bindings at the beginning of each ski day [45].

Rented or borrowed equipment

Among skiers younger than 13 years of age, children using rented equipment were more likely to be injured than children using their own equipment (adjusted odds ratio 7.14, 95% CI 2.59 to 19.87) [43]. Other studies of child and adult skiers and snowboarders have documented similar findings [11][42]. Concern has been raised regarding a lack of quality control at ski shops selling equipment and providing rentals, particularly when fitting and adjusting equipment for children [27]. Campaigns to advocate for the testing of
boot-binding systems according to industry-established standards have been called for worldwide [45][47].

**Facility and environment factors (design, maintenance, policies)**

Ski and snowboarding fatalities and serious injuries are often caused by colliding with a stationary object such as a tree or lift pole. Facility design features, maintenance and policy enforcement can minimize the risk of these collisions and of 'out-of-bounds' incidents. Mandatory helmet use, having training requirements for beginners, and the regulation of licensed resorts (eg, volume limits, trail design standards) could also contribute to reducing injuries at these facilities [48]. Slope conditions, including poor grooming and design, ice, damp snow and narrow, overcrowded trails have been reported as potential contributors to collisions and injuries [27]. The lowest risk of snowboard injury is on deep snow, such as powder, fresh snow or groomed slopes [34][35]. In an analysis of 'black spots' where injury incidents appeared to cluster in a ski resort area, it was found that as grooming hours decreased, injury rates increased [8]. While ski area operators have developed practices designed to address identified and predictable safety hazards, analyses of trail design and maintenance strategies and their impact on injury incidence and severity have not been reported [27][49]. Several studies have documented significantly more severe injuries and head injuries in terrain or snow parks designed for snowboarding than on ski runs [50][51][52].

**Prevention strategies**

**Helmets**

Recreational alpine skiing and snowboarding helmet standards have been developed by the Canadian Standards Association (CAN/CSA Z236.3-08), the Snell Foundation (RS-98 or S-98), the European Committee for Standardization (EN 1077:2007), and the American Society for Testing and Materials (ASTM F2040-06).

**Helmet effectiveness:** A recent systematic review found that helmets significantly reduce the risk of head injury. Skiers and snowboarders wearing a helmet were less likely to have a head injury (OR 0.65, 95% CI 0.55 to 0.79), with a greater reduction in studies that included children younger than 13 years of age (OR 0.41, 95% CI 0.28 to 0.62) [53]. The pooled analysis showed that helmet use reduces the risk of head injury by 35% (95% CI 21 to 46%). These findings are consistent with a special investigation report by the Consumer Product Safety Commission (USA), which estimated that more than 50% of skiing- and snowboarding-related head injuries among children younger than 15 years of age could be reduced by using a helmet, and 11 deaths in the United States could be prevented every year [54].

There has been concern raised in the literature regarding the potential for helmet wearers to experience an increased risk of cervical spine injuries [55]. This has not been supported by a number of case control studies of children [56], and of children and adults [53][57][60]. A recent systematic review also concluded that helmets were not associated with an increased risk of neck injury in a pooled analysis of six studies, including two studies of children (OR 0.89, 95% CI 0.72 to 1.09) [53]. There is also no evidence that helmet use in skiing and snowboarding is associated with riskier behaviour [53][61][62].

**Helmet use:** A number of national organizations recommend that helmets be worn by recreational skiers and snowboarders, including the Centers for Disease Control and Prevention (USA), the American Medical Association, the American Academy of Orthopaedic Surgeons, the Canadian Academy of Sport and Exercise Medicine, the Canadian Ski Council and the International Society for Skiing Safety [46][47][54][55][56].

Few observational studies of helmet use are reported in the literature. In the largest study of 1472 children, helmets were worn by 37%, with higher rates found in skiers than snowboarders (42% versus 32%), children accompanied by adults (60% versus 26% with peers) and children observed on the beginner slopes [66]. Surveys of ski area operators and skiers have documented helmet use at approximately 55% in Canada and 57% in the US, with higher rates in young children, older adults and more experienced participants [1][67].

Few studies have been published that evaluate interventions to increase helmet use. One regional social marketing campaign and a program which offered a free helmet loan with equipment rental were effective in increasing helmet rental when compared with control stores. Observed helmet use also increased over the study period on local ski slopes [68].

The effect of legislation to increase helmet use on the slopes, especially by children, is also unknown due to a dearth of such policies in North America. New
Jersey, however, has just passed legislation mandating helmets for children younger than 18 years of age, and some European countries, such as Italy, have enacted similar legislation over the past few years \[69][70\]. Although helmet legislation has been shown to be effective for cycling, the perceived potential lack of efficacy and enforceability of helmet legislation on the slopes has hampered other jurisdictions from passing similar legislation \[71\]. There is a need for authorities to develop effective policy that sends a clear message to all skiers and snowboarders, and their caregivers, on the importance of mandatory helmet use in preventing head injuries and saving lives.

**Wrist guards**

The most common injuries among snowboarders are wrist fractures and sprains \[9][21][72][73\]. A recent systematic review showed that wrist guards significantly reduced the risk of wrist injury (RR: 0.23; 95% CI: 0.13, 0.41), wrist fracture (RR: 0.29; 95% CI: 0.10, 0.87), and wrist sprain (RR: 0.17; 95% CI: 0.07, 0.41); results were similar for young snowboarders \[74\]. While some research has suggested that using wrist guards may increase the risk of sustaining an elbow, upper-arm or shoulder injury, the evidence is conflicting and has not been confirmed in a controlled trial or well-designed prospective study \[21][74][75\]. However, despite evidence that wrist guards prevent wrist injuries, the prevalence of wrist guard use is low, with use rates of 5% to 6% or less in both children and adults \[21][73][75\].

**Other interventions**

**Formal instruction**

A number of studies have evaluated the effectiveness of ski and snowboard instruction in increasing safer behaviours and reducing the risk of injury. Presenting an alpine skiing instruction and safety video on buses en route to ski areas resulted in fewer injuries (16% versus 23%, \( p < 0.05 \)) and in improved self-testing and adjustment of bindings \[76\]. On-slope staff involved in an injury prevention program consisting of a videotaped analysis of anterior cruciate ligament (ACL) injuries and facilitated group discussion had a reduced incidence of ACL injury of 62% (\( P < 0.005 \)) over three seasons \[77\]. In a study of LEER injuries, skiers with previous instruction were significantly less likely to be injured \[29\]. However, there is inconsistent evidence in the literature with respect to the effectiveness of formal training: one study documented an increase in injury risk after falls training \[35\]; another showed no effect for previous training \[43\].

**Ski area safety programs**

Ski area associations and ski patrol organizations in Canada and the United States have developed numerous safety programs and initiatives that emphasize the importance of helmet use and of skiing and snowboarding in a controlled and responsible manner. The National Ski Areas Association and industry partners develop slope safety education for guests, including the current “Heads-Up” campaign, terrain park safety initiatives (consumer guide, signage, website, videos), avalanche safety awareness programs, helmet information (www.lidsonkids.org), safety and trail signage, an annual safety week, a poster contest, and ski resort safety awards. Similar programs exist in Canada. Bilingual resources are available for school and group trips to ski resorts, consisting of a DVD/VHS (“A Little Respect”), an educational guide for school trip leaders, a helmet fitting card, and a safety brochure for parents to review with their child before the trip (www.thinkfirst.ca). Some ski areas require that this program be completed prior to group trips. Youth programs, curriculum ideas, and resource materials are also available online through the Canadian Avalanche Centre. Topics include ski and slope safety and signage, the Alpine Responsibility Code, snow science, winter survival skills and avalanche awareness (www.avalanche.ca). Additional ski and snowboarding safety resources are available online at www.nsaa.org and www.csps.ca.

**The Alpine Responsibility Code**

An Alpine Responsibility Code has been disseminated in many countries and is emphasized in snow sports prevention programs worldwide. This code includes the following measures to reduce the risk of injury: beginners should (a) take lessons from a certified instructor; (b) never ski or snowboard alone; (c) maintain and check ski and snowboard equipment; (d) exercise and stretch before each day of skiing/ snowboarding; (e) stay on marked trails; (f) follow the skiers/boarders responsibility code; (g) be alert to physical and environmental hazards; (h) wear appropriate gear, including helmets; (i) ski and snowboard on hills that are within your ability and skill level; (j) quit before becoming too tired \[17\]. Parents can view a child-friendly version of the code at www.lidsonkids.org.
Recommendations

The Canadian Paediatric Society recommends the following:

- **Physicians should provide office-based anticipatory guidance**, counselling families to:
  - Wear proper protective ski equipment, including a certified helmet and goggles, plus wrist guards for snowboarding;
  - Receive formal instruction, followed by a graduated exposure to more challenging terrain and conditions under the supervision of an experienced participant;
  - Become familiar with and adhere to the Alpine Responsibility Code;
  - Ensure a safe environment, including adequate supervision, terrain/runs and equipment appropriate to the child or youth’s age and ability;
  - Ensure proper fit and adjustment of equipment, particularly bindings; and
  - Understand the high risk of severe injury that comes with alcohol and/or drug use on the slopes.

- **Governments should develop policy/legislation making helmet use mandatory** by all ages while skiing and snowboarding, with concurrent messaging to educate the public and resort operators about the indisputable importance of helmets in saving lives and preventing head injuries.

- **Ski areas/resorts/snowparks should develop and enforce safety policies** that:
  - Make helmet use mandatory;
  - Improve helmet access at local ski facilities;
  - Establish industry standards for ski shops and resorts on binding adjustment;
  - Promote and enforce the Alpine Responsibility Code;
  - Ensure safe design and prevention-oriented maintenance programs for ski facilities; and
  - Promote safety awareness and education programs for participants, with consistent messaging and signage.

- **Schools should develop policies mandating proper equipment use, formal instruction, and appropriate supervision** for school-related trips, clubs and competitions.

- **Research should be supported** to address:
  - Interventions to increase helmet and wrist guard use;
  - Effective snow sport helmets and related design development and standards;
  - Improved binding design (eg, multidirectional release), standards and optimal adjustment;
  - The roles of preseason conditioning and training;
  - The risk and profile of injuries at ski area terrain parks;
  - The evaluation of existing interventions, such as promoting the Alpine Responsibility Code and “Keep your Lid On,” to determine their effectiveness and improve uptake;
– Ongoing surveillance of snow sports participation data for children, of emergency department, hospitalization, and mortality data for skiers and snowboarders, of protective equipment use, and of injuries due to ski/snowboard environments, such as falls in terrain parks and injuries related to ski lifts.

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References

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