ACTIVE & SAFE

Evidence Summary:
Skiing

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BC INJURY research and prevention unit

The British Columbia Injury Research and Prevention Unit (BCIRPU) was established by the Ministry of Health and the Minister's Injury Prevention Advisory Committee in August 1997. BCIRPU is housed within the Evidence to Innovation research theme at BC Children's Hospital (BCCH) and supported by the Provincial Health Services Authority (PHSA) and the University of British Columbia (UBC). BCIRPU's vision is *to be a leader in the production and transfer of injury prevention knowledge and the integration of evidence-based injury prevention practices into the daily lives of those at risk, those who care for them, and those with a mandate for public health and safety in British Columbia.*

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UBC BC Children's Hospital Research Institute

Evidence synthesis tool

SPORT	Skiing	**Target Group**	Recreational skiers	
Injury Mechanisms	Common injury mechanisms include technical error, collision with an inanimate object or a person, a fall on a slope, a fall after an aerial manoeuvre or/and a large drop to the ground or a fall from ski lift			
Incidence/ Prevalence	**Risk/Protective Factors**	**Interventions**	**Implementation/ Evaluation**	**Resources**
Overall Injury rates provided are between 2-3 injuries per 1000 skier days (Ackery, Hagel, Provvidenza, & Tator, 2007; Toth, 2006). **Fatal injury** The risk of ski fatalities is estimated at 0.5-1.96 per million skier visits (Ackery et al., 2007; Toth, 2006). **Spinal cord injury (SCI)** The incidence of SCI is approximately 0.001 to 0.075 per 1000 skier/snowboarder days (Ackery et al., 2007; Toth, McNeil, & Feasby, 2005). **Head and Neck Injury** Incidence rates of head injury reported are 0,01 per 1000 skiers days, 0.038 per 1000 visits and 0.005 per 1000 participants (Ackery et al., 2007).	**Modifiable Risk Factors** *Helmet Use:* The pooled odds ratio (OR) indicates that skiers and snowboarders with a helmet are significantly less likely than those without a helmet to have a head injury (OR: 0.65; 95% CI: 0.55–0.79). Helmets were not associated with an increased risk of neck injury (OR: 0.89; 95% CI: 0.72–1.09) (Russell et al., 2010). *Knee Brace Use:* Knee brace reduces the risk of a knee injury in skiers (OR: 0.21; 90%CI: 0.11-0.43) (Hume, Lorimer, Griffiths, Carlson, & Lamont, 2015). *Bindings Check:* No clear evidence that bindings check (skiers and snowboarders) reduces the risk of lower limbs injuries (OR: 1.09; 90% CI: 0.86-1.38) (Hume et al., 2015). *Rented Equipment:* Skiers and snowboarders that rent equipment have a higher risk of injury (OR: 2.58; 90% CI: 1.98-3.37) (Hume et al., 2015). *Ability:*	**Education Programs** Generally, educational programs are more likely to decrease the risk of injury. However, programs are too different to provide a combined odds ratio. Educational content appears to have an important impact on the outcome (Hume et al., 2015). **Cost-Effectiveness** Limited evidence for studies evaluating the cost to benefit ratio of countermeasure interventions (Hume et al., 2015).	**Prevention Program** A prevention program in collaboration with prevention-minded partners improves the implementation of measures (Bianchi & Brügger, 2015). **Multifaceted Approach** A multifaceted approach, including education, legislation, and enforcement is effective in achieving full helmet compliance among all ages of skiers and snowboarders (Fenerty et al., 2016). **Limitations** Resources for evaluation are limited. Research should be supported to address the evaluation of existing interventions or programs to determine their effectiveness and improve uptake (Hume et al., 2015)	**Resources** Think first Canada (injury prevention booklet) http://data.injuryresearch.bc.ca Québec Association of Ski Areas (safety messages) https://maneige.ski SportMedBC (safety messages) https://sportmedbc.com Parachute Canada (safety messages) http://www.parachutecanada.org The National Ski Areas Association (NSAA) and Burton Snowboards- Smart Style (educational program, safety messages, and terrain parks videos) http://www.nsaa.org http://www.terrainparksafety.org Injury prevention center (safety messages) http://injurypreventioncentre.ca

For skiers and snowboarders, incidence rates of head and neck injury are reported between 0.09 and 0.46 per 1000 outings (Russell, Christie, & Hagel, 2010). **Knee Injury** Incidence rates reported between 0.02 to 0.63 tears per 1000 exposures (Prodromos, Han, Rogowski, Joyce, & Shi, 2007). **Ankle Injury** The incidence rate for sprain injury is 1.6 per 1000 person-exposure (Fong, Hong, Chan, Yung, & Chan, 2007).	The beginner skiers are more likely to sustain an injury (OR: 2.72; 90% CI: 2.15-3.44) (Hume et al., 2015). *Lessons:* No clear evidence demonstrates that skiers and snowboarders who take lessons have a different risk of injury (OR: 1.18; 90% CI: 0.96-1.45) (Hume et al., 2015). *Education:* No clear evidence that education (skiers and snowboarders) is a protective factor for all injuries (OR: 0.67; 90% CI: 0.38-1.17) (Hume et al., 2015). *Alcohol /Drug Use:* Abstinence from alcohol/drugs recommended in ski slopes (Hume et al., 2015). *Terrain Conditions:* Inappropriate trail design and grooming can increase incidence on injuries at certain trail sites (Hume et al., 2015). *Type of Terrain:* Injuries sustained in TPs (skiers and snowboarders) are more likely to affect the head/neck complex (OR: 1.39; 95% CI: 1.34-1.45) (Audet et al., Unpublished work). Risk factors for injuries in TPs are snowboarding as activity (OR: 3.96; 95% CI: 3.59-4.35), being a male (OR: 3.94; 95% CI: 3.61-4.30), are rated as expert (OR: 3.13; 95% CI: 2.90-3.38), have a younger age, and using features that			Ontario Snow Resorts Association (security promotion) https://www.skiontario.ca Canadian Ski Council (safety messages) https://www.skicanada.org Accident Prevention Office (safety messages and injury prevention videos) http://www.bfu.ch Oslo Sports Trauma Research Center (scientific literature on injury prevention) http://www.ostrc.no

	promote aerial manoeuvres or/and large drops to the ground (e.g. jump, half-pipe) (Audet et al., Unpublished work). **Non-Modifiable Factors** *Age:* Skiers of younger age have more risk to be injured (Audet et al., Unpublished work; Hume et al., 2015). *Sex:* Compared to males skiers, females are more likely to be injured (OR: 1.21; 90% CI: 1.02-1.42) (Hume et al., 2015). Skiers and snowboarders females are less likely to sustain a head injury than males (OR: 0.72; 90% CI: 0.65-0.79) (Hume et al., 2015). Skiers and snowboarders females are more likely to sustain a knee injury than males (OR: 2.77; 90% CI: 2.01-3.81) (Hume et al., 2015). *Weather Conditions:* Poor visibility (poor vs good) increases the risk of injury in skiers and snowboarders (OR: 2.69; 90% CI: 1.43-5.07) (Hume et al., 2015).			

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Review of Sport Injury Burden, Risk Factors, and Prevention

Skiing

Incidence and Prevalence

The overall incidence of recreational skiing injuries is between 2-3 injuries per 1000 skier days (Ackery, Hagel, Provvidenza, & Tator, 2007; Toth, 2006). The most common injury types observed are fractures, dislocations, sprains, contusions/lacerations, and wounds. Generally, anatomic locations more likely to be involved when an injury occurs are the head, neck, spinal cord, shoulder, thumb, knee and ankle. It is well known that skiers are more affected by lower limbs injuries. Mechanisms most frequently reported are technical errors, collisions with an inanimate object or a person, simple falls on ski slopes or after the execution of an aerial maneuver or/and a large drop to the ground, and falls from ski lift.

For some specific anatomic locations, incidence rates were well described in the literature. Upper limb injuries including the shoulder and thumb (e.g. fracture, dislocation, and sprain) frequently occur while skiing. Often, they are the result of a fall. For lower limb injuries, the knee is a frequent location injured and ligament tears are commonly observed. Incidence rates reported are between 0.02 and 0.63 tears per 1000 exposures (Prodromos, Han, Rogowski, Joyce, & Shi, 2007). For the ankle, the sprain incidence rate is about 1.6 per 1000 person-exposure (Fong, Hong, Chan, Yung, & Chan, 2007). The reported incidence rates for head and neck injuries range between 0.09 and 0.46 per 1000 outings, for skiers and snowboarders (Russell, Christie, & Hagel, 2010). Spinal cord injury in skiing is rare; incidence rates have been reported between 0.001 and 0.01 per 1000 skier days (Ackery et al., 2007; Toth, McNeil, & Feasby, 2005). Head and spinal cord injuries mostly occur after a fall related to a loss of control during an aerial maneuver or/and a large drop to the ground (Ackery et al., 2007). In rare cases, a skier can suffer a fatal injury, and the incidence is estimated at 0.5-1.96 per million skier visits (Ackery et al., 2007; Toth, 2006).

Most of the relevant literature retrieved from systematic reviews focusing on incidence and prevalence data has been published between 2005 and 2010. Since, equipment optimization may have decreased the risk of injury over time, particularly for lower limb injuries (Hume, Lorimer, Griffiths, Carlson, & Lamont, 2015). Furthermore, incidence rates for head, neck and spinal cord injuries may have increased due to the increase of terrain parks (TP) in ski areas since the early 2000s (Audet et al., Unpublished work). TPs are particular slopes in ski areas that contain features promoting aerial maneuvers and high drops to the ground (e.g. jump, rail, box, half-pipe, etc.).

Risk and Protective Factors

Hume et al. (2015) published a systematic review of the literature with meta-analysis that described the range of risk and protective factors for ski and snowboard related injuries. Modifiable risk factors included use of equipment (helmet use, knee brace use, binding check,

and rented equipment), skiing ability, education, lessons, alcohol/drug use, terrain condition and type of terrain. Non-modifiable factors included age, sex, and weather conditions.

Modifiable Risk Factors

The use of helmets has been well documented to reduce the risk of head injury in skiing (Ackery et al., 2007; Benson, Hamilton, Meeuwisse, McCrory, & Dvorak, 2009; Cusimano & Kwok, 2010; Hume et al., 2015; Russell et al., 2010). One systematic review on helmet use demonstrated that skiers and snowboarders who wear a helmet are less likely to suffer of a head injury (OR: 0.65; 95% CI: 0.55–0.79) without an increased risk of neck injury (OR: 0.89; 95% CI: 0.72–1.09) (Russell et al., 2010). Knee brace is also demonstrated to be a protective factor for injury (OR: 0.21; 90%CI: 0.11-0.43) (Hume et al., 2015). However, this protective equipment is not supported by Smith, Laprade, Jansson, Aroen, and Wijdicks (2014), demonstrating that more research is still needed in that specific field. Checking the skiers binding may also play a role in injury risk but currently not enough evidence support bindings check as a protective factor (Hume et al., 2015).There is some literature to support the use of rental equipment as a risk factor for skiing injury. One study reports that those who rented equipment were at increased risk for injury, compared to those having their own equipment (OR: 2.58; 90% CI: 1.98-3.37) (Hume et al., 2015). However, rental locations are most often visited by people with less experience/ability; a significant confounding variable in this association. Thus, this could actually represent the population characteristics over rented equipment as a risk factor for injury. In fact, beginners are more likely to sustain an injury than more skilled skiers (OR: 2.72; 90% CI: 2.15-3.44) (Hume et al., 2015). More specifically, first four days of exposure are the most precarious and falls on ski slopes are the principal injury mechanism. Conversely, skiers with greater ability injured themselves in falls after the execution of an aerial maneuver or/and a large drop to the ground (Audet et al., Unpublished work; Hume et al., 2015; Toth et al., 2005). Education as a risk factor for injury in skiing have less support in the literature. Education (OR: 0.67; 90% CI: 0.38-1.17) and lessons (OR: 1.18; 90% CI: 0.96-1.45) (Hume et al., 2015) in skiers and snowboarders are not associated with an increasing or a decreasing risk of injury. However, various methods described by authors can explained that situation. Consumption of alcohol and/or drug in ski areas has also been studied. Intake of these substances affects judgment and decreases reaction time to a stimulus. Qualitative evidence support that consumption of alcohol and/or drug are a risk factor for injuries (Hume et al., 2015). Terrain condition can have a considerable impact on participants. One study cites an increased risk of injury caused by inappropriate trail design and/or grooming at certain trail sites (Hume et al., 2015). Additionally, the type of terrain is a risk factor for severe injury (Audet et al., Unpublished work). A systematic review of the literature on skiing and snowboarding injuries demonstrates an increase in head/neck (OR: 1.39; 95% CI: 1.34-1.45) and spinal injuries in TPs, compared to regular slopes (Audet et al., Unpublished work). Specifically, risk factors for injuries in TPs are activity (snowboarders over skiers, OR: 3.96; 95% CI: 3.59-4.35), sex (males over females, OR: 3.94; 95% CI: 3.61-4.30), skiing ability (experts over beginners and intermediates, OR: 3.13; 95% CI; 2.90-3.38), age (youngers skiers over older skiers), and using features that promote aerial maneuvers or/and large drops to the ground (e.g. jump, half-pipe) (Audet et al., Unpublished work). Analyses with adjustment for confounders should give more accurate results on helmet use in TPs.

Non-Modifiable Risk Factors

Non-modifiable risk factors for skiing include age (younger skiers over older skiers) and sex (females over males, OR: 1.21; 90% CI: 1.02-1.42) (Hume et al., 2015). In addition, when females were compared to males, a clear effect of sex in skiing and snowboarding was found for the risk of head injury (OR: 0.72; 90% CI: 0.65-0.79) and the knee injury (OR: 2.77; 90% CI: 2.01-3.81) (Hume et al., 2015). Finally, weather conditions can impact injury occurrence in skiers. One study reports that as compared to good conditions, poor visibility increases the risk of injury (OR 2.69; 90% CI: 1.43-5.07) (Hume et al., 2015).

Opportunities for Prevention: Effective Interventions, Cost-Effectiveness, Implementation and Evaluation

There is a dearth of literature examining the effectiveness of interventions to reduce injury in skiing. Before 2015, there were six studies examining the effectiveness of educational programs and only one on ski binding intervention (Hume et al., 2015). Some educational programs have demonstrated positive results to reduce injuries in specific contexts and populations. For example, an educational video for recreational skiers (45 minutes), a workshop and video education program for ski area on-slope staff (1 hour, specific to reducing knee sprain injury), a media campaign on ski binding adjustment to a local population, and a free text program that shares victims' stories and gives safety tips to ski club members, has demonstrated protective effects for injuries. However, there are studies that do not support educational programs as effective interventions for ski injury. Various educational strategies can explain that situation. Finally, the only intervention study on ski bindings may be effective to decrease the risk of injury by providing information on ski bindings adjustment and correct use of the ski poles to local recreational skiers. However, not enough evidence exists to do a clear statement.

A systematic review of the literature indicates that interventions for recreational skiers must target beginner to reduce the risk of injury caused by falls and young males to reduce the risk of severe injury mainly caused by falls after the execution of aerial maneuvers or/and large drops to the ground. Specific interventions should be targeted females to reduce the risk of the knee injury during skiing.

From reviews of the literature, there is no strong evidence on guidance around the implementation of countermeasures or programs in a skiing context. Some studies provide direction for future research. Hume et al. (2015) suggests the need to consider the current socio-cultural and technological context when implementing interventions to reduce ski-related injury. In addition, implementation strategies need collaboration between prevention partners (e.g. health-care providers, health-care funders, ski areas workers) that includes a multifaceted approach; education, legislation, and enforcement, has been shown to be effective for full helmet compliance among skiers and snowboarders of all ages (Fenerty et al., 2016). Literature has demonstrated that using various approaches may have a positive impact on the implementation of countermeasures/programs (Gielen & Sleet, 2003; Sleet & Moffett, 2009).

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Conclusion

This systematic review, mainly based on syntheses of the literature related to injury prevention in skiing, provides current information about incidence/prevalence, risk and protective factors and the effectiveness of interventions to reduce the burden of injury in skiing. Modifiable factors that can have an influence on injury risk include equipment (helmet use, knee brace use, binding check, and rented equipment), skiing ability, education, lessons, alcohol/drug use, terrain condition, and type of terrain whereas non-modifiable factors include age, sex, and weather conditions. There is limited research on the effectiveness of interventions; currently, only educational interventions showed promising results. Thresholds in the literature are existing for cost-effectiveness, implantation and evaluation of interventions.

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