Title: Recreational snow sports injury risk factors and countermeasures: A meta-analysis review and Haddon matrix evaluation

Running title: Snow sports injury risk factors and countermeasures

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Abstract

Background:

Snow sports (alpine skiing/snowboarding) would benefit from easily implemented and cost effective injury prevention countermeasures that are effective at reducing injury rate and severity.

Objective:

For snow sports, to identify risk factors and to quantify evidence for effectiveness of injury prevention countermeasures.

Methods:

Searches of electronic literature databases to February 2014 identified 98 journal articles focused on snow sports that met inclusion criteria and were reviewed. Pooled odds ratios with 90% confidence interval and inferences (OR; 90%CI, % likelihood benefit/harm) were calculated using data from 55 studies using a spread sheet for combining independent groups with a weighting factor based on quality rating scores for effects.

Results:

More experienced skiers and snowboarders are more likely to sustain an injury as the result of jumps, while beginners sustain injuries primarily as a result of falls. Key risk factors that countermeasure interventions should focus on include beginner skiers (OR 2.72; 90%CI 2.15-3.44, 99% most likely harmful), beginner snowboarders (OR 2.66; 90%CI 2.08-3.40, 99% harmful), skiers/snowboarders who rent snow equipment (OR 2.58; 90%CI 1.98-3.37, 99% harmful) and poor visibility due to inclement weather (OR 2.69; 90%CI 1.43-5.07, 97% harmful). Effective countermeasures include helmets for skiers/snowboarders to prevent head injuries (OR 0.58; 90%CI 0.51-0.66, 99% most likely beneficial), and wrist guards for snowboarders to prevent wrist injuries (OR 0.33; 90%CI 0.23-0.47, 99% beneficial).

Discussion:

The review identified key risk factors for snow sport injuries and evaluated the evidence for the effectiveness of existing injury prevention countermeasures in recreational (general public use of slopes, not racing) snow sports using a Haddon's matrix conceptual framework for injury causation (host/snow sport participant, agent/mechanism and environment/community).

Conclusion:

Best evidence for effectiveness of injury prevention countermeasures in recreational snow sports was for the use of helmets and wrist guards and to address low visibility issues via weather reports and signage.

1. Introduction

Snow sports are a popular recreational activity, however incidence of injury can be high for both skiers and snowboarders [1, 2]. Targeted injury prevention countermeasures have the potential to help reduce the incidence and severity of recreational snow sports injuries if they are based on an understanding of injury mechanisms and associated risk factors. Most research still focuses on the incidence and causes/mechanics of injuries rather than implementing preventive measures. Injuries result from a set of circumstances and pre-existing conditions that can be considered using Haddon's matrix [3] that provides a conceptual framework for injury causation. The temporal components of pre-event (primary injury prevention), event (secondary injury prevention) and post-event (tertiary injury prevention) phases were considered against human, agent and environmental factors. When considering recreational snow sport injuries, the key question is: "Where will injury prevention interventions be most effective within this matrix?" In selecting injury prevention countermeasures there needs to be: identification of the key problem hazards and resulting injuries; consideration of design change that ideally will not result in individuals having to take action each time the countermeasure is used; ensuring the countermeasure is accepted for use by the participants; ensuring there is a positive cost to benefit ratio; no unwanted side effects or misuse of the countermeasure; and the effects of the countermeasure can be measured. The effectiveness of common injury prevention countermeasures such as education and behaviour change programmes, environmental/equipment design changes, and regulation/legislation changes need to be evaluated.

2. Objective

The review aimed to identify key risk factors and evaluated the evidence for the effectiveness of injury prevention countermeasures in recreational snow sports using a Haddon's matrix [3] conceptual framework for injury causation (host/snow sport participant, agent/mechanism and environment/community).

3. Methods

3.1 Literature Search Methodology

Cochrane Collaboration [4] review methodology (literature search; assessment of study quality; data collection of study characteristics; analysis and interpretation of results; recommendations for practice and further research) was used to evaluate the injury risk factors and effectiveness of injury prevention countermeasures in snow sports.

3.2 Search Parameters and Criteria

A search of the literature was conducted for snow sport risk factors and mechanisms. The PubMed, CINAHL, Web of Science and SPORTDiscus databases, to February 2014 were searched for terms linked with the Boolean operators ('AND', 'OR', 'NOT'): 'ski*', 'snowboard*', 'injur*', 'risk', 'prevention'. Injury and prevention studies prior to the 1990s were considered relevant today as we learn from our historical approaches. However, due to changes in technology, some interventions surrounding equipment (bindings, braces, helmets) would hopefully have better effects the more recent the study. Given the limited number of studies for any risk factor, an inclusive approach was taken for the year of publication. Papers were selected based on title, then abstract and finally text. Manual searching of reference lists and the 'Cited by' tool on Google Scholar were used to identify additional articles. From volumes 6-19 of "Skiing Trauma and Safety" available for review, 324 articles were reviewed. These volumes from the American Society for Testing Materials (ASTM) series of conference proceeding articles were reviewed given this is a specific conference series containing full papers focused on snow injury issues. Papers were excluded if their content: (i) was unavailable in English; (ii) was unavailable in full text format; (iii) did not provide additional information for any of the identified sections and subsections of this review. Inclusion criteria for all articles were: (i) reported data for risk factors on snow-sport injury rate or severity; or (ii) reported data for interventions to reduce snow-sport injury. For subsequent analysis exclusion criteria were: (i) did not provide odd ratios (OR) or risk ratios (RR) and/or other statistics allowing assessment of the effect factors on injury (or data to enable their calculation e.g., cohort studies using only absolute and not relative injury rates); (ii) data reported solely for other forms of snow-sports e.g., telemarking, Nordic skiing, ski boarding; (iii) data reported only death rather than injury rate; (iv) data only compared injury risk between alpine skiing and snowboarding. In summary, articles were excluded if they were epidemiological studies with no injury risk focus, or provided no data allowing risk statistics to be calculated, or were intervention studies without an injury risk factor focus or did not provide enough data for the odds ratio analyses (Fig. 1 shows the flow of information through the systematic review).

A total of 6,738 papers were identified, of which 3,045 were duplicates. After selection for inclusion criteria and elimination based on exclusion criteria, 98 papers were left for inclusion into the final review (Fig. 1). Of the resulting 98 journal articles, ten intervention studies (outlined in Table 1) and 88 papers (outlined in Electronic Supplementary Material Table S1) detailing injury risk factors were reviewed with six of the intervention studies and 49 of the other studies summarised for the pooled odds ratio analyses. Although only the aforementioned papers were tabulated and used for pooled odds ratio analyses, additional papers were kept and used for supporting evidence. For example, 23 snow-sport literature reviews were identified via online searching focusing on topics including helmet use [5], wrist guard use [6], ski bindings [7] and alpine ski strength and conditioning [8]. Other groups of relevant articles included helmet use intervention or analysis [9-13] and injury mechanism analysis [14-16].

3.3 Assessment of Study Quality

Methodological quality evaluation is usually quantified using scales such as Delphi [17] or PEDro [18]; however, many of the criteria were not relevant in the current review. For example, none of the included studies of this review would meet 6/11 criteria of the Pedro Scale: (2) random allocation; (3) concealed allocation; (5) subject blinding; (6) therapist blinding; (7) assessor blinding; and (9) intervention-to-treat analysis. Given the studies included would receive poor methodological scores as a reflection of a poor choice in quality scale rather than in the study design, two authors from the current study independently assessed each article using a 6-item custom methodological quality assessment scale where 0=clearly no and 1=clearly yes. The six items included: (1) study design (0=prospective cohort or cross-sectional study, 1=case control - randomised); (2) study samples (0=no control or control not greater than 4:1, 1=adequate); (3) participant characteristics (0=not given, 1=sex and age reported); (4) sport details (0=not detailed, 1=detailed); (5) outcome variables (0=not appropriately defined or reported, 1=appropriate and tabulated); (6) statistical analyses included adjusted OR and/or RR adjusted for covariates (0=no, 1=yes). Covariates included age, sex, type of skier, weather condition, and self-reported experience level. The quality scores based on the paper selection criteria ranged from 1 to 6, and are shown in curved brackets in Tables.

3.4 Data Extraction

For studies passing the quality criteria, data were extracted, including study name, snow-sport type, aim/focus, study design, participants' characteristics, methodological quality, interventions, outcome measures and injury risk factor statistics results (Table 1 shows the ten intervention studies [19-28], and Electronic Supplementary Material Table S1 shows 88 injury risk factor studies used in the review - noting that only six of the intervention studies and only 49 of the injury risk factor studies had sufficient data to be included in the pooled odds ratio analyses). There was a large range in sample size, injury risk factors investigated, definition of injury risk factor categories (e.g. such as types of slope conditions of hard and icy, soft and powdery or slushy) and injury risk factor statistics (e.g. risk ratios, odd ratios, Pearson correlations) utilised throughout the risk factor studies. For example, skiing ability was assessed using readiness for risk and speed measured using a self-reported visual analogue scale (1 for minimum speed or minimum risk and 10 for maximum speed or risk) [29] or by participant self-reported categorical ability (beginner-intermediate, intermediate, intermediate-expert) [30]. This large variation in definition of outcomes and factors between studies made combined analysis difficult for some risk factors. For example, head injury was defined as serious (e.g. severe traumatic brain injury with intracranial bleeding with edema) in some papers, whilst a head/face injury (e.g. minor facial injury including a fractured nose) in other papers. The diagnosis of injuries in studies may have been provided by a range of medical personnel such as paramedics or physicians. Most studies did not adjust for covariates. A good exception was the conditional inference trees analysis by Halser [29] who identified non-helmet wearing snowboarders on icy slopes as at risk.

3.5 Analysis and Interpretation of Results

For individual studies the relative frequencies for injury (relative risk, odds ratio) were tabulated with 90% confidence intervals. For example, relative risk or risk ratio was calculated as the relative risk of injury for no helmet versus helmet as 25/10=2.5 if 10% of helmet users and 25% of non-helmet users were injured. The hazard ratio is similar, but is the instantaneous risk ratio. The odds ratio was calculated as (25/75)/(10/90)=3.0. Risk and hazard ratios are mostly reported for cohort studies, to compare incidence of injury between groups. Odds ratios are mostly reported for case-control studies, to compare frequency of exposure to the risk factor or countermeasure in injured and non-injured participants. Odds ratio is approximately the same as risk or hazard ratio in value and meaning when frequencies are less than 10% [31]. Pooled odds ratios with 90% confidence intervals and inferences (OR; 90%CI, % likelihood benefit/harm) were calculated using a spread sheet for combining independent groups with a weighting factor based on quality rating scores for effects. The likelihood that an effect was substantially harmful, trivial or beneficial was given in plain-language terms using the following scale: 0.0% to 0.5%, most unlikely; 0.6% to 5.0%, very unlikely; 5.1% to 25.0%, unlikely; 25.1% to 75.0%, possible; 75.1% to 95.0%, likely; 95.1% to 99.5%, very likely; 99.6% to 100%, most likely [31]. Values are reported with 90% confidence intervals to express the uncertainty in the true effect.

A Haddon matrix approach was used to summarize the identified injury risk factors, and injury prevention countermeasures likely to be effective in reducing injury incidence or severity (Table 3.)

4. Results

A wide range of risk factors have been investigated in a number of studies including modifiable factors such as helmet use [32, 10, 30, 33-36], wrist guard use [37-39, 6, 40], ability [41, 42], alcohol use [43, 44] and terrain condition [45-48]. Non-modifiable factors such as age [49-51], sex [52-55] and weather [56, 57, 29] have also been examined. In contrast to studies investigating a large number of risk factors with little depth, less frequently studies have gone into more depth focusing on a single factor such as physical condition [58] or ski binding factors [59-61]. Of the ten intervention studies (Table 1), six focused on education programmes [28, 21, 23, 22, 19, 26], three on wrist brace interventions [24, 25, 27], and one on a ski binding adjustment intervention [20]. Data from six of the intervention studies and 49 of the risk factor studies could be used in the pooled odds ratio analyses.

Table 2 provides a summary of the derived injury odds ratios and 90% confidence interval for host/participant, agent/mechanism, and environment/community risk factors from the 55 studies (Note that some studies contributed data to more than one risk factor, so the total number of studies does not add to 55 for Table S2 or Fig. 2). Fig. 2 of the pooled odds ratios (OR=crude odds ratio; LRA OR=linear regression adjusted odds ratio) can be interpreted as clear evidence for the benefit of a countermeasure or factor if the average and confidence interval is below 1.0 (e.g. wrist brace use for preventing wrist injuries). Conversely there is a clear negative risk of injury if the countermeasure or risk factor is above 1.0. Table 3 provides a summary of host/snow participant, agent/mechanism and environment/community snow sport risk factors, the potentially modifiable risk factors and those where there is evidence from the scientific literature for effective injury prevention countermeasures targeted at the risk factors. Key risk factors to focus on for countermeasure interventions include beginner skiers and snowboarders, participants who rent skis and snowboards, female participants, knee injuries in females, snowboarders, and poor visibility. Countermeasures shown to be effective included: injury prevention education for all injuries for skiers and snowboarders; helmets for both ski and snowboarding for head and neck injuries; wrist guards for ski and snowboarding for wrist injuries; and knee braces for knee injuries in skiers.

5. Discussion

Many studies detailed snow sports injury characteristics and injury risk factors from epidemiological studies, however there was limited evidence for effectiveness of injury prevention countermeasures from randomized controlled trials or studies evaluating cost to benefit ratio of countermeasure interventions. Some important host factors (e.g. age and sex), and environmental factors (e.g. weather) are unalterable. Interventions should focus on affecting modifiable factors such as education, protective equipment (in particular wrist guards and helmets), equipment design/set up and limiting the snow sport participant's exposure to poor run conditions and jump planning.

5.1 Effects of skiing/snowboarding experience

For both snowboarding [62-65, 50, 66, 67, 55, 68] and skiing [62, 69, 41, 64, 70, 50, 71-73, 67, 74-78, 55, 68] self-rated beginners were far more likely to sustain an injury than individuals who were self-reported intermediate or advanced ability [55]. More experienced skiers and snowboarders were more likely to sustain an injury as the result of jumps, while beginners sustained injuries primarily as a result of falls [42]. Analysis of two decades of injury data in France showed that injury risk slowly increased up until 2005 when a reversal in injury risk occurred [67]. This reversal in trend was attributed primarily to a decrease in snowboarding injury risk. Beginners contributed most to the number of recorded injuries, with the first four days of exposure being the most precarious.

5.2 Effectiveness of education interventions

The effectiveness of education interventions was unclear based on the confidence interval (CI); however education interventions were rated as 65% possibly beneficial using the classification system of Hopkins [31]. This result is probably due to the diverse nature of the education campaigns and target populations. Due to the limited number of studies it remains unclear what the best format and content is for the education sessions for particular target groups of participants (e.g. based on age, sex or skiing/snowboarding ability).

Screening of a 45 minute educational video, on long haul bus trips specifically to ski slopes, was effective in reducing injury risk, collisions and falls, particularly in beginners [23]. Key messages covered in this video were basic skills and safety requirements, including binding checking and helmet use. Screening occurred during an 18-hr to 24-hr bus trip in the afternoon or evening. A 1-hr group education workshop was beneficial for more experienced individuals (on-slope employees) and showed a clear benefit in reducing injury rate [21]. The workshop used video directed discussions including identifying and responding to possible hazard situations, and participants developing risk factor identification for anterior cruciate ligament injury. The nature of the education programme and the target audience appear to be keys to success of the education program. Injury risk initially decreased following a media campaign, however effectiveness declined with time [19]. Providing past injury information and technique and safety tips to ski club members by paper hand outs and leaflets clearly reduced hospital ski injury admittance [22]. However, a 30 minute teaching session with a 20 minute educational video "A Little Respect: ThinkFirst!" and brochure followed by a test were ineffective in reducing the risk of injury in 11-12 y school children over four school supervised ski days [28]. The video focused on the alpine responsibility code, proper helmet use and clothing attire, trail and terrain sign interpretation, and emergency procedures in the event of an injury. Although there was a trend for a reduction in injury, the ineffective result was due probably to the inadequate sample size [28].

Three studies investigated the effect of taking lessons on injury risk. Two studies produced unclear results, however, Langran et al. [42] found lessons were associated with increased risk of injuries not only in those injured on their first day of skiing or snowboarding but also in all individuals injured. Increased risk taking as a result of confidence after having taken lessons may increase injury risk.

5.3 Effects of equipment

The use of rented equipment was clearly harmful (OR 2.37; 90% CI 1.84-3.05) however, it was not clear from the studies whether it was the equipment per se, it's maintenance, or the people who used rental equipment that resulted in rental equipment being a risk factor. A number of factors were likely contributing to this result, primarily the age (children) of the skier or snowboarder, skill level (beginner) and knowledge of the equipment. The studies with adjusted odds ratios were performed on children [79], who usually have less experience and also have reduced coordination when compared to adults [49], or on individuals who were injured on their first day on the slope [42]. Beginners were most likely more at risk of injury having less specific strength, coordination and skill than more experienced skiers and snowboarders [64, 51].

Pooled odds ratios for having bindings checked within the last year showed a likely trivial effect. Individual analysis of a study of 572 injured and 576 uninjured control recreational downhill skiers indicated that bindings checked within the last year showed a 63% possibly beneficial effect and a 35% trivial effect [60]. Similar results were reported for a randomized intervention where the intervention population had bindings tested and properly adjusted prior to the start of the season (60% possibly beneficial, 39% trivial) [20]. Later studies, 1996-97 season [64] and 2002-03 season [80], showed binding checks to be possibly harmful. No details about who performed the binding checks were given for the 1996-97 season [64]. While injuries reported during the 2002-03 season included time since the last professional binding check, no details were given as to whether calibration machines were used. Boulter et al. [60] distinguished between how binding checks were performed, test apparatus, with skier characteristics or without characteristics and found the risk increased slightly the less specific the testing method. In France when the recommended binding settings were lowered using the French AFNOR settings for females, knee injuries did reduce.

The evidence supports that helmets were clearly beneficial for reducing risk of head injuries in skiers and snowboarders [81, 30, 82-85] and possibly useful in the reduction of neck and other injuries [86, 87, 29, 88]. A clear effect of sex was found for head injuries with males more likely to sustain head injuries than females [84, 83, 89]. Whether males have increased risk taking behaviour or less helmet usage is unclear. Non-helmet users were 2.3 times more likely to die from a head injury than helmet users [90]. Resistance to helmet use includes the perception there is no need to wear one, and that they were uncomfortable [91]. Reduced ability to hear and see the surroundings were also given as reasons for non-use of helmets.

Snowboarders sustained upper extremity injuries, particularly wrist fractures [92]. Use of a customized wrist brace in a group of Austrian school children snowboarding showed a clear effect for reducing wrist fractures [25]. Comfort of the brace was noted as a hindrance to retention of the intervention. Use of a wrist brace showed definite reduction in wrist injuries for snowboarders in a population of recreational snowboarders, however, presentation of the use of a wrist brace prior to recruitment and randomization introduced a selection bias for only individuals willing to try using a wrist brace [24]. The design of the wrist guard is important [93, 94]. A compulsory wrist brace wearing policy implemented with secondary school students (12-16 y) in a single school snow sport programme showed a possible large effect on reducing wrist fractures [27]. However, the efficacy of implementing such policies outside of a school environment is unknown. Wrist guards may increase risk of elbow, upper arm and shoulder injuries whilst reducing risk of hand, wrist and forearm injuries [38]. This is potentially due to impact forces being transmitted up the kinetic chain of the limb.

Females were at greater risk of knee injuries for both skiing and snowboarding [95, 56, 87, 54, 96, 97]. Knee braces for skiers were most likely beneficial and use should be encouraged [95, 98]. However, the practical issues of hygiene and fit of braces used in a rental setting need to be addressed.

5.4 Effects of weather and terrain

Inclement weather is clearly harmful, increasing the risk of injury substantially. Visibility and condition of the snow appear to be key factors contributing to increased risk of injury [56, 29, 99]. Increasing the size and frequency of signage to improve visibility during inclement weather periods may help decrease injury incidence. The average reaction time, from the time a sign comes into view to respond to avoid an obstacle, is 1,056 ms in clear visibility, therefore during adverse weather conditions there is a need to allow greater times for reacting to signage before obstacles [100].

Inappropriate trail design and grooming can increase incidence of injuries at alpine ski areas at certain trail sites [99]. Other risk factors such as jump planning and type of terrain need further investigations using epidemiology risk factor analyses so that odds ratios can be determined. Experimental studies have indicated that design of the landing surface is important for reducing injury risk [45, 48].

5.5 Priorities for countermeasure interventions

Based on the strength of the evidence from the effect size analysis, priorities for countermeasure interventions could be:

- *Signage.* Increase the size and frequency of signage to improve visibility during poor weather periods. The average reaction time from the time a sign comes into view to respond to avoid an obstacle is ~1,000 ms in clear visibility, therefore in adverse weather conditions there needs to be allowance for greater times for reacting to signage before obstacles. There is a need for consistent signage, incorporating the science behind what signage influences behaviour.
- *Weather reports.* Increase the frequency of mountain reports including snow conditions and include in educational programs for beginners how to check mountain reports and how to interpret the reports. To avoid ski field operators 'talking up' the weather and snow conditions to entice participants onto the field, this information needs to be independent of the ski field operators.
- *Trail grooming.* Increase grooming hours during periods of fresh snow fall, no recent snow fall, or icy conditions. Groom during the day to maintain slope integrity. There is a need for regulation or competency requirements for ski-field groomers.

- *Terrain park design.* The design of terrain parks should be considered. Filtering systems could be developed where more challenging obstacles (e.g. a big jump) are placed at the start of a terrain park to filter out those without the necessary skill to use the park.
- *Education.* Develop educational videos targeted at beginners for screening on tour buses and at key rental locations. Video length should be considered with short but catchy messages for rental locations and more detailed explanations for bus videos. Key messages to include in beginner targeted videos would be safety rules and key safety protocols (helmets, wrist guards in snowboarders, knee braces for skiers), important skills, hazard awareness (collisions with other people and rocks and trees), understanding the weather and snow conditions and how these can affect speed, stopping ability and visibility issues which change the impact of hazards. Create partnerships with tour companies that transport participants to the ski areas by bus, so that TV messages on snow sport injury prevention messages can be played on the buses. Develop workshops for more experienced skiers and snowboarders, using videos of injurious or near injurious events to promote thought and discussion of key things to be aware of and how to respond to different potentially injurious situations. All on-slope personnel should attend these workshops regularly (i.e. every 2 y with first aid refresher). Lesson instructors should be required to remind beginner skiers not to take risks with their newly acquired skills that exceed their ability. Beginner participants should be encouraged to build up speed and technical aspects slowly. All lessons should be undertaken with helmets worn. It often happens with children but needs to be across the board with instructors setting the example. The Norwegian expression is: "if you don't wear a helmet you have already had a head injury!"
- *Rental equipment.* Target information to equipment renters regarding helmet and wrist guard use, appropriate equipment fitting, awareness and key injury prevention skills. Possible options could include compulsory reading of information before equipment is provided, free fitting/bindings check and helmet/wrist/knee braces, and educational videos at rental facilities.
- *Digital assets.* Use digital assets such as cell phones, web sites and TV screens mounted at ski area facilities to provide injury prevention message information. For example, mount TV screens in rental facilities so that while participants are waiting in line to get their snow equipment, they can view the short key messages on injury prevention regarding use of helmets and wrist guards, the ski slope rules, and techniques for how to stop safely etc. Mount TV screens in other areas where queues form such as in food venues and on chair-lift facilities.
- *Protectors.* Helmet use should be a key feature in education campaigns with a focus on appealing to the male population. Free helmets with all rentals should be considered to ensure those at higher risk

of injury (i.e. beginners) are well protected. Free wrist braces should be available for snowboarders to use. This would encourage those willing to utilise wrist guards to do so. As design of wrist guards is important, careful selection of guards is needed. Design must consider how to increase user compliance by addressing comfort, ease of cleaning (hygiene) and effectiveness of reducing injury. Design must consider how to increase use compliance by addressing comfort, ease of cleaning, and effectiveness at reducing injury. Interventions regarding knee brace use should be targeted to females. Written and video information should note the higher risk in females and that use of knee braces are effective preventative measures. As the design and type of knee brace is a determinant of its injury prevention effectiveness, education messages about considering the use of professionally fitted knee braces could be provided. The evidence suggests that the more precise and specific the binding adjustments are to the individual, the more likely binding adjustments are to prevent injury. In France when the recommended binding settings were lowered using the French AFNOR settings for females, knee injuries were reduced. The issue of time pressures for technicians in adjusting bindings in rental outlets needs to be addressed, so that correct binding adjustments are made rather than reverting to a “thump the heel of the boot and if it releases then all is OK” adjustment. Public education could drive shop practices.The use of the more sensitive and specific torque calibration machines should be considered.

In analysis of the countermeasures reported in the studies from 1981 to 2013, there was no adjustment for the historical and socio-cultural context in which these studies occurred. For example, an education campaign that was conducted nearly 20 years ago with a video in a bus may not have the same impact on a cohort carrying their own personal entertainment devices via their phones in 2014. Placing digital information screens on slopes will require these devices to operate at temperatures that can be <30°C. Consideration of educational or warning signage becoming an object hazard would also be required. Technology and equipment changes may result in different effect sizes for injury risk. Therefore an implementation plan for countermeasure interventions for skiers and snowboarders needs to consider the current socio-cultural and technological context.

6. CONCLUSIONS

Snow sports would benefit from easily implemented and cost effective injury prevention countermeasures that are effective at reducing injury rate and severity. The best evidence for effectiveness of injury prevention countermeasures for recreational snow sports was for use of helmets for skiers/snowboarders to prevent head injuries and wrist guards for snowboarders to prevent wrist injuries. Key risk factors that injury prevention countermeasure should focus on include beginner skiers and snowboarders, skiers/snowboarders who rent snow equipment and poor visibility due to inclement weather.

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Figure & Table Legends

Figures

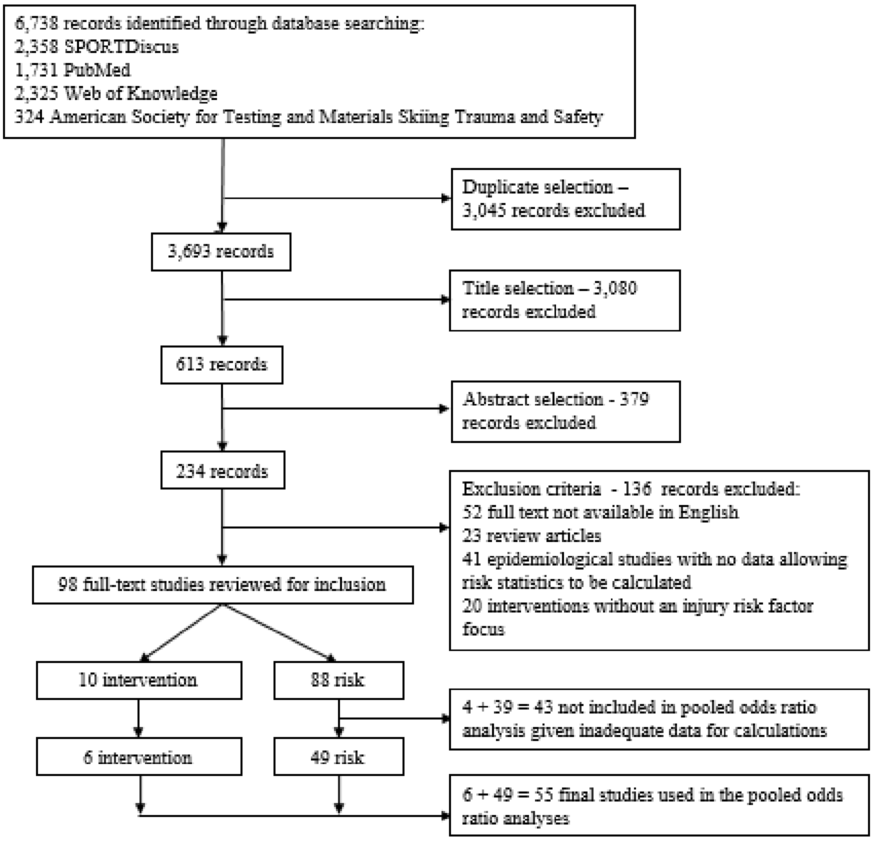

Fig. 1 Flow of information through the systematic review.

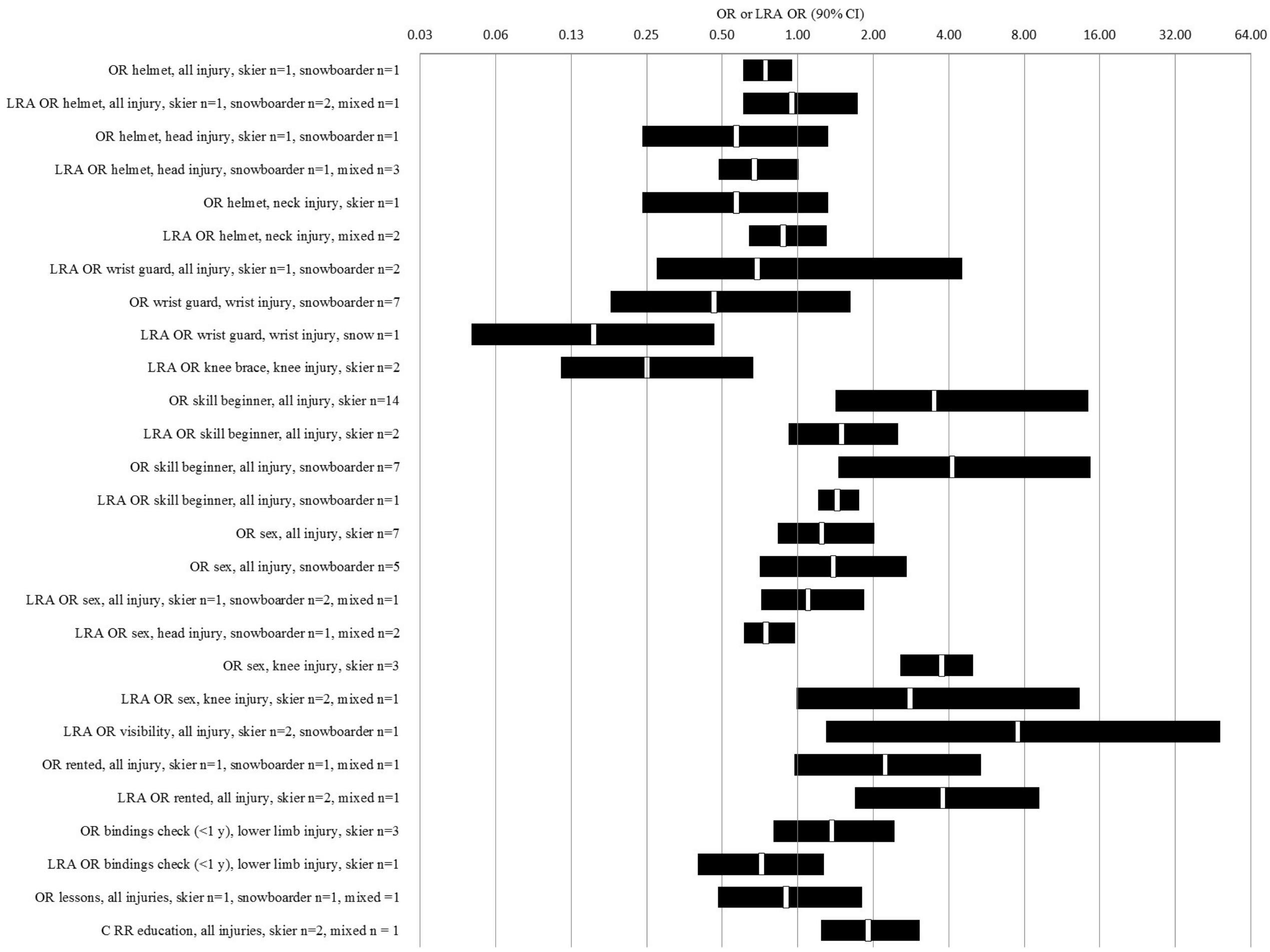

Fig. 2 Forest plot of effect sizes (ES) with 90% confidence intervals (90%CI) for risk factors for snow sport. Number of contributing studies to each variables' results is n. The average odds ratio (OR) (white bar) and average 90%CI (black bar) for each risk factor or countermeasure from the pooled odds ratios reported in the studies are shown. An OR <1 indicates a preventive factor. OR=crude odds ratio, LRA OR= linear regression analysis odds ratio, C RR= crude risk ratio, sex=female versus male, visibility=poor versus good.

Tables

Table 1 Interventions studies that aimed to reduce snow-sport injury.

Table 2 Summary of the pooled injury odds ratios and 90% confidence limits for host/participant, agent/mechanism, and environment/community factors.

Table 3 Summary of host/snow participant, agent/mechanism and environment/community snow sport risk factors, the potentially modifiable risk factors and those where there is evidence from the scientific literature for effective injury prevention countermeasures targeted at the risk factors. [a]factors derived from literature, [b]factors included in intervention studies, [c]factors not yet addressed in studies, [d]unalterable factors.

Electronic Supplementary Material Table S1 Studies (n=88) that provided details for the pooled odds ratios analysis for risk factors for snow-sport injury.

Table 1 Interventions studies (n=10) that aimed to reduce snow-sport injury

Study	Study design, focus (quality rating)	Participant characteristics. Injury recording	Intervention detail	Injury reduction	Critique and recommendations for further interventions
Jorgensen, 1998 [23]	Prospective randomised control, ski, educational bus video. (5)	Recreational skiers, 243 video exposure, 520 control. 1 week post-video exposure, self-reported injury. Total 8 ski days.	Randomly selected buses screened educational video in afternoon or evening of 18-24 h bus trips to alps ski resorts (for week long skiing trip). Focus: how to get started in downhill skiing and injury prevention advice including binding test and adjustment. Questionnaire 1 week post intervention included control questions for key messages of video.	Intervention vs control. *Overall injury rate* 16% vs 23% RR 0.70; 95%CI 0.39-1.22 $p<0.05$. *Injuries caused by falls* 12.6% vs 16.2% RR 0.78; 95%CI 0.40-1.52 $p<0.05$. *Injuries caused by collision* 6% vs 12% RR 0.50; 95%CI 0.20-1.23 $p<0.05$. *Beginner injury rate* 5% vs 44% RR 0.11; 95%CI 0.05-0.26 $p=0.002$. *Experienced injury rate* 17% vs 21% RR 0.80; 95%CI 0.45-1.43 $p=0.30$.	Bus video education resulted in less injuries, less collisions, less falls. Those less experienced benefited more from video. Develop an educational video, and collaborate with tour companies to show video on buses.
Ettlinger, 1995 [21]	Prospective randomised control, ski, video education programme for knee sprains. (4)	Ski area, on-slope staff, 25 ski areas intervention (5 lost to follow-up), 22 ski areas control. 2 y pre-intervention, 1 y post-intervention.	One hour workshops for on-slope staff, injury mechanism video, guided discovery develop risk profiles for knee injuries. Focus: avoiding high risk behaviour, recognizing potential dangerous situations, responding to such situations.	Average normalised ACL sprains by educated staff, expected vs actual: 26.6 vs 10.6 (60% decrease) $p<0.005$. Control, expected vs actual: 22 vs 29.	Guided discovery with video of near injury and injury events significantly reduced the number of ACL injuries among on-slope staff (experienced skiers). Learn to identify and respond to potential injury events.

Cusimano, 2013 [28]	Prospective randomised control, ski and snowboard, video education programme. (3)	11-12 y students (n=35 intervention, n=34 control). 4 school supervised ski days.	30 min teaching session with 20 min video "A Little Respect: ThinkFirst! and brochure (control=30 min question answer session abut snow sports). Pre and post-test assessing knowledge, behaviour and attitudes around snow sport safety.	Teaching group vs control group: *Injury total (over 4 days)* 2 (14.3/1,000 ski days) vs 4 (29.4 injuries/1,000 ski days) RR 0.49; 95%CI 0.04-3.39. All injuries minor.	No clear effect. Education program may reduce injuries. Video teaching session improved test scores.
Danielsson, 1985 [19]	Pre-test post-test, ski, binding adjustment media campaign. (3)	Swedish ski slopes. 1 season pre-intervention, 8 seasons post-intervention.	Media campaign focus: importance of correct binding adjustment, offering free binding checks, retailers to use testing devices.	From 1974/75 season to 1981/82 season campaign estimated to decrease injuries 4%. 1974/75 season 12% decrease lower limb and 3% decrease upper body injuries. Dropped ~20% over 8 years, as did binding checking.	Tendency to decrease injury risk initially following media campaign. Effectiveness declined with time. Indirect injury risk analysis method, results should be interpreted with caution.
Ytterstad, 1996 [22]	Prospective pre-post analysis, ski, education. (3)	Harstad, Norway residents (n=22,660). 5 years pre-, 3 years post-intervention.	Free texts (victims' stories), post-intervention injury data and recommendations for targeted intervention: promoting helmet use and binding/boot fitting; preventing collision injuries; preventing ski lift injuries, sent to local resort with only downhill ski slopes.	5-year baseline vs 3-year intervention, Incidence/1,000 person y: *Downhill skiing injury (exposure adjusted)* 16.1 vs 10.6, 0.85, *CRR* 95%CI 0.66-1.10, p=0.24. *Downhill skiing hospital admittance* 2.8 vs 1.0.	Free text handouts to ski club members can reduce injuries. Develop a ski club information handout system to promote key injury prevention messages.
Laporte, 2003 [26]	Pre-post analysis, ski, simplification and media dissemination of binding international safety standards. (2)	Four ski departments (North Alps, Haute Savoie, Savoie and Isere) for ACL risk assessment. 18 French skiing resort control group (1597 skiers) and 204 equipment renters for measuring impact of	30 second TV broadcast over 3 weeks on 6 French channels and leaflet distribution. Focus: regular binding adjustment, ski renters fitting bindings. Ski renters were provided with written information. Focus: familiarise and abide by new regulations.	ACL injuries risk incidence (MDBI: mean days between injuries): Pre 2000 v post 2001, 3,000 vs 3,314, $p<0.05$. Overall injuries risk incidence (MDBI): Pre 2000 v post 2001, 377 v 401 ($p>0.05$).	Only small decrease in injuries. Impossible to assess effectiveness of campaign.

		campaign. 1 season post-intervention.			
Hauser, 1989 [20]	Prospective randomised control, ski, binding adjustment and ski pole design. (4)	Recreational skiers, 460 bindings checked and adjusted, 143 bow ski poles (sub group), 690 control.	Media recruitment, randomised. Bindings of experimental group were checked and errors were assumed to correspond with control group. Errors corrected prior to ski season. Bow ski poles designed to protect the thumb from skiers thumb.	*Bindings intervention, All injuries* RR 0.72; 95%CI 0.42-1.23. *Number of injuries, None* 1.09 (1.03-1.16) *1* 0.68 (0.52-0.89) *2* 1.64 (0.94-2.86) *3* 5.63 (1.98-16.06) *>4*, *Ski pole intervention, Skier's thumb* 0.70 (0.17-2.80).	Well informed binding adjustment showed a likely moderate effect at reducing overall injury rate. All should be encouraged to test their bindings regularly. Bow ski pole design showed a possibly moderate effect to reduce 'skier's thumb'. Further research with larger sample size is needed.
Machold, 2002 [25]	Prospective randomised control, snowboard, custom designed wrist protector. (5)	Austrian school children during school ski days, 342 protector, 379 control. Protected 2483 half snowboarding days. Control 3048 half days snowboarding.	Austrian students randomised to wear a custom designed wrist protector or control (no protector or alternative design). Only moderate or severe injuries (fractures) were assessed. Intention to treat analysis to account for students who discarded protectors.	C HR (95% CI), Severe injury of the wrist: *Wrist protector* 0.13 (0.02-1.04) p=0.054 *Experience* 0.83 (0.70-0.99) p=0.036 All severe injuries: *Wrist protector* 0.23 (0.05-1.07) p=0.061 *Experience* 0.81 (0.68-0.96) p=0.014.	The specific wrist protector design used showed significant protective effect although comfort and design with respect to retention needs to be considered.
Ronning, 2001 [24]	Prospective randomised control, snowboard, custom wrist protector. (5)	Recreational snowboarders >9 y, protector 2,515, control 2,514 recreational. Single ski day.	Demonstration of wrist brace prior to recruitment. D-ring wrist brace (Smith & Nephew, Nesbru, Norway). Block randomisation to keep number of control and protected at pistes even. No prior injury. Participation on multiple days possible - each observation considered independently. Intention to treat analysis.	Wrist brace vs control: *Wrist injuries* 0.32% vs 1.15% p=0.001 C RR (95% CI) 0.28 (0.13-0.59) *All injuries* 33% vs 51% C RR p=0.05.	Wearing braces decreased risk of wrist injuries. Promote purchase of wrist guards, and hiring of wrist guards, or sponsor wrist guard free use.
Slaney, 2009 [27]	Pre-post analysis, snowboard, compulsory wrist guard policy. (2)	Secondary school students (12-16 y) in single school snow sport program. 315 pre-policy (4 years),	Single school with a 10 day snow sport program. Introduced compulsory wrist guard policy.	Post-policy vs pre-policy wrist fracture: 0.95% vs 0.37% p=0.38 C RR (95% CI) 0.39 (0.06-2.73).	Compulsory wrist brace wearing policy showed a possible large effect on reducing wrist fractures. However, efficacy of implementing such policies outside of a school environment is unknown.

267 post-policy (3 years).

C=crude; HR=hazard ratio; RR=risk ratio; ACL=anterior cruciate ligament; MDBI=mean days between injuries.

Table 2 Summary of the effect sizes for the pooled injury odds ratios and 90% confidence limits for host/participant, agent/mechanism, and environment/community factors.

					True value of the effect statistic (% likelihood)						
Risk factor (n=number of contributing studies)	Pooled odds ratio	Lower 90% CL	Upper 90% CL	Inference - clinical	Substantially beneficial (%)		Trivial (%)		Substantially harmful (%)		Practical implications to focus injury prevention
Skill beginner, all injuries, skier, n=16	2.72	2.15	3.44	Most likely harmful	0.00	Most unlikely	0.00	Most unlikely	100.00	Most likely	Beginner skiers
Skill beginner, all injuries, snowboarder, n=8	2.66	2.08	3.40	Most likely harmful	0.00	Most unlikely	0.00	Most unlikely	100.00	Most likely	Beginner snowboarders
Lessons, all injuries, skier and snowboarder, n=5	1.18	0.96	1.45	Likely trivial	0.04	Most unlikely	78.29	Likely	21.68	Unlikely	-
Education, all injuries, skier and snowboarder, n=3	0.67	0.38	1.17	Unclear; more data needed	66.03	Possibly	31.47	Possibly	2.50	Very unlikely	Education for all injuries for skiers and snowboarders
Sex (F v M), all injuries, skier, n=7	1.21	1.02	1.42	Likely trivial	0.00	Most unlikely	77.22	Likely	22.78	Unlikely	-
Sex (F v M), all injuries, snowboarder, n=8	1.02	0.81	1.29	Likely trivial	2.16	Very unlikely	93.48	Likely	4.36	Very unlikely	-
Sex (F v M), head, skier and snowboarder, n=3	0.72	0.65	0.79	Likely beneficial	88.33	Likely	11.67	Unlikely	0.00	Most unlikely	Females
Sex (F v M), knee, skier and snowboarder, n=7	2.77	2.01	3.81	Most likely harmful	0.00	Most unlikely	0.00	Most unlikely	100.00	Most likely	Female knee injury

Helmet, all injuries, skier and snowboarder, n=6	0.74	0.57	0.97	Possibly beneficial	58.66	Possibly	41.31	Possibly	0.03	Most unlikely	Helmets for ski and snowboarding for all injuries
Helmet, head, skier and snowboarder, n=6	0.58	0.51	0.66	Very likely beneficial	99.99	Most likely	0.01	Most unlikely	0.00	Most unlikely	Helmets for ski and snowboarding for head injuries
Helmet, neck, skier and snowboarder, n=3	0.82	0.64	1.04	Possibly beneficial	34.06	Possibly	65.86	Possibly	0.08	Most unlikely	Helmets for neck injuries
Wrist guard, all injuries, skier and snowboarder, n=3	0.66	0.27	1.61	Unclear; more data needed	61.53	Possibly	27.85	Possibly	10.62	Unlikely	Wrist guards for ski and snowboarding for all injuries
Wrist guard, wrist, snowboarder, n=8	0.33	0.23	0.47	Most likely beneficial	99.99	Most likely	0.01	Most unlikely	0.00	Most unlikely	Wrist guards for snowboarders
Knee brace, knee, skier, n=2	0.21	0.11	0.43	Most likely beneficial	99.89	Most likely	0.11	Most unlikely	0.00	Most unlikely	Knee braces for skiers
Bindings check (<1y), lower limb, Skier and snowboarder, n=4	1.09	0.86	1.38	Very likely trivial	0.69	Very unlikely	88.08	Likely	11.22	Unlikely	-
Rented, all injuries, skier and snowboarder, n=6	2.58	1.98	3.37	Most likely harmful	0.00	Most unlikely	0.00	Most unlikely	100.00	Most likely	Rental ski and snowboard participants
Visibility (poor v good), all injuries, skier and snowboarder, n=3	2.69	1.43	5.07	Very likely harmful	0.06	Most unlikely	2.85	Very unlikely	97.09	Very likely	Visibility when poor

y=year; F=female; M=male; CL=confidence limit

Table 3 Summary of host/snow participant, agent/mechanism and environment/community snow sport risk factors, the potentially modifiable risk factors and those for which there is evidence from the scientific literature for effective injury prevention countermeasures targeted at the risk factors.

Host/snow participant
Behaviour
Abstinence from alcohol[a]/alcohol intoxication[a]
Abstinence from drugs[a]
Readiness for risk[a]
Readiness for speed[a]
Risk taking behaviour; judgment & recklessness[a]
Use of appropriate equipment[a,b]
Lessons[a]
Ability/experience
Seasons of experience in snowsports[a]
Self-reported ability (beginner intermediate, expert)[a]
Body – motor control
Physical conditioning[a]
Duration of warm-up before the first ride[c]

Weight[a]	
Body composition[c]	
Nutrition and hydration[c]	
Fitness[a]	
Psychomotor skill development[c]	
General health	
Age[a,d]	
Sex[a,d]	
History of injury[a,d]	
Knowledge	
Knowledge about snow-sport safety and injury mechanisms[a,b]	
Knowledge of trail details & safety rules[a,b]	
Knowledge of injury prevention strategies[b]	

Agent/mechanism
Behaviour
Protector use (e.g. spine protector, knee brace)[a]
Wrist guard worn[a,b]

Helmet worn[a]

Other protective equipment worn[a]

Equipment ownership[a]

Seasonal checking of ski/snowboard equipment by specialist[a]

Snow-sport type[a]

Injury and treatment

Effectiveness of treatment[a]

Severity of injury[a,d]

Protectors

Equipment design[a]

Age of equipment[a]

Binding release type[a]

Binding release check[b]

Storage of equipment[a]

Environment/community

Behaviour

Proximity to other participants[a]

Experience of aggressive behaviour of other participants[a]

Injury and treatment

First-aid[c]

Help-seeking behaviour[c]

Access/transport to hospital care[c]

Quality/affordability of health care[c]

Weather and terrain

Snow/slopes and weather[a]

Slope conditions (hard/icy, soft/powdery, slushy)[a]

Snow conditions (fresh snow, old snow, artificial snow)[a]

Accessibility to trails[c]

Terrain bans or access (barriers, signage)[a]

Terrain[a]

Trail grooming[a]

Jump planning[a]

Weather and visibility (sunny/good visibility, cloudy/bad visibility)[a,d]

Temperature[a]

Protectors

Protective mats[c]

Noise[c]

[a]Factors derived from literature, [b]Factors included in intervention studies, [c]Factors not yet addressed in studies, [d]Unalterable factors.

Supplementary material

Electronic Supplementary Material Table S1 Studies (n=88) that provided details for the pooled odds ratios analyses for risk factors for snow-sport injury.

Study	Study design; focus (quality rating)	Characteristics of subjects, age (mean±SD) and snow sport ability level	Injury risk statistics
Bergstrom, 2004 [99]	Prospective cohort, 5 y; Resort/run design and maintenance. (3)	1410 (835) injured (grooming analysis), recreational skiers/snowboarders.	Number lift journeys vs injury rate r^2=0.98 p<0.02 grooming hours vs injury rate r=-0.99 p<0.02.
Bissell, 2008 [62]	Retrospective case-control; Humerus fracture risk factors in skiers and snowboarders. (4)	318 humerus fracture cases (270 skiers, 48 snowboarders), 3950 skier controls and 291 snowboarder controls, recreational.	C OR (95% CI), skiers vs snowboarders, humerus fractures: sex, female vs male 1.86 (0.93-1.52) vs 1.21 (0.63-2.35) experience, beginner/novice vs ≥ intermediate 0.97 (0.68-1.37) vs 3.21 (1.05-10.10) helmet vs no helmet 1.13 (0.74-1.73) vs 0.61 (0.29-1.27) dry powder/packed powder vs other condition 1.73 (1.31-2.29) vs 2.64 (1.11-6.30) or (95% ci), skiers vs snowboarders, all injuries: female vs male 1.34 (1.25-1.44) vs 1.20 (0.91-1.58) experience, beginner/novice vs intermediate 1.62 (1.46-1.81) vs 5.33 (2.11-13.48) helmet vs no helmet 0.81 (0.71-0.92) vs 0.64 (0.50-0.83) dry powder/packed powder vs other condition 2.31 (2.03-2.65) vs 2.99 (1.55-5.77).
Blitzer, 1984 [49]	Case control 9 season; Children vs adults downhill skiing. (3)	3182 injured (696 children, <17 y), 1268 uninjured control (228 children), recreational.	C OR (95% CI), all injury: age, ≥17 y 0.79 (0.37-1.70) [78% of 3182 inj/81.8% of 771690 un) 14-16 y 1.19 (0.42-3.42) [10.1% of 3182 inj/ 8.6% of 771690 un) 11-13 y 1.65 (0.39-7.40) (6.1%of 3182 inj/ 3.8% of 771690 un) ≤10 y 1.04 (0.27-4.00) (5.7% of 3182 inj/ 5.5% of 771690 uninj) experience (total days skied) injured vs control not significantly (p > 0.05): 14-16 y upper body, ≥ 10 y upper body, ≥ 10 y knee sprains.
Boldrino, 1998 [101]	Retrospective cross-sectional cohort; Injury risk factors in snowboarding. (3)	196 injured, 185 non injured control, recreational snowboarders.	C OR (95% CI), injured vs uninjured, board type, freestyle 1.94 (1.03-3.65) p<0.01 (43.1% of 195 inj/28.1% of 185 un) raceboard 0.75 (0.41-1.40) (34.4% of 195 inj/ 41.1% 185 un) other 0.66 (0.33-1.30) (22.6% of 195 inj/ 30.8% of 185 un) skateboader p<0.05 soft vs hard p<0.05 halfpipe preference p<0.05 other style vs carving p<0.001

			hand and finger protective equipment p>0.05 skill level p>0.05 age 2.2 vs 22.7 p<0.01 sex p>0.05.
Boldrino, 1999 [64]	Prospective case control; Injury risk factors in skiing and snowboarding. (4)	160 injured skier 38.7 y and 102 injured snowboarder 18.2 y case, 750 uninjured skier 34.0 y and 750 uninjured snowboarder 21.9 y control, recreational.	C OR (95% CI), injured vs uninjured, all injury: snowboard vs ski, sex (female) 1.68 (0.90-3.13) vs 0.82 (0.45-1.48) instruction received (yes) 0.73 (0.40-1.35) vs 0.92 (0.49-1.70) skill level, beginner 1.00 vs 1.00 intermediate 0.47 (0.19-1.18) vs 1.14 (0.14-10.55) advanced 0.27 (0.10-0.66) vs 1.74 (0.22-15.72) expert 0.44 (0.14-1.36) vs 1.78 (0.20-17.84) self-reported fitness level (good and very good), physical stamina 1.14 (0.61-2.12) vs 2.85 (1.51-5.40) strength upper body 1.23 (0.67-2.25) vs 1.44 (0.79-2.61) strength lower extremities 0.86 (0.44-1.68) vs 2.36 (1.24-4.50) speed 1.43 (0.76-2.69) vs 1.27 (0.70-2.30) flexibility 1.80 (0.90-3.62) vs 1.35 (0.73-2.52) coordination 0.91 (0.47-1.75) vs 1.20 (0.64-2.24) motivational factors (important to very important), getting to know good people 0.72 (0.40-1.31) vs 0.58 (0.32-1.07) pleasure from skill 1.00 (0.27-3.66) vs 1.19 (0.49-2.94) pleasure in movement 0.80 (0.29-2.20) vs 1.26 (0.28-5.81) keeping fit/sports/activity 0.84 (0.34-2.06) vs 1.00 (0.32-3.09) nature/fresh air/relaxation 1.46 (0.69-3.11) vs 1.00 (0.30-3.33) learning your own limits 0.73 (0.39-1.37) vs 0.54 (0.30-0.99) mastering difficult situations 0.59 (0.33-1.08) vs 0.43 (0.21-0.86) being faster and better than others 0.58 (0.25-1.36) vs 0.70 (0.19-2.57) attitudes to risk, risk attitude (cautious and very cautious) 1.53 (0.80-2.94) vs 0.52 (0.27-0.99) attitudes to skiing (dangerous and very dangerous) 0.47 (0.20-1.09) vs 0.77 (0.32-1.87) attitudes to snowboarding (dangerous and very dangerous) 1.18 (0.50-2.83) vs 0.81 (0.43-1.49) snowboard, rented equipment (yes) 3.75 (1.42-10.25) ski boots vs hard/soft boots 2.19 (0.96-5.04) ski, bindings checked this season (yes) 1.62 (0.89-2.95) bindings professionally checked 1.18 (0.50-2.83) bindings checked personally 0.74 (0.13-4.06).
Bouter, 1988 [69]	Retrospective case-control; Sensation seeking and injury risk in downhill skiing. (5)	219 injured cases, 288 non-injured controls, recreational skiers.	LRA OR (95% CI), injured vs uninjured model without thrill and adventure seeking (TAS) vs model with TAS: beginners vs intermediate/advanced 1.38 (0.84-2.23) vs 1.25 (0.76-2.06) bad/intermediate vs good self-reported physical condition 0.78 (0.49-1.22) vs 0.77 (0.48-1.22) inadequate vs adequate ski equipment knowledge 2.09 (1.26-3.47) vs 2.18 (1.30-3.63) afraid of accident before ski holiday vs not afraid 0.60 (0.32-1.11) vs 0.56 (0.30-1.06).

Bouter, 1989 [41]	Retrospective case control; Ability and physical condition as ski injury risk factors. (5)	572 injured case 32.0 y, 576 uninjured control 32.6 y, recreational skiers.	M-H A OR (95% CI), injured vs uninjured: ability, beginner 1.00 intermediate 0.6 (0.5-0.8) advanced 0.6 (0.3-1.1) instruction on artificial slope before holiday (yes) 1.5 (0.8-2.8) physical condition before holiday, intermediate or bad vs good 0.7 (0.5-0.9) course in ski gymnastics before holiday (yes) 1.1 (0.7-1.6) warming up during holiday, never 1.00 sometimes 1.2 (0.9-1.5) after breaks 2.0 (1.2-3.4) inadequate equipment knowledge compared to adequate with 10 ski holidays 4.5 (1.9-10.1).
Bouter, 1989 [60]	Retrospective case control; Self-reported binding function and injury risk. (5)	572 injured (32.0 y), 576 uninjured control (32.6 y), recreational downhill skiers.	M-H A OR (for age/sex) (95% CI), lower extremity injury (LE) vs Non-LE: binding release, male, two bindings 1.0 one binding 2.1 (1.0-4.1) no release 3.2 (1.6-6.5) female, two bindings 1.0 one binding 2.7 (1.3-5.7) no release 3.3 (1.7-6.5). M-H A OR (for ability) (95% CI), Injured vs uninjured: time since adjustment, recently 1.0 1 year ago 0.7 (0.4-1.1) >1 year ago 0.6 (0.4-1.1) adjustment protocol, with test apparatus 1.0 with skier characteristics 1.1 (0.8-1.5) without information 1.1 (0.7-1.8) place of adjustment, ski shop in Holland 1.0 ski shop in ski area 1.2 (0.9-1.6) elsewhere 0.9 (0.3-3.2) ownership of skis, owned 1.0 rented 1.3 (1.0-1.8) knowledge about equipment, adequate 1.0 inadequate 1.6 (1.2-2.2) storage at night, inside 1.0 outside 2.0 (1.2-3.4). M-H A OR (for ability) (95% CI), LE only vs uninjured: time since adjustment, recently 1.0 1 year ago 0.7 (0.4-1.2) >1 year ago 0.7 (0.3-1.4) adjustment protocol, with test apparatus 1.0 with skier characteristics 1.1 (0.7-1.7) without information 1.2 (0.7-2.1) place of adjustment, ski shop in Holland 1.0 ski shop in ski area 1.6 (1.2-2.2) elsewhere 0.8 (0.3-2.0) ownership of skis, owned 1.0 rented 1.8 (1.3-2.5) knowledge about equipment, adequate 1.0 inadequate 1.9 (1.4-2.8) storage at night, inside 1.0 outside 1.5 (0.7-3.1). M-H A OR (for ability) (95% CI), LE vs non-LE: time since adjustment, recently 1.0 1 year ago 0.8 (0.4-1.9) > 1 year ago 1.1 (0.4-2.5) adjustment protocol, with test apparatus 1.0 with skier characteristics 1.0 (0.6-1.5) without information 1.2 (0.6-2.5) place of adjustment, ski shop in Holland 1.0 ski shop in ski area 2.2 (1.4-3.2) elsewhere 0.8 (0.2-2.7) ownership of skis, owned 1.0 rented 1.8 (1.2-2.8) knowledge about equipment , adequate 1.0 inadequate 1.5 (1.0-2.4) storage at night, inside 1.0 outside 0.6 (0.3-1.1).

Bouter, 1989 [57]	Retrospective case control; Personal risk factors and run conditions. (5)	572 injured 32.0 y, 576 uninjured 32.6 y, recreational downhill skiers.	M-H A OR (for age/sex) (95% CI), personal risk factors, injured vs uninjured: underweight 1.8 (1.2 - 2.7) feeling rested, good 1.0 moderate 0.4 (0.3-0.7) during menstruation, no 1.0 yes 1.2 (0.6-2.5) afraid of an accident, not afraid 1.0 slightly afraid 0.6 (0.4-0.8) very afraid -, education, university or higher professional education 1.0 other education 1.4 (1.1-1.8) smoking, non-smoker 1.0 smoker 1.4 (1.1-1.8). M-H A OR (for age/sex) (95% CI), environmental risk factors, injured vs uninjured: pistes marking, good 1.0 moderate 0.9 (0.6-1.4) bad -, snow quality, fresh snow 1.0 old snow1.2 (0.9-1.7) icy spots 1.4 (1.0-1.9) wet snow - thickness of snow, sufficient 1.0 patchy 0.8 (0.6-1.1) visibility, good 1.0 poor 0.4 (0.3-0.7) cloudiness, cloudless 1.0 partly cloudy 0.7 (0.5-0.7) cloudy 0.5 (0.4-0.7) temperature, not cold 1.0 slightly cold 0.5 (0.4-0.7) cold 0.6 (0.4-0.7).
Bouter, 1991 [102]	Retrospective case control; Ski injury risk factors. (5)	572 injured case 32.0 y, 576 uninjured control 32.6 y, recreational skiers.	M-H A OR (95% CI), Injured vs uninjured: Ski lessons (no), First holiday 2.5 (1.1-5.0) Third holiday 0.9 (0.6-1.4) Alcohol consumption during breaks, Never 1.00 Sometimes 0.6 (0.4-0.8) Everyday 0.5 (0.3-0.9) Alcohol consumption daily, 0 1.00 1-2 0.8 (0.5-1.1) 3-4 0.8 (0.5-1.1) 5≤ 0.5 (0.3-0.7).
Brooks, 2010 [103]	Retrospective cross-sectional; Injuries on terrain parks vs ski slopes. (4)	3953 injuries, terrain park 20.5 y, ski slopes 27.2 y, recreational skiers and snowboarders.	LRA A RR (95% CI) ski terrain park vs ski slopes: type of injury, fracture 1.09 (1.03-1.15) concussion 1.64 (1.44-1.88) sprain/strain/dislocation 0.87 (0.83-0.92) abrasion/laceration/bruise 0.97 (0.90-1.06) location of injury, head 1.31 (1.16-1.48) face 1.25 (1.05-1.49) neck 1.14 (0.86-1.51) back 1.96 (1.67-2.29) chest/abdomen 1.05 (0.86-1.28) lower extremity/hip 0.85 (0.80-0.91) upper extremity/shoulder 1.06 (1.02-1.10).

Burtscher, 2008 [80]	Prospective case control; Knee injury risk factors in skiing. (3)	132 knee injury case (female 37.9±15.4 y male 30.7±10.6 y), 211 non-knee injury control (female 33.4±15.7 y male 37.9±15.4 y), recreational.	C OR (95% CI), knee injury vs non-knee injury: males, physical activity, ≤1 hr/wk vs >1hr/wk 0.69 (0.38-1.26) difficulty of slopes, easy and moderate vs hard 0.83 (0.40-1.75) day time, before noon vs after noon 1.00 (0.54-1.84) altitude, ≤2000m vs >2000m 1.30 (0.60-2.80) weather, sunny vs cloudy 1.33 (0.70-2.56) temperature, cold days February vs warm days march 0.85 (0.42-1.71) last binding adjustment, ≤ 1y vs >1y 1.28 (0.70-2.36) females, physical activity, ≤1 hr/wk vs >1hr/wk 1.99 (1.07-3.71) difficulty of slopes, easy and moderate vs hard 0.63 (0.25-1.59) day time, before noon vs after noon 1.78 (0.92-3.45) altitude, ≤2000m vs >2000m 0.53 (0.19-1.44) weather, sunny vs cloudy 1.00 (0.54-1.85) temperature, cold days February vs warm days March 2.56 (1.30-5.07) last binding adjustment, ≤ 1y vs >1y0.94 (0.52-1.71).
Burtscher, 2008 [80]	Prospective case series; Development of bindings and carving ski use. (3)	17914, 32.5±17.5 y, recreational skiers.	C OR (95% CI) binding adjustment 1 y > vs 1 y <, knee injury: carving skiers, male 0.8 (0.6-1.2) female 1.8 (1.3-2.6) traditional skiers, male 1.2 (0.8-1.9) female 1.3 (0.9-1.9).
Cadman, 1996 [53]	Retrospective case series; Age and sex effect on ski and snowboard injury. (2)	2139 cases, recreational.	C RR (95% CI): age, overall injury vs non-minor injury vs head/face injury, 0-6 y 1.00 vs 1.00 vs 1.00 7-12 y 1.25 (0.35-4.40) vs 1.83 (0.35-9.54) vs 0.55 (0.06-5.32) 13-17 y 1.14 (0.32-4.12) vs 1.92 (0.37-9.90) vs 0.69 (0.08-5.94) 18-64 y 0.66 (0.15-2.85) vs 1.07 (0.18-6.54) vs 0.36 (0.03-4.40) >65 y 0.78 (0.19-3.15) vs 1.00 (0.16-6.27) vs 0.67 (0.08-5.85) sex (female), age, knee vs wrist injury, ski 0-6 y 0.72 (0.39-1.33) vs - 7-12 y 1.81 (1.01-3.26) vs 1.87 (0.48-7.26) 13-17 y 2.05 (1.15-3.65) vs 0.67 (0.18-2.53) 18-30 y 1.88 (1.12-3.15) vs 0.81 (0.18-3.67) 31-42 y 2.23 (1.37-3.62) vs 0.44 (0.07-2.86) 43-64 y 1.94 (1.20-3.14) vs - >65 y 5.50 (2.77-10.95) vs - snowboard 0-6 y - vs - 7-12 y 1.33 (0.88-2.01) vs - 13-17 y 2.45 (1.27-4.73) vs 0.52 (0.35-0.77) 18-30 y 1.76 (0.97-3.19) vs 0.78 (0.26-2.35) 31-42 y 1.00 (0.76-1.32) vs 4.00 (2.90-5.67) 43-64 y - vs - >65 y - vs -.
Carr, 1981 [104]	Prospective case-control; Upper extremity injuries in skiing. (4)	1711 upper extremity (UE) injuries 24.1 y, 998 uninjured controls 25.7 y, recreational skiers.	UE injured vs uninjured: age 24.1 y vs 25.7 y p<0.05 more skilled > less skilled p< 0.05 hard packed and icy surfaces p<0.05 injury of the collateral ligament of the metacarpophalangeal joint vs controls: injury frequency (controlled for sex, height, weight, ability, and experience) p>0.05 age 22.9 y vs 25.7 p<0.05.

Diamond, 2001 [105]	Retrospective cohort; Head injury severity and outcome in skiing. (2)	118 head injuries, 27.5±16.3 y, recreational skiers.	C OR (95% CI), age: ≤17 y 11.05 (4.67-26.13) 18-24 y 6.07 (2.46-14.96) 25-44 y 3.57 (1.53-8.36) 45-64 y 1.00 65≤ y 9.72 (3.27-28.93).
Dickson, 2011 [37]	Prospective case control; Injury risk factors for snowboarding wrist fractures. (5)	108 wrist fracture case, 503 non-wrist fracture control, 22.1±8.1 y, recreational.	C OR (95% CI), wrist fracture: male vs female 0.79 (0.52-1.21) age, <16 y vs >16 y 3.97 (2.54-6.22) snowboard experience, 1 day vs >1 day 2.04 (1.15-3.64) <7 days vs 7 days or more 1.67 (1.10-2.55) wrist guard usage (no) 1.46 (0.73-2.95) reason for being in alpine region, holiday vs living or working for season 2.77 (1.47-5.21) previous snowboard lessons (no) 0.84 (0.50-1.43). LRA OR (95% CI), wrist fracture: age (<16 y) 3.6 (2.26-5.6) p<0.001 reason for being on holiday in the region (on holidays) 2.3 (1.12-4.74) p=0.022 wearing wrist guard (not) 2.34 (1.01-5.00) p=0.028 days experience (<7 days) 1.33 (0.84-2.10) p=0.225. C OR (95% CI), wrist guard design, case vs control: protection location, palm side only design vs dorsal or both sides design 2.28 (0.58-8.98) protection location and wrist guard length, short, palm-side only design vs short or long, dorsal or both sides design 4.17 (0.89-19.52).
Ekeland, 1989 [70]	Retrospective case control; Ski injury risk factors. (3)	328 injured case, 316 uninjured control, median age 23 y (range 2-70 y), recreational.	C OR (95% CI), injured vs uninjured: ability, all injury vs shoulder injury vs knee sprains vs tibial fractures, beginner 1.00 vs 1.00 vs 1.00 vs 1.00 intermediate 0.14 (0.05-0.37) vs 0.23 (0.07-0.79) vs 0.09 (0.03-0.26) vs 0.11 (0.02-0.51) advanced 0.16 (0.06-0.47) vs 0.42 (0.12-1.46) vs 0.11 (0.03-0.34) vs 0.15 (0.03-0.75) expert 0.29 (0.09-0.92) vs 1.25 (0.35-4.50) vs 0.24 (0.07-0.77) vs 0.24 (0.04-1.38) alpine seasons, all injury, <3 1.00 3-4 0.68 (0.26-1.78) 5-9 0.49 (0.21-1.13) 10-14 0.73 (0.28-1.91) >14 0.34 (0.11-1.07) skiing lessons, current season 1.00 previous season 1.59 (0.56-4.62) never 1.89 (0.70-5.16) bindings, LEER injury, untested vs tested 1.76 (0.97-3.21) slope condition, groomed alone vs groomed and powder 2.25 (1.08-4.73).
Ekeland, 1993 [106]	Retrospective case control; Lower extremity equipment related skiing injuries. (3)	132 case (140 injuries), 316 control, recreational skiers.	C RR, injured vs uninjured: lower leg fractures <10 y vs >20 y 9.0 p<0.0005 all injuries, female vs male 1.1 p>0.05 beginners vs beginners and above 6.0< p<0.0001 self-tested vs untested bindings 0.57 p=0.02 self-tested bindings and previous ski school 0.33 p<0.001.

Ekeland, 1993 [107]	Retrospective case control; Injury risk factors in children skiers. (3)	59 injury case, 63 uninjured control, recreational.	C OR (95% CI): lower extremity equipment related injuries, <10 y vs 10-14 y 2.68 (1.38-5.20) ability, beginners 1.00 intermediate 0.05 (0.01-0.23) advanced 0.06 (0.01-0.30) expert 0.20 (0.01-2.60) skiing seasons, <3 1.00 3-4 0.37 (0.13-1.04) 5-10 0.27 (0.01-0.75) type of slope, groomed slope only vs groomed slope and powder skiing 2.43 (1.28-4.60).
Ekeland, 2005 [51]	Prospective case control; Injury rates and types in skiing, snowboarding and telemarking. (3)	6138 injured case (6402 injuries), 3002 uninjured controls, recreational.	C OR (95% CI): all injury, sex, female vs male 0.96 (0.52-1.76) age, ≤12 y 1.00 13-19 y 0.44 (0.19-1.02) ≥20 y 0.43 (0.20-0.94) ability, beginner 1.00 intermediate 0.44 (0.19-1.02) advanced 0.52 (0.22-1.24) expert 0.83 (0.27-2.60) previously received formal instruction (yes) 0.91 (0.48-1.73) rental equipment (yes) 1.33 (0.70-2.53) helmet use (yes), head injury 0.68 (0.31-1.46) neck injury 0.73 (0.34-1.55).
Ekeland, 2011 [108]	Retrospective cohort; Injury risk factors in skiing and snowboarding. (3)	8149 (9235 injuries), recreational.	C RR (95% CI): head injury, helmet use (yes) 0.92 (0.57-1.33).
Ettlinger, 2006 [109]	Retrospective case control; Binding function and ski injury risk. (3)	122 case (79 knee injury, 43 ACL sprains), 99 uninjured controls, recreational.	C OR (95% CI), knee injury vs uninjured, binding status: ≥1 critical quantitative defect, control 1.00 ACL injury 0.80 (0.34-1.83) lower leg injury 3.12 (1.54-6.37) ≥1 critical qualitative defect, control 1.00 ACL injury 0.90 (0.46-1.78) Lower leg injury 3.17 (1.69-6.00) ≥1 critical quantitative and qualitative defect or both, control 1.00 ACL injury 0.92 (0.49-1.71) lower leg injury 2.79 (1.51-5.16) minor defect, control 1.00 ACL injury 1.15 (0.61-2.18) lower leg injury 1.83 (0.98-3.43) minor and critical combined, control 1.00 ACL injury 0.73 (0.40-1.32) lower leg injury 3.6 (1.84-7.22) ≥1 failed indicator, lower leg injury vs control 2.04 (1.08-3.86), lower leg injury, minor and critical combined, control 1.00 twist 5.70 (2.69-12.28) bend 2.09 (1.12-3.91).
Fukuda, 2007 [84]	Retrospective cohort; Headwear use effect on injury rate. (4)	1190 injured recreational snowboarders.	LRA OR (95% CI), serious head injury: female 0.550 (0.421-0.718) p<0.0001 age, 5 y 1.02 (0.890-1.17) p=0.737 jump, yes 2.25 (1.48-3.43) p<0.0001 technique, upper 1.17 (0.821-1.68) p=0.39 cap with jump helmet or knit cap p=0.036 helmet 0.661 (0.323-1.35) p=0.253 knit cap 0.770 (0.495-1.20) p=0.245.
Giddings, 1993 [110]	Retrospective cohort; Children ski injury comparison. (1)	2297 >12 y, 204 ≤12 y, recreational.	C RR (95% CI), >12 y vs ≤12 y: knee sprain/strain 0.18 (0.01-4.22) lower leg fracture 6.20 (2.49-15.44) ankle sprain/strain 1.25 (0.51-3.07) thumb sprain/strain 0.11 (0.03-0.43).

Girardi, 2010 [1]	Retrospective cohort; Injury severity in skiers and snowboarders (including skill level). (3)	2511 skiers, 843 snowboarders, recreational.	Injury severity score (ISS): female 2.9±3.1 male 3.6±4.9 p=0.01 skiers 3.5±4.6 type of rider, snowboarders 3.0±3.4 p>0.05 self-reported skills level, 1st time 2.7±2.3 beginner 2.7±2.5 medium 3.3±4.0 expert 3.4±4.3 unknown 11.6±12.8 p=0.001 age 0-20 y 3.1±3.2 21-30 y 3.1±4.6 31-40 y 2.9±4.1 41-50 y 3.2±3.9 51-60 y 3.7±4.5 60< y 4.6±5.6 p=0.001 type of accident, fall 3.3±4.3 collision3.4±4.1 p>0.05 resident, local resident 2.6±2.9 non-local resident 4.0±5.2 p<0.001. ISS <4 vs ISS ≥ 4 (%): age (y) (median IQR) 30 (18-43) vs 33 (17-48) p<0.001 males 61 vs 63 p>0.05 type of accident (fall) 87 vs 88 p>0.05 typology of rider (snowboarder) 25 vs 27 p>0.05 local resident 56 vs 38 24-h snowfall (cm), mean (SD) 3 (6) vs 3 (5) p>0.05 self-reported skills level, 1st time 3 vs 4 beginner 16 vs 16 medium 42 vs 42 expert 38 vs 35 unknown 1 vs 3 p=0.001. linear model for ISS vs trauma risk factors (adjusted for age, sex, type of skier, weather condition, self-reported experience level), Parameter: age and sex 21-30 y -0.11 p=0.02 31-40-0.13 p=0.01 41-50 -0.03 p>0.05 51-60 0.09 p>0.05 >60 y 0.21 (<0.001) sex (male) 0.10 p<0.001 weather condition, 24-h snowfall (cm) -0.01 p=0.03 average snow level (cm) 0.00 p>0.05 temperature min. -0.01 p>0.05 type of skier, local resident -0.32 p<0.001 snowboard 0.10 p=0.01 type of accident (fall) 0.03 p>0.05 experience level, 1st time -0.05 p>0.05 beginner -0.12 p=0.02 medium -0.04 p>0.05 unknown 0.44 p<0.001. note: used 5 ski resorts as level factor; reference profile was non-local resident female skier age 0-20 y.
Goulet, 1999 [79]	Prospective case control; Equipment and skill in children. (6)	41 injured, 346 non-injured, 9.4±2.2 y, recreational skiers ≤12 y.	LRA OR (95% CI), injured vs uninjured: skill level, low 7.54 (2.57-22.15) equipment, rented 7.14 (2.59-19.87) (post-hoc low skill and rented equipment related) binding adjustment, incorrect 2.11 (1.02-4.33).
Goulet, 2000 [52]	Prospective case control; Risk taking and injury risk in skiing. (4)	190 injured case 24.7 y, 219 uninjured control 30.7 y, recreational.	C OR (95% CI), injured vs uninjured, all injury: sex (female) 1.53 (0.84-2.78). injured vs uninjured, all injury: age (y) 24.7 vs 30.7 p<0.001 skill (beginner=1…expert=5) 3.2 vs 3.8 p<0.001 level (not important=0…extremely important=3) and source of motivation, excitement 1.2 vs 1.2 p>0.05 relaxation 2.1 vs 2.0 p>0.05 mastering skills 2.1 vs 2.2 p>0.05 social relations 1.4 vs 1.6 p>0.05 attitudes towards risk taking (not dangerous at all=0...extremely dangerous=3) 2.5 vs 2.4 p>0.05 risk taking behaviour (never=0...often=3) 0.4 vs 0.4 p>0.05.

Goulet, 2007 [111]	Retrospective case control; Risk factors of serious injuries in snow parks and other slopes. (6)	6995 injured cases, 43598 non-injured controls, recreational skiers and snowboarders.	LRA OR (95% CI), injured vs uninjured, evacuated by ambulance vs type of injury (severe or not): female vs male 1.03 (0.98-1.09) age, <12 y 1.00 12-17 y 1.23 (1.14-1.33) 18-34 y 1.12 (1.03-1.23) ≥35 y 1.22 (1.12-1.34) activity, ski 1.00 snowboard 0.92 (0.87-0.97) hill type, snow park 1.26 (1.17-1.35) other slopes 1.00 skill level, beginner/intermediate 1.00 expert 1.05 (0.99-1.12) helmet use (no) 1.03 (0.95-1.12).
Goulet, 2010 [112]	Retrospective case control; Skill level effect on injury severity. (5)	22078 injured, recreational, skiers and snowboarders.	A OR (95% CI), severity, expert vs beginner: skiing, evacuation by ambulance 1.28 (1.11-1.46) severe injury 1.88 (1.58-2.23) ambulance or severe injury 1.39 (1.23-1.57) snowboarding, evacuation by ambulance 1.18 (0.99-1.41) severe injury 1.13 (0.99-1.36) ambulance or severe injury 21.6/17.3, 1.18 (1.02-1.38). A OR (95% CI), body region of severe injury, expert vs beginner: skiing, head and neck 1.86 (1.65-2.10) trunk 1.76 (1.47-2.10) upper extremity1.88 (1.68-2.11) lower extremity 0.43 (0.39-0.47) snowboarding, head and neck 1.10 (0.95-1.28) trunk 1.13 (0.93-1.38) upper extremity0.68 (0.60-0.76) lower extremity1.63 (1.42-1.88). A OR (95% CI), severity and body region, expert vs beginner: skiing, head and neck 1.17 (0.93-1.46) trunk 0.88 (0.62-1.24) upper extremity 1.02 (0.75-1.40) lower extremity 1.43 (1.18-1.74) snowboarding, head and neck 0.72 (0.56-0.94) trunk 1.06 (0.73-1.54) upper extremity1.67 (1.21-2.30) lower extremity 1.30 (0.92-1.83).
Greenwald, 1996 [54]	Retrospective case control; Sex effect on ski injury. (3)	5360 injury case 33.2±14.0 y, 244 uninjured controls 34.8±14.4 y, recreational.	C OR (95% CI), injured vs uninjured: sex (female), all injury 1.13 (0.62-2.05) knee injury 2.68 (1.44-5.00) shoulder injury 0.40 (0.11-1.38) upper extremity fracture 0.63 (0.18-2.20) laceration 0.29 (0.07-1.14) ability, all injury, beginner 0.74 (0.37-1.48) intermediate 1.34 (0.73-2.47) advanced 0.93 (0.46-1.87) expert 1.13 (0.47-2.74).
Greenwald, 2009 [50]	Retrospective case control; Effect of age and experience on ski and snowboard injury. (3)	32123 injured case (ski 31.8±16.0 y, snowboard 21.9±11.4 y), 2404 uninjured control, recreational.	C RR (95% CI), injured vs uninjured: all injury, ability, ski vs snowboard, beginner 1.00 vs 1.00 intermediate 0.63 (0.18-2.22) vs 0.29 (0.10-0.84) advanced 0.22 (0.04-1.27) vs 0.13 (0.03-0.54) lower leg fractures, ability, ski vs snowboard, beginner 1.00 vs 1.00 intermediate 0.38 (0.17-0.82) vs 0.54 (0.19-1.52) advanced 0.11 (0.03-0.39) vs 0.33 (0.01-1.12) age, ≤16 y vs 16r< 6.25 (2.27-17.19).

Greve, 2009 [113]	Retrospective cohort; Skiing and snowboarding head injuries. (2)	1002 head injuries (males 25.0±14.9 y, females 26.6±15.7 y), recreational.	Likelihood of losing consciousness, terrain park vs ski slope χ^2=5.800 p<0.05 likelihood of losing consciousness when striking fixed object, helmet use vs non-helmet use χ^2=5.800 p<0.05.
Hagel, 2004 [89]	Retrospective case series; Risk factors relating to injury. (4)	28831 skiers, 18996 snowboarders, recreational.	LRA RR (95% CI), head and neck injuries, injuries/1000 participants vs injuries/1000 outings: age 12-17 y 4.9 (3.9-6.2) vs 4.2 (3.4-5.2), 18-24 y 1.9 (1.5-2.4) vs 1.9 (1.5-2.3) 25-34 y 1.0 (0.8-1.3) vs 1.0 (0.8-1.3), 35< y 1.0 vs 1.0 male 1.0 vs 1.0 female 0.9 (0.8-1.1) vs 1.0 (0.9-1.2) snowboard 3.4 (2.9-4.1) vs 3.3 (2.8-3.9) ski 1.0 vs 1.0. LRA RR (95% CI), trunk injuries, injuries/1000 participants vs injuries/1000 outings: age 12-17 y 4.5 (3.5-5.8) vs 3.8 (3.0-4.9) 18-24 y 2.0 (1.5-2.6) vs 2.0 (1.6-2.6) 25-34 y 1.0 (0.8-1.3) vs 1.0 (0.8-1.3) 35< y 1.0 vs 1.0 male1.0 vs 1.0 female 0.9 (0.8-1.1) vs 1.1 (0.9-1.3) snowboard 2.1 (1.7-2.6) vs 2.0 (1.7-2.4) ski 1.0 vs 1.0. LRA RR (95% CI), upper extremity injuries, injuries/1000 participants vs injuries/1000 outings: age 12-17 y 4.5 (3.6-5.8) vs 3.9 (3.1-4.9) 18-24 y 1.8 (1.4-2.4) vs 1.9 (1.5-2.3) 25-34 y1.2 (1.0-1.6) vs 1.2 (1.0-1.6) 35< y 1.0 vs 1.0 male 1.0 vs 1.0 female 0.9 (0.8-1.1) vs 1.0 (0.9-1.2) snowboard 3.4 (2.9-4.1) vs 3.3 (2.8-3.9) ski 1.0 vs 1.0. LRA RR (95% CI), lower extremity injuries, injuries/1000 participants vs injuries/1000 outings: age 12-17 y 3.1 (2.4-4.0) vs 2.7 (2.2-3.4) 18-24 y 1.5 (1.2-2.0) vs 1.5 (1.2-1.9) 25-34 y 1.2 (0.9-1.5) vs 1.2 (0.9-1.5) 35< y 1.0 vs 1.0 male 1.0 vs 1.0 female 1.5 (1.2-1.7) vs 1.7 (1.4-2.0) snowboard 0.8 (0.7-1.0) vs 0.8 (0.6-0.9) ski 1.00 vs 1.00.

Hagel, 2005 [38]	Retrospective matched case control; Wrist guard effect on upper extremity (UE) snowboard injuries. (5)	1066 UE injury, 970 non-UE injury control, recreational snowboarders.	C OR (95% CI) UE injury vs non-UE injury: hand to forearm injury, wrist guard use (yes) 0.40 (0.20-0.79) hours of participation before injury event, 2> hr 1.00 2-5 0.78 (0.640.96) 6≤ hr 0.88 (0.61-1.27) non-wrist-guard equipment damage (yes) 0.42 (0.29-0.61) self-reported speed, slow 1.00 average 0.73 (0.57-0.93) fast 0.44 (0.33-0.59) participation at time of injury, lesson or school outing 1.00 recreation 0.96 (0.74-1.22) mechanism of injury, collision or jump 0.68 (0.56-0.83) fall 1.00 run difficulty, easy 1.00 difficult 0.67 (0.53-0.85) very difficult/extremely difficult 0.66 (0.51-0.84) other protective equipment (yes) 0.83 (0.68-1.02) visibility, good 1.00 average-fair 1.13 (0.85-1.52) snow conditions, groomed-hard-pack/ice 1.32 (1.05-1.65) powder/wet 1.00 temperature ≥0°c 1.00 -1°c to -10°C 1.33 (0.99-1.77) <-10°C 0.98 (0.66-1.44). C OR (95% CI), Elbow to shoulder injury: wrist guard use (yes) 1.65 (0.98-2.77) hours of participation before injury event, <2 hr 1.00 2-5 0.89 (0.69-1.15) ≥6 hr 1.43 (0.96-2.12) non-wrist-guard equipment damage (yes) 0.70 (0.47-1.05) self-reported speed, slow 1.00 average 1.33 (0.96-1.85) fast 1.48 (1.06-2.06) participation at time of injury, lesson or school outing 1.00 recreation 1.50 (1.08-2.09) mechanism of injury, collision or jump 0.83 (0.66-1.05) fall 1.00 run difficulty, easy 1.00 difficult 1.05 (0.79-1.41) very difficult/extremely difficult 1.01 (0.74-1.37) other protective equipment (yes) 0.91 (0.72-1.16) visibility, good 1.00 average-fair 1.08 (0.76-1.54) snow conditions, groomed-hard-pack/ice 1.48 (1.12-1.95) powder/wet 1.00 temperature. ≥0°C 1.00 -1°C to -10°C 0.92 (0.67-1.27) <-10°C 0.92 (0.60-1.43). U vs M-H vs U LRA vs A LRA OR (95% CI): hand to forearm 0.40 (0.20-0.79) vs 0.31 (0.15-0.67) vs 0.26 (0.11-0.63) vs 0.15 (0.05-0.45) elbow to shoulder 1.65 (0.98-2.77) vs 2.50 (0.99 vs 6.32) vs 2.46 (1.0-6.08) vs 2.35 (0.70-7.81).
Hagel, 2005 [81]	Retrospective matched case control; Helmet use and non-head/neck severity and crash circumstances. (5)	3295 non head/neck injury case, matched control, recreational skiers and snowboarders.	M vs AM OR (95% CI), injury severity, helmet no vs yes: evacuated by ambulance 1.14 (0.79-1.63) vs 1.17 (0.79–1.73) admitted to hospital 0.70 (0.53-0.94) vs 0.79 (0.53-1.18) normal daily activities restricted=7 days 0.61 (0.48-0.78) vs 0.93 (0.65-1.34). M vs AM OR (95% CI), helmet no vs yes, injury characteristics: non-helmet equipment damage 1.38 (0.88–2.16) vs 1.20 (0.71-2.04) fast self-reported

			speed 1.28 (0.96-1.70) vs 1.06 (0.68-1.66) participation on a more difficult run 0.74 (0.54-1.03) vs 1.28 (0.79-20.8) jumping cause of injury 1.86 (1.42-2.43) vs 1.19 (0.77-1.83).
Hagel, 2005 [30]	Matched case control with case cross-over; Helmet use on head and neck injury. (5)	1082 head injury, 3295 non head/neck injury, recreational skiers and snowboarders.	LRA (M vs PAM vs IM vs FAM) OR (95% CI), any head injury: 0.81 (0.64-1.02) vs 0.78 (0.61-1.0) vs 0.73 (0.49-1.08) vs 0.71 (0.55-0.92) potentially severe head injury: 0.67 (0.40-1.11) vs 0.59 (0.34-1.0) vs - vs 0.44 (0.24-0.81), any neck injury: 1.11 (0.67-1.83) vs 0.96 (0.56-1.66) vs - vs 0.62 (0.33-1.19). LRA M OR (95% CI) potentially severe neck injury: 1.29 (0.41-4.04).
Hagel, 2010 [86]	Retrospective case control; Helmet use effect on neck injury. (6)	2986 neck injury, 97408 control non-neck/head injury control, recreational skiers and snowboarders.	LRA OR (95% CI), neck injury vs non-head/neck injury: all ages, any neck injury, LRA, crude 1.30 (1.18-1.43) age, sex, activity, ability and season 1.10 (0.98-1.24) all covariates 1.09 (0.95-1.25) LRA, matched set 1.20 (1.06-1.36) age, sex, and ability 1.07 (0.93-1.22) isolated neck with ambulance evacuation, LRA, crude 1.59 (1.30-1.93) age, sex, activity, ability and season 1.23 (0.99-1.53) all covariates 1.28 (0.96-1.71) LRA, matched set 1.17 (0.88-1.57) age 1.11 (0.81-1.52) neck/cervical/spine fracture/dislocation, LRA, crude 1.29 (1.00-1.65) age, sex, activity, ability and season 1.14 (0.87 vs 1.50) age, sex, activity, ability, biennium, and no. of skier days 1.02 (0.79-1.31) LRA, matched set 1.05 (0.74 vs 1.50) age and sex 1.13 (0.78-1.64). LRA OR (95% CI), children aged <11 y: any neck injury, LRA, crude 1.26 (1.02-1.57) sex, activity, ability, and biennium 0.98 (0.74-1.29) All covariates 0.94 (0.60-1.48) LRA, matched set 1.11 (0.68-1.81) sex 1.11 (0.69-1.81) isolated neck with ambulance evacuation, crude 2.12 (1.39-3.23) sex, activity, ability, and biennium 1.56 (0.98-2.48) matched set 0.77 (0.26-2.24) neck/cervical/spine fracture/dislocation, crude 1.19 (0.61-2.29) sex, activity, and ability 1.03 (0.53-1.99) LRA, matched set 0.36 (0.04-3.10) sex 1.11 (0.69-1.81).
Hansom, 2010 [114]	Retrospective cohort; Skiing and snowboarding injury risk factors. (2)	181 injuries, recreational.	C RR (95% CI): previous injury, beginner 1.00 intermediate 1.38 (0.85-2.25) advanced 2.90 (1.96-4.42) expert 3.19 (21.7-4.83). injury rate: age (25-29 y) p<0.05.

Hasler, 2009 [88]	Retrospective case control; Injury risk factors for skiing. (5)	782 injured case 40 y, 496 non-injured control 35 y, average experience (y): Patient 20, Control 22, recreational skiers.	LRA OR (95% CI), injured vs uninjured: high readiness for risk vs low readiness for risk 1.84 (1.04-3.27) p=0.0365 low readiness for speed vs high readiness for speed 0.29 (0.14-0.60) p=0.0008 no aggressive behaviour vs aggressive behaviour 0.19 (0.09-0.37) p=0.0001 new skiing equipment vs old skiing equipment 0.59 (0.37-0.93) p=0.0228 warm-up performed vs no warm-up performed 1.79 (1.25-2.57) p=0.0015 old snow vs artificial snow 0.21 (0.07-0.60) p=0.0037 old snow vs fresh snow 0.31 (0.12-0.80) p=0.0155 powder snow vs slush snow 0.25 (0.10-0.63) p=0.0035 alcohol abstinence (vs no alcohol abstinence) 0.14 (0.05-0.34) p=0.0001 drug consumption vs no drug consumption 5.92 (1.74-20.11) p=0.004 age 0.69 (0.27-1.78) p=0.4464 bad weather/visibility (vs good weather/visibility) 2.56 (0.89-7.39) p=0.0818 seasonal checking of skiing equipment (vs no seasonal checking of skiing equipment) 0.46 (0.20-1.02) p=0.0561 sex (female)1.24 (0.62-2.45) p=0.5435 years of experience of alpine skiing 1.57 (0.62-3.93) p=0.340 use of helmet 1.44 (0.69-3.02) p=0.3312 use of spine protector 0.93 (0.28-3.03) p=0.8977 use of wrist protector 0.58 (0.03-10.03) p=0.7093 hard vs powder snow 0.83 (0.31-2.17) p=0.6989.
Hasler, 2010 [29]	Prospective case control; Injury risk factors for snowboarding. (5)	306 injured case 20 y, 253 uninjured 19 y, average experience (range) Injured 5 y (0-30) Uninjured 7 y (0-30), recreational snowboarders.	LRA OR (95% CI), injured vs uninjured: low readiness for speed 0.20 (0.06-0.64) p=0.0073 fresh snow 0.11 (0.02-0.68) p=0.0174 bad weather/visibility 19.06 (2.70-134.73) p=0.0031 years of experience in snowboarding (1st quartile vs 3rd quartile) 1.86 (0.46-7.53) p=0.3860 warm-up performed 1.49 (0.57-3.85) p=0.4165 sex (female) 0.42 (0.09-2.00) p=0.2767 low readiness for risk3.09 (0.54-17.66) p=0.2048 age (1st quartile vs 3rd quartile) 0.89 (0.24-3.35) p=0.8694 new skiing equipment 0.94 (0.67-1.31) p=0.7046 use back protector (yes) 1.55 (0.33-7.31) p=0.5784 use wrist protector (yes) 0.54 (0.14-2.10) p=0.3706 artificial snow (vs old snow) 1.87 (0.31-11.32) p=0.4943 slush snow (vs powder snow) 1.35 (0.24-7.60) p=0.7356 hard and icy snow (compared powder snow) 2.21 (0.35-13.75) p=0.3969 seasonal checking of snowboarding equipment (yes) 1.93 (0.45-8.24) p=0.3739 alcohol abstinence (yes) 0.28 (0.04 -2.19) p=0.2237 offensive snowboarding style0.49 (0.09-2.57) p=0.3985 helmet use (no) 4.65 (0.94-23.05) p=0.0595 drug consumption (yes)

			17.54 (0.73-418.70) p=0.0768 aggressive behaviour (no) 0.27 (0.07-1.01) p=0.0520.
Hauser, 1985 [71]	Prospective case control; ski injury risk factors. (4)	211 injury case, 825 uninjured controls, recreational.	C OR (95% CI), injured vs uninjured: age, all injuries vs knee ligament injuries vs tibial fracture, <16 y 1.00 vs 1.00 vs 1.00 16 y ≤ (male) 0.55 (0.21-1.45) vs 0.49 (0.18-1.33) vs 0.21 (0.08-0.49) 16 y ≤ (female) 0.58 (0.21-1.61) vs 0.81 (0.29-2.24) vs 0.13 (0.05-0.36) ability, non-LEER vs LEER vs knee ligament vs tibia, beginner 1.00 vs 1.00 vs 1.00 vs 1.00 intermediate 0.71 (0.30-1.70) vs 0.23 (0.10-0.50) vs 0.20 (0.09-0.44) vs 0.11 (0.03-0.32) expert 0.51 (0.17-1.48) vs 0.17 (0.06-0.48) vs 0.13 (0.06-0.28) vs 0.13 (0.04-0.35). relative deviation of binding setting from recommendations (%), C RR (95% CI) (vs control), IAS vs BfU: Non-LEER injury 70 vs 36, 1.00 vs 1.00 sprained knee 84 vs 46, 1.2 (0.71-2.04) vs 1.28 (0.68-2.41) fractured tibia 146 vs 84, 2.09 (1.25-3.48) vs 2.33 (1.29-4.25).
Idzikowski, 2000 [66]	Retrospective case control; Upper extremity injury snowboarding risk factors. (4)	7430 injured 22.5 y (range 7-71) (3645 upper extremity), 3107 uninjured control (825 from study data, 2282 from other study data), recreational.	C OR (95%), injured vs uninjured: all injury, ability, beginner 1.00 intermediate 0.49 (0.22-1.11) advanced 0.18 (0.08-0.39) wrist guard use for wrist injuries, with vs without, all wrist 0.48 (0.21-1.11) distal radius fracture 0.49 (0.19-1.27) wrist sprain 0.71 (0.21-2.33).

Ishimaru, 2012 [63]	Retrospective case control; Hip pads and common snowboarding injury risk factors. (5)	3035 common injury case, 2026 uncommon injury control, recreational snowboarders.	LRA OR (95% CI), common injury vs uncommon injury: age (y) <20 y 1.00 20-30 y 0.97 (0.83-1.13) >30 y 0.95 (0.78-1.15) p=0.86 sex, male 1.00 female 1.07 (0.95-1.19) p=0.27 skill level, beginner 1.00 intermediate 0.75 (0.67-0.85) expert 0.68 (0.57-0.81) p<0.001 experienced seasons, 1 1.00 2-5 0.89 (0.76-1.05) 6-10 0.74 (0.62-0.88) >10 0.69 (0.54-0.89) p<0.001 experienced days (univariate) 1-10 1.00 11-50 0.80 (0.70-0.91) 51-100 0.74 (0.62-0.88) >101 0.46 (0.38-0.54) p<0.001 experienced days (multivariate) 1-10 1.00 11-50 0.81 (0.71-0.92) 51-100 0.75 (0.63-0.90) >101 0.47 (0.40-0.56) p<0.001 snowboarding school, yes 0.92 (0.78-1.08) no 1.00 p=0.30 helmet, yes 0.94 (0.74-1.19) no 1.00 p=0.60 elbow pad, yes 1.12 (0.83-1.52) no 1.00 p=0.46 wrist guard, yes 0.90 (0.65-1.24) no 1.00 p=0.51 backbone guard, yes 0.90 (0.73-1.11) no 1.00 p=0.33 hip pad (univariate), yes 0.78 (0.70-0.87) no 1.00 p <0.001 hip pad (multivariate), yes 0.84 (0.75-0.95) no 1.00 p <0.01 knee pad, yes 0.79 (0.70-0.91) no 1.00 p <0.01. lra or (95% ci), hip pad for each common injury: distal radial fracture (univariate), yes 0.77 (0.66-0.89) no 1.00 p<0.001 distal radial fracture (multivariate), yes 0.85 (0.73-0.99) no 1.00 p<0.05 head injury, yes 0.91 (0.76-1.10) no 1.00 p=0.32 clavicle fracture, yes 1.04 (0.83-1.29) no 1.00 p=0.76 humerus fracture, yes 1.01 (0.80-1.26) no 1.00 p=0.97 glenohumeral dislocation (univariate), yes 0.67 (0.52-0.86) no 1.00 p<0.01 glenohumeral dislocation (multivariate), yes 0.61 (0.45-0.81) no 1.00 p<0.01 spinal fracture, yes 1.30 (1.00-1.68) no 1.00 p=0.05 elbow dislocation, yes 0.84 (0.61-1.15) no 1.00 p=0.27 acromioclavicular dislocation, yes 0.83 (0.58-1.18) no 1.00 p=0.29.
Jenkins, 1985 [72]	Retrospective case control; Collision injury in downhill skiing. (3)	3536 injured case (648 collision injuries 23.4±10.4 y, 2879 non-collision injuries 24.3±10.5 y), 1344 uninjured control 25.9±11.1 y, recreational.	C OR (95% CI): ability, collision injuries vs non-collision injuries, beginner 1.00 vs 1.00 novice 0.51 (0.11-2.32) vs 0.39 (0.01-1.45) intermediate 0.65 (0.18-2.29) vs 0.33 (0.10-1.04) advanced intermediate 0.62 (0.16-2.27) vs 0.24 (0.07-0.79) expert 0.81 (0.21-3.11) vs 0.26 (0.01-0.94). C RR (95% CI): injury severity, collision vs non-collision injury, grade 1 1.04 (0.65-1.64) grade 2 1.72 (1.15-2.60) grade 3 0.53 (0.32-0.84) grade 4 0.62 (0.27-1.38) grade 5 0.70 (0.06-7.81).

Kim, 2012 [94]	Retrospective case control; Trends in snowboarding and alpine skiing injuries. (3)	11725 injured case (2260 snowboard 20.4 y, 9465 ski 30 y), 2366 uninjured control (291 snowboard 24.0 y, 2075 ski 33.2 y), recreational.	C OR (95% CI), injured vs uninjured: snowboard, all injury, regular stance (left foot lead) 1.26 (0.68-2.36) wrist injury, wrist guard worn (yes) 0.78 (0.16-3.62) snowboard vs ski, all injury, terrain park usage (yes) 0.70 (0.35-1.39) vs 0.82 (0.29-2.31) injured vs uninjured: snowboard, mean age 20.4 vs 30.0 p<0.01 male/female ratio 2.29 p<0.009 experience (no. of seasons prior) 2.9 vs 6.9 p<0.001 experience (no. of days per season) 17.6 vs 24.7 p<0.01.
Kocher, 2003 [95]	Prospective cohort; Knee bracing effect on ski ACL injury. (3)	180 ACL deficient skiers, 101 brace, 79 non-brace, 38.6 ±14.4 y, professional skiers.	LRA OR (95% CI), ACL injury rate: age (y) 1.06 (0.93-1.22) sex, male 0.22 (0.03-1.7) involved side 1.7 (0.29-7.36) occupation 0.56 (0.28-1.12) no. years skied 1.0 (0.84-1.07) ski days/season 0.99 (0.98-1.02) giving way 1.15 (0.52-6.21) Lachman examination 0.71 (0.20-2.70) pivot-shift examination 1.70 (0.51-5.75) KT-1000 MM Involved 0.78 (0.54-1.12) KT-1000 MMD 1.32 (1.06-1.64) bracing (no) 8.0 (2.24-43.37).
Lamont, 1993 [73]	Retrospective cohort; New Zealand ski injury risk factors. (2)	2542 (2732 injuries) injured case, field survey control, recreational.	C OR (95% CI):all injury vs leg injury, ability, female, learner 1.00 vs 1.00 intermediate 1.04 (0.53-2.04) vs 0.78 (0.40-1.50) advanced 0.68 (0.26-1.76) vs 0.52 (0.20-1.34) expert 0.31 (0.01-3.70) vs - male, learner 1.00 vs 1.00 intermediate 0.92 (0.41-2.09) vs 0.84 (0.38-1.89) advanced 0.73 (0.26-2.01) vs 0.39 (0.15-1.02) expert 0.22 (0.04-1.08) vs 0.13 (0.02-0.79).
Langran, 2002 [115]	Prospective case control; Snow sport risk factors. (5)	674 injured (732 injuries), 336 control, recreational skiers, snowboarders and telemarkers.	LRA OR (95% CI), injured vs uninjured: age, ≤15 y 1.9 (1.14-3.17) 16-25 y 0.71 (0.44-1.14) 26-40 y 0.79 (0.51-1.24) <40 y 1.00 equipment, snowboard 4.07 (1.65-10.08) alpine 3.82 (1.6-9.13) skiboard 1.05 (0.37-2.94) telemark 1.00 ski days this season, 0-5 days 1.00 6-10 days 0.50 (0.33-0.76) >11 days 0.74 (0.46-1.18) total experience, 1st day 1.00 1st week 0.50 (0.3-0.83) 1-4 weeks 0.57 (0.34-0.94) 4-8 weeks 0.63 (0.37-1.08) >8 weeks 0.43 (0.25-0.73).
Langran, 2004 [42]	Retrospective case control; Injury risk among 1st day skiers (FDS). (5)	2124 injured 21.9±9.7 y, 1782 uninjured 21.8±8.6 y, 1st day participants, recreational skiers, snowboarders and skiboarders.	LRA OR (95% CI), injured vs uninjured: age, ≤ 16 y 3.16 (1.78-5.61) 17-25 y 1.00 26-40 y 1.96 (1.18-3.27) >40 y 2.17 (0.86-5.49) equipment, alpine 1.00 snowboard 1.83 (0.87-1.14) skiboard 0.58 (0.32-1.06) gear origin, own 0.38 (0.21-0.67) ski area rental 1.00 other shop rental 0.93 (0.57-1.53) borrowed gear 7.96 (0.98-64.86) lessons taken, yes 2.81 (1.7-4.66) no 1.00. A LRA OR (95% CI), FDS vs other days: alpine ski 2.76 (2.03-3.14) snowboard 2.58 (1.83-3.60) skiboard 2.25 (1.81-3.86) all sports 2.49 (2.03-3.04).

Laporte, 2000 [96]	Retrospective case control; ACL ruptures at French Ski Resorts 1992-1999. (5)	21303 ACL ruptures, 1618 uninjured controls, recreational.	C OR (95%) ACL ruptures vs uninjured controls: leg and ankle fractures, children ≤10 y vs adults 2.39 (1.70-3.38) p<0.001 ACL rupture, female vs male, teenagers 2.59 16<y 3.41 (3.26-3.56) beginners <7 days experience, 24< y, female 3.00 male 2.82 24< y, female vs male 3.63.
Laporte, 2009 [97]	Prospective case control; Lower leg injury and ski bindings. (3)	129 knee and below injury case, 341 uninjured controls, recreational.	C OR (95%), knee and below injury vs uninjured: knee and below injury, ability, beginner 1.00 intermediate 0.79 (0.22-2.70) advanced 0.24 (0.07-0.78) expert 0.08 (0.01-0.71) age, <11 y 1.00 11-15 y 0.51 (0.07-3.47) 16-24 y 0.23 (0.03-1.32) 25-55 y 0.37 (0.07-1.73) >55y 0.26 (0.04-1.41) type of ski, side cut <15m vs side cut ≥15m 1.76 (0.92-3.41) sex, female vs male, other injury 1.55 (0.84-2.87) knee injury 4.90 (2.98-5.34) type of release, normal release 1.00 inadvertent release 1.75 (0.38-8.11) non-release 37.9 (10.95-146.09) binding release value, toe injury, correct 1.00 below 1.70 (0.34-8.57) above 1.84 (0.96-3.55) heel injury, correct 1.00 below 0.67 (0.25-1.78) above1.87 (0.98-3.59).
Laporte, 2012 [67]	Prospective cohort; Injury risk during skiing and snowboarding in France. (5)	419,809 injuries, recreational skiers and snowboarders.	C RR (95% CI): All injury, beginner vs advanced, ski 4.90 (4.22-5.74) snowboard 2.61 (2.35-2.90) leg and ankle fracture, beginner vs advanced, ski 8.90 (8.50-9.30) wrist fracture, beginner vs advanced, snowboard 9.9 (9.18-10.68).
Lystad, 1985 [74]	Prospective case control; Ski injury risk factors. (3)	143 injured (51 LEER injury), 126 uninjured, recreational.	C OR (95% CI), injured vs uninjured: age, <15 y vs >15 y, LEER injury vs all injury 3.36 (1.52-7.50) vs 2.85 (1.28-6.43) ability, beginner 1.00 vs 1.00 intermediate 0.39 (0.17-0.92) vs 0.54 (0.22-1.29) good 0.11 (0.04-0.27) vs 0.22 (0.09-0.53) expert 0.15 (0.05-0.47) vs 0.43 (0.15-1.18) equipment, rented (yes), LEER injury 3.94 (1.46-11.42) other injury 1.42 (0.45-4.58) deviation from BfU and IAS binding setting references, LEER injury vs control, -11%> 0.56 (0.29-1.08) ±10% 0.58 (0.19-1.69) +11-50% 0.79 (0.40-1.57) >50% 2.56 (1.35-4.89) experience, first season vs first 3 seasons, LEER injury 2.24 (0.78-6.65) other injury 1.83 (0.57-5.9).

Lystad, 1989 [75]	Prospective case control; Ski injury risk factors. (3)	883 injured case, 379 uninjured control, 24.2 y (range 3-70), recreational.	C OR (95%), injured vs uninjured: age, all injury vs fractures <10 y 2.34 (0.52-11.9) vs 7.49 (1.99-33.99) 10-4 y 1.22 (0.49-3.08) vs 1.99 (0.85-4.74) 15-19 y 1.31 (0.59-2.94) vs 0.51 (0.19-1.35) 20-24 y 0.91 (0.42-1.95) vs 1.10 (0.52-2.31) 25-29 y 0.72 (0.32-1.62) vs 0.20 (0.06-0.64) 30-39 y 0.74 (0.34-1.61) vs 0.74 (0.34-1.61) 39<y 1.29 (0.47-3.56) ability, LEER injury vs Non-LEER injury, beginner 1.00 vs 1.00 intermediate 0.21 (0.09-0.50) vs 0.26 (0.11-0.60) advanced 0.14 (0.05-0.37) vs 0.24 (0.10-0.57) expert 0.20 (0.07-0.55) vs 0.21 (0.07-0.60) experience, LEER injury vs Non-LEER injury, seasons 1 1.00 vs 1.00 3 0.48 (0.15-1.41).
Lystad, 1989 [116]	Prospective case control; Ski collision injury risk factors. (3)	158 collision injured case (97 skier, 61 tree), 379 uninjured control, 24.2 y (range 3-70), recreational.	C OR (95% CI), collision injured vs uninjured: age, <10 y 2.85 (0.76-11.67) 10-14 y 1.77 (0.75-4.20) 15-19 y 0.95 (0.41-2.20) 20-24 y 0.92 (0.43-1.97) ability, skier and tree group, beginner 2.17 (0.99-4.83) tree group, expert 1.18 (0.56-2.51).
Macnab, 1996 [117]	Retrospective cohort; Injury trends in alpine skiing and snowboarding. (2)	2092 injuries, 720066 population, recreational.	C RR (95 % CI): age, total injury vs significant injury 0-6 y 1.00 vs 1.00 7-12 y 1.24 (0.88-1.77) vs 1.82 (1.10-3.04) 13-17 y 1.14 (0.81-1.61) vs 1.92 (1.17-3.16) 18-64 y 0.66 (0.48-0.93) vs 1.07 (0.66-1.74) 65+ y 0.58 (0.34-1.01) vs 1.00 (0.51-2.00).
Macnab, 1999 [118]	Prospective case control; Knowledge and behaviour in young skiers. (4)	118 injured, 863 uninjured, 5-17 y recreational.	C OR (95% CI), injured vs uninjured: perception of ability/style, fast skiers 1.00 (0.47-2.11) daring 1.00 (0.44-2.27) ski in control 0.69 (0.38-1.26) ski recklessly - ski when scared 2.04 (0.31-16.47) previous lessons, 2-9 in previous y 0.70 (0.34-1.41) no lesions in previous y 1.69 (0.89-2.95) never heard of 'the skier's responsibility code (SRC)' 0.74 (0.38-1.44) heard of SRC but could not list the six points 1.00 (0.55-1.81) no knowledge of right of way 1.00 (0.51-1.97) incorrect identification of run severity grading 1.74 (0.55-5.65) helmet use, never 1.78 (0.92-3.45) sometimes 0.68 (0.26-1.74) always 0.57 (0.26-1.28).
Macnab, 2002 [119]	Retrospective cohort; Helmet use effect on face and neck injury in children (<13 y) skiers and snowboarders. (3)	70 injured <13 y, recreational skiers and snowboarders.	C RR (95% CI), no helmet: cervical/spine 2.0 (0.8-5.65) head/face/neck injury, all 2.24 (1.23-4.12) skiing 1.74 (0.82-3.73) snowboarding 1.82 (0.59-6.31). M-H A RR (95% CI), No helmet: Head/face/neck injury 1.77 (0.99-3.19) p=0.055.

Made, 1996 [43]	Retrospective case control; Ski injury risk factors. (3)	481 injured case 22.9 y (range 3-70), 60 uninjured control, recreational.	C OR (95% CI): Alcometer SD-2 test (positive) 0.21 (0.01-1.80).
Made, 2004 [120]	Retrospective cohort; Snowboard injury risk factors. (2)	568 injured 19 y (range 6–51, median 18), recreational.	C RR (95 % CI): ability, fractures, beginner 1.00 average 0.82 (0.55-1.19) advanced 0.79 (0.531.16) lower arm/wrist, beginner 1.00 average 0.79 (0.49-1.01) advanced 0.44 (0.28-0.69) head/neck, beginner 1.00 average 1.23 (0.63-2.40) advanced 1.30 (0.68-2.20) knee, beginner 1.00 average 1.25 (0.53-2.96) advanced 1.38 (0.59-3.20).
Merkur, 2003 [121]	Prospective case control; Effect of ski shape on injury location and severity. (3)	123 shaped ski case, 74 conventional ski control, recreational.	C OR (95%): observed injury rate compared to expected, shaped vs conventional, forearm/wrist/hand injury 2.58 (0.63-10.99) concurrent ACL/MCL meniscal tear 0.47 (0.15-1.48) MCL meniscal tear 3.07 (0.80-12.32) severity of ACL and/or MCL injury, grade I 2.78 (0.65-13.54) grade ii 1.75 (0.70-4.45) grade iii 0.65 (0.34-1.26).
Meyers, 1997 [44]	Retrospective case control; Alcohol use and ski injury. (5)	389 injured cases, 899 uninjured controls, 34.1±11.7 y, recreational.	C OR (95% CI), injured vs uninjured: all injury, sex (female) 2.3 (1.7-3.2) $p<0.001$ first time skier 0.96 (0.95-0.97) $p<0.001$ first year skier 1.02 (1.01-1.03) sensation seeker 0.43 (0.29-0.66) $p=0.004$ excitement seeker 0.55 (0.37-0.83) $p<0.001$ self-report drink and ski 0.36 (0.24-0.53) self-report alcohol use 24 hr previous 11.5 (8.2-16.0).
Mueller, 2008 [82]	Retrospective case control; Helmet use effect on head, face and neck injury. (6)	3701 above shoulder injury cases, 17674 below shoulder injury controls, recreational skiers and snowboarders.	LRA OR (95% CI), above shoulder injury vs shoulder and below injury: helmet use (yes), all skiers 0.85 (0.76-0.95) ski resort 1 0.85 (0.67-1.09) ski resort 2 0.78 (0.63-0.97) ski resort 3 0.88 (0.76-1.02) alpine or other 0.84 (0.69-1.01) snowboard 0.85 (0.75-0.98) $p=0.83$ beginner 0.69 (0.53-0.89) intermediate 0.86 (0.72-1.02) expert 0.92 (0.77-1.09) $p=0.15$ male 0.80 (0.70-0.92) female 0.98 (0.80-1.19) $p=0.09$ age, 1-12 y 0.60 (0.47-0.77) 13-24 y 0.80 (0.69-0.94) ≥40 y 1.13 (0.93-1.36) $p<0.001$.
Oates, 1999 [122]	Retrospective cohort; Injury and treatment history effect on knee injury in skiing. (2)	4748 group A no knee injury history, 138 group B ACL deficient but no surgery, 274 group C knee tendon reconstruction and injured contralateral knee, professional.	C RR (95% CI): knee injury, group a (per knee) 1.00 group b (per deficient knee) 6.32 (4.00-9.76) group c (per reconstructed knee) 3.18 (2.00-5.02).

Ogawa, 2010 [123]	Retrospective cohort; Skill level effect on injury in snowboarding. (2)	19539 injured 24.2±0.0 y (range 4-70), recreational.	ISS mean±SD (range), novice 2.87±0.08 (1–25) beginner 3.12±0.03[a] (1–36) intermediate 3.36±0.03[b] (1–30) expert 3.54±0.06[c] (1–29) iss >9 % (n) novice 2.1[d] (25) beginner 1.7 (111) intermediate 3.1 (286) expert 4.7 (90) note: [a]=p<0.01 vs novice, [b]=p<0.01 vs beginner, [c]=p<0.05 vs intermediate, [d]=p<0.0001 vs beginner.
Oliver, 1991 [76]	Retrospective case control; Ski injury risk factors. (3)	21 injured case 39 y (range 30-53), 146 uninjured control 37 y (17-74 y), recreational.	C OR (95% CI), injured vs uninjured: all injury, sex (female) 0.96 (0.53-1.74) ability, beginner 1.00 intermediate 0.94 (0.39-2.30) advanced 1.20 (0.42-3.46) regular exercise (yes) 1.32 (0.70-2.50) equipment ownership (rental) 1.46 (0.79-2.71) bindings adjusted (yes) 1.05 (0.55-2.02).
Ruedl, 2009 [124]	Prospective case control; Oral contraceptive (OC) and menstrual cycle effect on ACL injury in female skiers. (3)	93 case 38.8±7.9 y (range 14–53), 93 control 38.1±6.6 (range 28–56) recreational.	C OR (95% CI) injured vs non-injured: previous knee injury0.7 (0.4-1.4) p=0.357 OC use (yes) 0.9 (0.5–1.7) p=0.878 preovulatory vs postovulatory phase, OC users and non-users 1.92 (1.07–3.44) p=0.028 OC non-users1.88 (0.92–3.88) p=0.084.
Ruedl, 2011 [125]	Prospective case control; Risk factors for ACL injuries in female skiers. (4)	68 ACL injured case 44.0±8.0 y, 136 matched uninjured control 44.2±7.8 y, recreational.	C OR (95% CI) ACL injured vs non-injured: ability, beginner 1.00 intermediate 0.64 (0.16-2.53) advanced 0.53 (0.13-2.07) expert 0.89 (0.09-8.53) fitness level, very good 1.00 good 0.81 (0.28-2.30) average 0.78 (0.26-2.26) poor 1.07 (0.23-4.89) skiing duration, <3 hr vs >3 hr4.36 (2.21-8.65) perception of fatigue, local, no fatigue 1.00 a trace of fatigue 0.62 (0.23-1.67) slightly tired 0.15 (0.06-0.36) tired 0.01 (0.03-0.30) very tired - overall, no fatigue 1.00 a trace of fatigue 0.36 (0.15-0.85) slightly tired 0.18 (0.08-0.41) tired 0.10 (0.02-0.48) very tired.
Ruedl, 2011 [126]	Prospective case control; Intrinsic and extrinsic risk factors for ACL injuries in female skiers. (5)	93 case 38.8±7.9 y (range 14–53), 93 control 38.1±6.6 y (range 28–56), recreational.	LRA A OR (95% CI), univariate: physical activity ≤1 h/week (yes) 0.9 (0.5-1.8) p=0.988 ski type, traditional ski vs carving ski 7.4 (1.6-33.8) p=0.003 binding adjustment, ≤1 y vs >1 y 1.0 (0.6-1.9) p=0.959 environmental factors, snow conditions, fresh snow (yes) 2.2 (0.9-5.5) p=0.087 grippy (yes) 0.3 (0.1-0.5) p<0.001 icy (yes) 21.1 (6.2-72.1) p<0.001 slushy/soft (yes) 0.3 (0.1-0.7) p=0.005 difficulty of the downhill slope, easy (blue) (yes) 1.3 (0.7-2.5) p=0.470 moderate (red) (yes) 0.5 (0.3-0.9) p=0.024 hard (black) (yes) 6.8 (1.5-31.4) p=0.005 weather, sunny (yes) 0.4 (0.2-0.8) p=0.014 overcast (yes) 1.6 (0.8-3.4) p=0.243 snowfall (yes) 9.9 (1.2-79.6) p=0.009. OR (95% CI), multivariate: icy 24.33 (6.8-86.5) p<0.001 snowfall 16.63 (1.8-152.1)

			p=0.013 traditional ski 10.49 2.0– 54.5 p=0.005 preovulatory phase 2.59 (1.2-5.5) p=0.013.
Ruedl, 2012 [56]	Retrospective case series; Environmental risk factors for knee injuries recreational skiers. (2)	1039 non-contact knee injuries, males 36.8 (16.5) y, females 37.8 (15.4) y, recreational skiers.	C OR (95% CI), females with knee injuries: 1st two temperature quartiles vs 2nd two temperature quartiles 1.35 (1.07–1.69) p=0.01 1st temperature quartile vs 4th temperature quartile 1.60 (1.16–2.22) p=0.005.
Ruedl, 2012 [56]	Retrospective cohort; ACL injury risk factors in carving skiing. (3)	59 males 43.6±11.5 y (17-75), 161 females, recreational 42.25±10.31 y (14-72)	C OR (95% CI): bindings not releasing, male vs female 2.6 (1.32-5.05) p=0.005 forward twisting fall vs other fall types5.7 (2.38-13.75) p<0.001.
Ruedl, 2012 [127]	Retrospective cohort; Leg dominance as a risk factor for ACL injury. (4)	193 with ACL rupture, males 37.8±11.0 y, females 41.5±11.4 y, recreational skiers.	LRA OR (95% CI), univariate, ACL injury on dominant leg/non-dominant leg (%): male 54.7/45.3 female 36.9/63.1 2.1 (1.1-3.8) p=0.20. LRA OR (95% CI), multivariate, ACL injury non-dominant leg: female vs male 2.00 (1.00-3.78) p=0.49 Age 1.00 (0.98-1.03) p=0.833 more skilled vs less skilled 1.37 (0.71-2.66) p=0.355 physical fitness, very good 1.00 p=0.770 good 1.16 (0.51-2.62) p=0.720 average 0.91 (0.38-2.14) p=0.822 poor 0.51 (0.08-3.12) p=0.463.
Ruedl, 2013 [128]	Retrospective case control; Injury risk factors at snow parks and slope intersections compared to on-slope. (6)	134 snow park case injured, 106 slope intersection case injured, 2036 on-slope non-injured control, 36.2±15.2 y (range 5-79), recreational skiers and snowboarders.	LRA OR (95%), univariate, slope intersections vs ski slopes: males vs females 1.4 (0.9-2.0) p=0.130 ski helmet use 1.1 (0.7-1.7) p=0.704 snowboard vs ski 1.1 (0.7-1.8) p=0.707 cause of injury, collision with person vs fall 2.0 (1.2–3.3) p=0.006 weather, sunny 1.1 (0.7-1.7) p=0.677 overcast 0.8 (0.5-1.3) p=0.328 snow fall 1.3 (0.7-2.6) p=0.427 snow conditions, fresh snow 1.1 (0.6-2.0) p=0.755 grippy 1.3 (0.8-2.1) p=0.293 icy 0.4 (0.1-1.8) p=0.237 slushy/soft 0.6 (0.3-1.4) p=0.252. LRA OR (95%), univariate, snow parks vs ski slopes: males vs females 4.7 (2.9-7.5) p<0.001 ski helmet use 1.6 (1.0-2.4) p=0.044 snowboard vs ski 3.5 (2.4-5.0) p<0.001 cause of injury, collision with person vs fall 1.1 (1.1-1.1) p<0.001 weather, sunny 1.2 (0.8-1.8) p=0.445 overcast 1.1 (0.7-1.7) p=0.734 snow fall 0.4 (0.1-1.1) p=0.062 snow conditions, fresh snow 0.5 (0.3-1.0) p=0.058 grippy 0.9 (0.6-1.4) p=0.684 icy 1.1 (0.5-2.5) p=0.887 slushy/soft 1.9 (1.2-3.1) p=0.009. LRA OR (95% CI), multivariate: slope intersections vs ski slopes, collision vs fall 2.07 (1.25-3.40) p=0.004 arm injury 2.10 (1.26-3.49) p=0.004 snow parks vs ski slopes, males vs females 3.46 (2.10-5.72) p<0.001 1.06 (1.04-1.08) p<0.001 slushy/soft snow 1.87

			(1.06-3.32) p=0.032 knee injury 0.38 (0.19-0.75) p=0.006 back injury 5.50 (2.96-10.23) p<0.001.
Russell, 2013 [46]	Retrospective case series; Aerial vs non-aerial Injuries sustained in a terrain park. (3)	333 (379 injuries) case, recreational snowboarders.	LRA OR vs A OR (95% CI), aerial vs non-aerial: head/neck 2.69 (1.44-5.04) vs 2.58 (1.37-4.85) trunk 3.58 (1.71-7.52) vs 3.65 (1.68-7.95) lower extremity 0.80 (0.42-1.53) vs 0.68 (0.35-1.34) sprain/strain 0.49 (0.27-0.89) vs 0.55 (0.29-1.08) bruise/abrasion/laceration 0.73 (0.39-1.39) vs 0.90 (0.44-1.85) concussion 1.42 (0.62-3.27) vs 1.50 (0.59-3.83) soft tissue/pain/other 1.39 (0.69-2.80) vs 1.59 (0.75-3.37).
Rust, 2013 [2]	Retrospective cohort; Injury patterns with and without snowboarders. (2)	376817 visits and 811 injuries pre-snowboarding, median age 39 y (range 4-100), 548366 visits and 1355 injuries post-snowboarding median age 31 y (range 4-99), recreational skiers and snowboarders.	C RR (95% CI), post-snowboarding vs pre-snowboarding: all injury 1.13 (1.04-1.24) head/neck injury 1.31 (0.93-1.84) lower extremity injury 0.99 (0.84-1.17) trunk/pelvis injury 1.03 (0.73-1.44) upper extremity injury 1.39 (1.14-1.69).
Sandegard, 1991 [85]	Retrospective cohort; Ski injury risk factors. (2)	8621 injuries, recreational.	C OR (95% CI), head injury: helmet (yes) 0.43 (0.17-1.08).

Shealy, 1985 [77]	Retrospective case control; Ski injury risk factors. (3)	16877 injured case (median age 19 y), 2148 uninjured control (median age 22 y), recreational.	C OR (95%), all injury: ability, beginner 1.00 lower intermediate 0.48 (0.60-1.41) intermediate 0.43 (0.18-1.01) advanced 0.19 (0.07-0.53) expert 0.15 (0.04-0.50) pole design used, moulded 1.00 strap 2.51 (1.34-4.71) other/none 0.34 (0.01-7.06) retention device, runaway strap 1.00 ski brake 0.64 (0.35-1.18) none 0.39 (0.02-4.84).
Shealy, 1993 [78]	Retrospective case control; Ski injury risk factors. (3)	21817 injured case, 2318 uninjured controls, recreational.	C OR (95% CI): ability, female vs male, beginner/novice 1.00 vs 1.00 intermediate 0.27 (0.13-0.57) vs 0.27 (0.01-0.73) advanced 0.14 (0.05-0.36) vs 0.16 (0.06-0.43) sex (female), beginner/novice 0.73 (0.25-2.12) intermediate 0.74 (0.39-1.42) advanced 0.65 (0.27-1.55) number of falls, 0-1 0.19 (0.01-0.36) 2-9 3.48 (1.80-6.76) 10≤ 10.34 (1.71-109.64).
Shealy, 1996 [55]	Retrospective case control; Sex-related ski injury patterns. (3)	Ski area 1 (snow sport comparison) 23011 accident case, 2573 uninjured control, Ski area 2 (equipment comparison) 11356 injury case, 2180 uninjured control, recreational.	A (for ability) RR, all injury, sex (female): ski 1.12 snowboard 0.92. c or (95% ci), sex (female): injury type, tibial plateau fracture 2.90 (1.57-5.38) other tibial fracture 0.99 (0.53-1.83) grade iii knee sprain 2.24 (1.22-4.11) grade iii mcl sprain 3.55 (1.90-6.64) all other injuries 1.25 (0.68-2.29) injury mechanism, ski vs snowboard, hit by own equipment 0.44 (0.12-1.54) vs 0.35 (0.03-2.80) twist/bend 2.35 (1.25-4.42) vs 3.71 (1.86-7.43) impact snow 0.55 (0.29-1.04) vs 0.37 (0.20-0.69) impact other skier 1.31 (0.43-4.12) vs 0.85 (0.11-6.22) impact fixed object 0.66 (0.22-1.92) vs 0.30 (0.04-1.63). c rr (95% ci), all injury, female vs male: ski, beginner/novice 1.00 vs 1.00 intermediate 0.27 (0.08-0.99) vs 0.27 (0.07-1.05) advanced 0.10 (0.02-0.63) vs 0.11 (0.05-0.21) snowboard, beginner/novice 1.00 vs 1.00 intermediate 0.17 (0.04-0.68) vs 0.19 (0.05-0.72) advanced 0.05 (0.01-0.44) vs 0.07 (0.01-0.48).
Shealy, 2003 [129]	Retrospective case control; Femur and tibial plateau fracture risk factors in skiing. (4)	432 tibial shaft fractures (TSFx) 21.4±14.0 y, 88 tibial plateau fractures (TPFx) 36.8±12.2 y, 67 femur fractures (FFx) 22.4±12.9 y, 1972 all other fractures (OthFx) 28.7±14.3 y, 14232 all other injuries (OthIj) 28.7±14.3 y, 3247 uninjured controls 28.1±12.7 y, recreational.	C OR (95% CI): sex (female), control 1.00 TSFx 1.19 (0.64-2.21) TPFx 0.54 (0.30-0.99) FFx 1.66 (0.87-3.15) OthFx 1.19 (0.64-2.21) OthIj 0.69 (0.38-1.26).

Stepien-Slodkowska, 2013 [130]	Case-control; Collagen polymorphisms as ACL injury risk factors. (4)	138 male ACL injury cases 27±2 y, 183 uninjured male control 26±3 y, recreational skiers.	C OR (95% CI) COL1A1 gene polymorphisms, ACL injured vs non-injured: allele distribution1.43 (0.91-2.25) p=0.101 genotype distribution using "collapsing cells method" p=0.045.
Sterett, 2006 [98]	Prospective cohort; Functional bracing effect on skiers with ACL reconstruction (ALRA). (5)	157 brace 35 y, 563 non-brace 37 y, professional skiers.	LRA OR (95% CI), non-braced vs brace: knee injury 2.74 (1.2-4.9) knee injury requiring surgery 3.9 (1.2-12.3). LRA OR (95% CI), knee surgery: age 0.99 (0.97-1.0) p=0.74 Lachman 1.5 (1.0-2.4) p=0.05 pivot shift 0.84 (0.50-1.41) p=0.50 non-braced group 2.5 (1.2-5.2) p=0 .016.
Sulheim, 2006 [83]	Retrospective case control; Helmet use and head injury risk. (5)	3277 injury (578 head injury), 2992 control, recreational skiers and snowboarders.	C vs LRA OR (95% CI): without helmet 1.00 vs 1.00 with helmet 0.71 (0.56-0.90) vs 0.40 (0.30-0.55) p<0.001 age, <13 y 1.00 vs 1.00 13-20 y 1.24 (0.93-1.65) vs 0.71 (0.49-1.04) >20 y 0.47 (0.35-0.62) vs 0.27 (0.19-0.40) p<0.001 female 1.00 vs 1.00 male 1.36 (1.12-1.64) vs 1.46 (1.18-1.79) p<0.001 Norwegian 1.00 vs 1.00 Swedish 0.66 (0.51-0.86) vs 0.72 (0.55-0.96) Danish 0.81 (0.64-1.03) vs 0.85 (0.65-1.12) non-Nordic 1.31 (0.93-1.86) vs 1.38 (0.93-2.05) p=0.02 expert 0.54 (0.40-072) vs 0.60 (0.43-0.84) good 0.50 (0.39-0.65) vs 0.54 (0.40-0.71) intermediate 0.41 (0.32-0.54) vs 0.42 (0.31-0.56) beginner 1.00 vs 1.00 p<0.001 alpine skis 1.00 vs 1.00 snowboard 2.08 (1.72-2.51) vs 1.53 (1.22-1.91) telemark skis 0.67 (0.46-0.99) vs 0.74 (0.49-1.11) p<0.001.
Sulheim, 2011 [87]	Prospective case-control; Risk factors for injury in alpine skiing, telemark skiing and snowboarding. (5)	1607 ski, 1391 snowboard and 179 telemark injured cases, 2992 uninjured control, recreational alpine and telelmark skiers and snowboarders.	C OR vs LRA OR (95% CI), any injury: equipment p=0.001 vs p<0.001 alpine skiers 1.00 vs 1.00 snowboarders 2.11 (1.80-2.46) vs 2.11 (1.81-2.46) telemark skiers 0.93 (0.70-1.22) vs 0.96 (0.77-1.19) skiing ability p<0.001 vs p<0.001 experts 1.00 vs 1.00 good 1.04 (0.88-1.23) vs 1.07 (0.88-1.31) intermediate 1.09 (0.92-1.30) vs 1.11 (0.90-1.38) beginners 2.70 (2.20-3.34) vs 2.72 (2.12-3.47) age p<0.001 vs p<0.001 <13 y 1.00 vs 1.00 13–20 y 1.32 (1.02-1.71) vs 1.25 (1.00-1.54) >20 y 0.66 (0.51-0.73) vs 0.58 (0.47-0.71) nationality p=0.001 vs p=0.001 Norwegian 1.00 vs 1.00 Swedish 1.10 (0.95-1.13) vs 1.16 (0.97-1.39) Danish 0.98 (0.83-1.16) vs 0.95 (0.77-1.17) non-Nordic 1.58 (1.24-2.00) vs 1.80 (1.37-2.36) skiing instruction p=0.68 vs p=0.30 attended 1.00 vs 1.00 not attended 0.97 (0.84-1.12) vs 0.94 (0.83-1.06) rented equipment p=0.30 vs p=0.44 not rented 1.00 vs 1.00 rented 1.10 (0.93-1.30) vs 1.05 (0.92-1.22) sex p=0.003 vs p=0.09 males 1.00 vs 1.00 females 0.81 (0.70-0.93) vs 0.91 (0.81-

			1.02) helmet use p=0.037 vs p=0.21 non helmet 1.00 vs 1.00 helmet users 1.13 (1.01-1.28) vs 1.10 (0.95-1.28). LRA OR (95% CI), lower leg injury: equipment p<0.001 snowborders 1.00 alpine skiers 2.65 (1.47-4.80) telemark skiers 1.07 (0.44-2.60) skiing ability p<0.001 non-beginners 1.00 beginners 2.50 (1.61-3.85) age p<0.001 <13 y 1.00 13-20 y 0.24 (0.14-0.41) >20 y 0.09 (0.05-0.15) nationality p=0.008 Nordic skiers 1.00 non-Nordic 2.50 (1.27-5.00) skiing instruction p=0.058 attended 1.00 not attended 0.64 (0.41-1.02) rented equipment p=0.64 not rented 1.00 rented 1.12 (0.77-1.79) helmet use p=0.73 non helmet 1.00 helmet users 0.90 (0.50-1.63) sex p=0.30 males 1.00 females 0.80 (0.52-1.23). LRA OR (95% CI), knee injury: equipment p<0.001 snowborders 1.00 alpine skiers 1.82 (1.39-2.38) telemark skiers 1.01 (0.64-1.59) skiing ability p<0.001 non-beginners 1.00 beginners 3.13 (2.50-3.85) age p<0.001 <13 y 1.00 13–20 y 0.89 (0.63-1.22) >20 y 1.20 (0.90-1.61) nationality p=0.008 Nordic skiers 1.00 non-Nordic 2.50 (1.27-5.00) skiing instruction p=0.058 attended 1.00 not attended 0.81 (0.66-0.99) rented equipment p=0.64 not rented 1.00 rented 1.24 (1.01-1.52) helmet use p=0.73 non helmet 1.00 helmet users 1.14 (0.86-1.50) sex p=0.30, males 1.00 females 1.67 (1.38-2.03). LRA OR (95% CI), shoulder injury: equipment p<0.001 snowborders 1.00 alpine skiers 1.16 (0.77-1.74) telemark skiers 1.70 (1.30-2.23) skiing ability p<0.001 non-beginners 1.00 beginners 1.28 (0.92-1.79) age p<0.001 <13 y 1.00 13–20 y 0.45 (0.28-0.73) >20 y 0.74 (0.50-1.07) nationality p=0.008 Nordic skiers 1.00 non-Nordic 1.82 (1.43-2.78) skiing instruction p=0.058 attended 1.00 not attended 0.98 (0.75-1.26) rented equipment p=0.64 not rented 1.00 rented 0.88 (0.53-1.18) helmet use p=0.73 non helmet 1.00 helmet users 1.13 (0.84-1.53) sex p=0.30 males 1.00 females 0.54 (0.42-0.69).
Van Dommelen, 1989 [131]	Retrospective case control; Upper extremity injuries in skiers. (3)	44 UE injury case, 144 uninjured control, recreational.	C OR (95 % CI), injured vs uninjured: grip type, i strap under thumb 1.20 (0.34-4.08) ii strap over thumb 0.93 (0.32-2.64) iii strap not used 0.95 (0.34-2.60) pole type, a 0.35 (0.15-0.80) b 2.08 (0.86-4.98) c 1.57 (0.76-3.27) pole type, strap vs saber 0.64 (0.31-1.33).

Wadsworth, 2012 [93]	Prospective case control; Wrist guard use and design effect on wrist injury. (3)	89 wrist injury case, 126 uninjured control, recreational snowboarders.	C OR (95% CI), wrist injury: wrist guard (yes) 0.68 (0.34-1.40) wrist guard design, short vs long 1.53 (0.72-3.30) wrist guard rigidity, rigid 1.09 (0.59-2.04) soft 4.18 (1.02-20.05) flex all 0.39 (0.05-2.33) flex wrist 0.58 (0.24-1.39) wrist guard coverage, palm 1.41 (0.78-2.55) dorsal 0.34 (0.11-1.03) both 1.03 (0.56-1.90)
Zacharopoulos, 2009 [68]	Prospective case control; Injury risk factors in skiing and snowboarding. (4)	978 injury case (565 skiers, 210 snowboarders), 755 uninjured controls (565 skiers, 210 snowboarders), recreational.	C OR (95% CI), ski vs snowboard, all injuries: sex (female vs male) 0.83 (0.46-1.52) vs 1.23 (0.56-2.69) age, <16 y 1.00 vs 1.00 16-20 y 0.11 (0.02-0.47) vs 0.58 (0.17-1.95) 21-25 y 0.13 (0.03-0.45) vs 0.85 (0.27-2.67) 26-30 y 0.17 (0.05-0.63) vs 1.79 (0.48-6.77) 31-40 y 0.18 (0.05-0.64) vs 4.00 (0.70-25.15) >40 y 0.5 (0.11-2.19) vs - ability, beginner 1.00 vs 1.00 intermediate 0.45 (0.19-1.04) vs 1.44 (0.70-2.98) experienced 0.22 (0.09-0.53) vs 0.95 (0.38-2.37) instructor/athlete 0.30 (0.08-1.13) vs - . C RR (95 % CI), ski vs snowboard, injury severity: grade, i 1.46 (0.62-3.50) ii 1.29 (1.06-1.59) iii 0.36 (0.20-0.65) iv 2.39 (1.00-5.70).

OR=odds ratio, RR=risk ratio, A=adjusted, C=crude, M=matched, PAM=partially adjusted match, IM=ideally matched, FAM=final adjusted match, M-H=Mantel-Haenzsel, AM=adjusted matched, LRA=logistic regression analysis.