

A REVIEW OF COUNTERMEASURES
FOR SNOWBOARDING INJURIES

by

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A review of countermeasures for snowboarding injuries

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Abstract:

Snowboarding is quickly becoming a popular sport at alpine resorts. In contrast to alpine skiing, where injuries to the knee and thumb are most common, the wrist (and forearm) and ankle are the most frequently injured body regions for snowboarders. General guidelines for snowboarding safety are available and are similar to the recommendations for general snow/ski safety. Unfortunately, the rapid international growth of the sport has not been matched by detailed epidemiological evaluation of the injuries specific to snowboarding or the countermeasures to prevent them. The aim of this report is to critically review the literature describing injury prevention measures, or countermeasures, for snowboarding. In doing so, it provides an evaluation of the extent to which these countermeasures have been demonstrated to be effective. Few countermeasures specific for snowboarding were found to have been formally demonstrated to actually prevent injury. The countermeasures to which some attention has been paid are boots, bindings, wrist guards, skill level and methods of falling. Skill level and the other injury countermeasures apply more generally across the sport. Recommendations for countermeasure implementation include: education for snowboarders, adherence to snow conduct and safety codes, preparing snowboarders for their activity and maintenance of parks and runs. Recommendations for improved data collections include: maintaining existing data collections, collecting information about equipment used by snowboarders. Further biomechanical and epidemiological research needs to be undertaken on knee/ankle and wrist/forearm injuries. Evaluation of countermeasures needs to keep pace with the rapid developments in this field. Particular attention should be directed towards evaluations of the role of wristguards, boots/bindings, fall technique and lessons in preventing injuries. Given the rapidly increasing popularity of the sport, the need for the safety equipment to be evaluated would seem to be a priority, along with identifying the mechanisms of injury.

Key Words:

Snowboarding, injury prevention,
countermeasures, evaluation

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EXECUTIVE SUMMARY

Snowboarding is quickly becoming a popular sport in many alpine resorts. Some information about snowboarding injuries is becoming available (eg from the Australian Snowboarding Injury Database) and these data collections are valuable resources for injury prevention research. The Australian Snowboard Injury Database study has reported an injury rate of 4.2 per 1000 visits at 3 major Australian ski resorts. This rate is comparable to the rates of 4-6 per 1000 visits reported by international studies and also to that of alpine skiing. There appears to be a predominance of males aged around 20 years and novices amongst injured snowboarders.

In contrast to alpine skiing, where injuries to the knee and thumb are most common, the wrist (and forearm) and ankle are the most frequently injured body regions for snowboarders. In Australia, the majority (57%) of injuries are to the lower limbs and followed by the upper limbs (30%). In some international studies, the opposite has been noted. Other studies have shown an increasing, or relatively larger proportion, of upper extremity injuries to snowboarders. The most common types of injuries in snowboarding are sprains (31.53%), fractures (24-27%) and contusions (12-19%).

The technology of snowboarding equipment has progressed rapidly and snowboarders, like skiers, have a choice in equipment design. Changes in equipment are rapid and occur as frequently as from season to season. Ankle injuries are more common amongst snowboarders wearing soft shell boots; these soft boots are typically worn by intermediate and advanced riders. Knee injuries and distal tibial fractures, on the other hand, are more common in snowboarders wearing hard shell boots, the type of boot favoured by novices. Falls, often with a torsional movement component, are the most common mechanism of injury.

General guidelines for snowboarding safety are available and are similar to the recommendations for general snow/ski safety. Unfortunately, the rapid international growth of the sport has not been matched by a detailed epidemiological evaluation of the injuries specific to snowboarding. Furthermore, demonstrating the effectiveness of injury prevention countermeasures specifically for snowboarding has not kept pace with the popularity of the sport.

The overall aim of this report is to critically review the literature describing injury prevention measures, or countermeasures, for snowboarding. In doing so, it provides an evaluation of the extent to which these countermeasures have been demonstrated to be effective.

The countermeasures to which some attention has been paid are boots, bindings, wrist guards, skill level and methods of falling. Boots and bindings are particularly relevant to lower limb injuries and wrist guards (and falling techniques) to wrist fractures, sprains and other upper limb injuries. Skill level and the other injury countermeasures apply more generally across the sport.

A limited number of studies have evaluated the effectiveness of countermeasures for preventing snowboarding injuries. Support for these countermeasures is generally in the form of anecdotal or informed opinion. Other studies have concluded that a particular countermeasure would be effective on the basis of an examination of injury trend or epidemiological data only. Neither of these types of 'evidence' can be considered to be a

formal or controlled evaluation of the efficacy of the proposed countermeasures. For example, the large frequency of wrist fractures/sprains amongst snowboarders has prompted the recommendation that wristguards be worn. There has yet to be any evaluation of the effectiveness of wristguards for preventing these snowboarding injuries, however, and their use may increase the potential for injuries higher up the arm.

Based on the literature review presented in this report, the following recommendations can be for further research, development and implementation of countermeasures to reduce the occurrence and severity of snowboarding injuries:

Wristguards

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury-
- Further detailed study of the nature and severity of snowboarding injuries is warranted with particular attention to wrist and forearm injuries. This information has the most potential for influencing the rate of injury, through improved equipment design and new countermeasure development.
- Determine the current levels of protective equipment usage by snowboarders, particularly wristguards. This could be achieved by observational surveys-
- Determine current attitudes about, and barriers to, the use of wristguards in a cross-section of snowboarders.
- The effectiveness of wristguards for preventing wrist injuries needs to be evaluated as a matter of priority. This type of protective equipment is widely promoted. Its potential to increase fractures and other injuries further up the forearm, arm and shoulder needs to be examined in any evaluation. There may be other unwanted effects of wristguards that should also be explored.

Fall technique

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury-
- The role of specific snowboarder training and lessons (particularly with regard to falling technique) should be explored.
- Determine the extent to which snowboarders undertake specific lessons in snowboarding and falling techniques before they participate in the sport-
- Develop education programs or lessons to teach snowboarders about correct falling and snowboarding techniques.

Boots and bindings

- Further detailed study of the nature and severity of snowboarding injuries is warranted with particular attention to knee and ankle injuries. This information has the most potential for influencing the rate of injury, through improved equipment design and new countermeasure development.

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury.
- The effects of different types of equipment design (particularly the boots and bindings) on snowboarding injuries need to be fully evaluated in a controlled way. This also needs to keep pace with the rapid development of new snowboarding equipment, with new equipment being demonstrated to be 'safe'.
- The relative risks of injuries should be determined overall for those snowboarders wearing boots of varying stiffness in future studies, not only among injured snowboarders.
- Develop a Standard for snowboarding equipment that will 'guide' future design directions-
- Encourage snowboarders to maintain their equipment in good order.
- Ensure that rental equipment is properly fitted and adjusted by means of an accreditation scheme for hirers.

Speed control

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- Ensure that snowboarders are well aware of, and adhere to, general snow conduct and safety codes.
- Separation of snowboarders and skiers
- Continue to give high priority to the design and maintenance of snowboard parks and runs.
- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury.

Other countermeasures

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- The effects of different types of equipment design on snowboarding injuries need to be fully evaluated in a controlled way. This also needs to keep pace with the rapid development of new snowboarding equipment, with new equipment being demonstrated to be 'safe'.
- Develop an education program to inform snowboarders about the need to be well prepared for snowboarding.
- Ensure that young snowboarders are fully supervised.

- Ensure that injured snowboarders receive adequate treatment and rehabilitation of injuries before resumption of snowboarding.
- Continue to promote the presence of ski patrollers as a major feature of snow safety programs.

Improved data collections

- Establish a 'snowboarder' category of 'resort user' as an integral component of routine alpine injury data collections (eg Ski Patrol Injury Report forms).
- Data collections should collect information about specific equipment used by the injured snowboarders (eg type of boots) and the injury countermeasures (eg wristguards used).
- Injury data collections should routinely collect information about the mechanisms of snowboarding injury-
- Maintain ongoing injury surveillance in relation to snowboarding injuries. In Australia, the Australian Snowboard Injury Database should be maintained. Given the rapid pace at which new snowboarding equipment is introduced, the maintenance of ongoing injury surveillance is crucial.
- Where possible, data collection should conform to the requirements of injury surveillance standards and/or minimum data sets (eg the National Data Standards for Injury Surveillance). As sports injury versions are developed, the data should conform with these.

1. INTRODUCTION

Snowboarding originated in North America in the 1970s. It combines the principles of surfing and skateboarding, and provides an exciting challenge to participants who may already have developed skills in alpine skiing, surfing or skate-boarding (Victorian Ski Association, 1995). With technological advances resulting in safer boards and bindings and a cult following among young people, it has advanced as a sport since the mid 1980s (Bladin and McCrory, 1995). Despite some initial resistance, over 95% of ski resorts now allow snowboarding. Some resorts have developed specific areas (snowboard parks) for snowboarders to perform freestyle manoeuvres on specially prepared snow constructions such as the 'half pipe' (Bladin and McCrory, 1995). Most Australian ski resorts provide excellent facilities for snowboarders (Rennie, 1996).

Snowboarding is becoming very popular at resorts and ski areas throughout North America, Europe, Australia and New Zealand (Johnson, 1990; Sohlic, 1990; Janes and Fincken, 1993). The sport has grown rapidly and snowboarders now make up about 10% of slope users at ski resorts, and up to 50% at some resorts (Transworld Snowboarding, 1991).

Australia has about 20,000 snowboard users per year. It has been estimated that the growth rate of 20% exceeds that of other alpine sports (Alpine Safety Conference, 1995).

The rapid international growth of the sport has not been matched by a detailed epidemiological evaluation of the injuries specific to snowboarding or the countermeasures to prevent them. Although some reports describing snowboarding injuries have been published, there have been no controlled comparisons of snowboarding injury data with that for skiing injuries (Bladin and McCrory, 1995).

2. AIMS

The overall aim of this report is to critically review the literature describing injury prevention measures, or countermeasures, for snowboarding. In doing so, it will provide an evaluation of the extent to which these countermeasures have been demonstrated to be effective.

An excellent overview of the profile of snowboarding injuries has recently been published (Bladin and McCrory, 1995) and the interested reader is referred to that paper. This present report does not, therefore, describe the epidemiology of snowboarding injuries in detail. The focus of this report is an examination of the countermeasures promoted to prevent such injuries.

3. METHODS

The sources of information used to compile this report were:

- Medline CD-ROM search for published medical literature
- Sport Discus CD-ROM search for published sports literature
- discussions with key Australian researchers and sporting organisations
- correspondence with relevant state and national sporting organisations
- correspondence with relevant researchers registered by the National Sports Injury Research Centre
- posting to the Injury List on the Internet
- Standards Australia
- presentations at the 1995 Alpine Safety Conference, Melbourne, November 1995
- the Victorian Snow safe booklet and video
- world-wide standards index on CD-ROM 1995/96 issue. US Database: with key words of helmet, sport, recreation
- NEXUS database scan on the keyword snowboarding
- scanning of other Internet and world wide web sites.

This review is based largely on English-language material. However, foreign language articles with English abstracts have been included.

The literature gathered for this review was critically assessed to determine the extent to which the various countermeasures had been fully evaluated and demonstrated to be effective in preventing injuries. In this review, we considered the demonstration of the effectiveness of a countermeasure's performance in the field to be the highest level of 'proof' that the countermeasure was effective in preventing injuries. This is particularly important for sports injury countermeasures where any change to the nature of snowboarding, including the level of enjoyment and participation, is an important factor to be considered. In general, changes to factors such as how snowboarding is performed, the behaviour of snowboarders and the level of enjoyment can only be measured during "in-the field" evaluations.

At the lowest level of proof are anecdotal reports of injuries and their prevention and comments based on informed or expert opinion. This category would include, for example, statements like "I treated 5 cases of wrist fracture during last year's season and all would have been prevented if they were wearing wristguards at the time".

Data-based evidence can take a number of forms. Case-series studies or routine surveillance systems document the incidence of new injury cases over periods of time.

Patterns in data can be examined over time to draw conclusions about the value that countermeasures may have on injury rates. Cross-sectional epidemiological studies provide some information about injury prevalence at a given point of time but are unable to assess the influence of countermeasures on injury rates. Quasi-experimental studies are not controlled evaluations but do enable a comparison of pre-intervention with post-intervention data to examine the effects of some countermeasures.

Controlled evaluations provide the most definitive evidence for the impact of countermeasures. Case-control studies and longitudinal (cohort) studies are common forms of controlled studies. However, neither study type allows random assignment of people (or injuries) to test and control groups, though they are good example of natural experiments. A randomised controlled trial is considered to provide the best form of rigorous scientific evidence. In such studies, the units of interest (ie snowboarders, resorts, types of equipment, etc) are randomly assigned to test and control groups.

Another important aspect of countermeasure implementation is the extent to which they are accepted or adopted by the users for whom they were intended. Countermeasures should be acceptable to those they were designed to protect. Community consultation and awareness programs must therefore be considered in any implementation process. It is also important to assess barriers towards use of injury countermeasures and an examination of attitudes, knowledge and behaviours is crucial to this. Studies looking at these factors are generally conducted after implementation of a countermeasure and can highlight the need for behavioural or educational change at either the individual or organisational level. No studies looking at this aspect specifically for snowboarders was identified in this review.

4. AN OVERVIEW OF THE EPIDEMIOLOGY OF SNOWBOARDING INJURIES

The Australian Snowboard Injury Database study has collated an injury profile of Australian snowboarders (Bladin et al, 1993). This study found a predominance of males (male:female ratio of 3: 1) and an average age of 21 years (ranging from 12 to 46) for both sexes.

Approximately 60% of injuries are to novices. This is a higher percentage than that found for alpine skiing, and reflects the profile of participants in snowboarding as a developing sport (Bladin et al, 1993).

International studies confirm the predominance of males aged around 20 years and novices amongst injured snowboarders (Pino and Colville, 1989; Shealy and Sundman, 1989; Abu-Laban, 1991; Shealy, 1993; Zollinger et al, 1994; Biasca et al 1995).

The Australian Snowboard Injury Database study (Bladin et al, 1993) reports an injury rate of 4.2 per 1000 visits at 3 major Australian ski resorts (Mt Hotham, Falls Creek and Mt Buller). This rate is comparable to the rates of 4-6 per 1000 visits reported by other studies (Shealy and Sundman, 1989; Shealy, 1993) and also to that of alpine skiing. A recent study from Switzerland found that the snowboarding injury rate (1.7-8.0/1000 snowboard days) was higher than that for alpine skiers (2-4/1000 skier days) (Biasca et al, 1995).

Prall et al (1995) estimated the incidence of snowboarding injuries that were severe enough to require tertiary referral to be 0.03 injuries per 1000 snowboarding days. In terms of immediate assistance with injury, snowboarders tend to go directly to Medical Centres themselves (that is, they are the 'walking wounded') and are not generally picked up by Ski Patrollers. They may therefore be under-estimated in Australian Ski Patrol statistics (Alpine Safety Conference, 1995).

The table below summarises some of the data from the Australian snowboard injury data base study for the period 1989-1992. Fifty-seven per cent of Australian snowboarding injuries occur to the lower limbs and 30% to the upper limbs (Bladin et al, 1993). The

opposite was found in an Austrian study, where the upper extremity was the predominant site of injury (51 %) followed by the lower extremity (34%) (Oberthaler et al, 1995). Other studies have shown an increasing, or relatively larger proportion, of upper extremity injuries to snowboarders (Pino and Colville, 1989; Janes and Fincken, 1993; Oberthaler et al, 1995; Warne et al, 1995).

Table Commonly injured body regions and types of injuries amongst Australian snowboarders

Body Region	Proportion of all injuries (%)	Type of injury	Proportion of all injuries (%)
ankle/foot	23	sprain	53
knee	23	fracture	24
wrist/hand	16	contusion	12
head/neck/face	11		

Adapted from: Bladin et al, 1993

The most common types of injuries in snowboarding are sprains (31-53%), fractures (24-27%) and contusions (12-19%) (Pino and Colville, 1989; Abu-Laban, 1991; Bladin et al, 1993; Bladin and McCrory, 1995). In comparing injuries in Australian snowboarders and skiers, snowboarders had 2.4 times as many fractures, particularly to the upper limbs (35% versus 21% of upper limb injuries). However, they also had fewer knee injuries (23% versus 44% of lower limb injuries), but more ankle injuries (23% versus 6% of lower limb injuries) (Bladin and McCrory, 1995). Ninety-one per cent of all lower limb injuries in the Australian study were to the leading leg. Zollinger et al (1994) also found the leading leg to be injured in a large proportion (80%) of cases with a lower extremity injury in their Austrian snowboarding study.

Novice snowboarders sustain significantly more upper limb fractures and more knee injuries. In contrast, intermediate and advanced skiers sustain more ankle injuries (Bladin et al, 1993). Snowboarding knee injuries are less severe than those associated with skiing in terms of length of hospitalisation and time off work (Bladin and McCrory, 1995). Knee sprains amongst snowboarders have been reported in 14%-17% of injured cases (Abu-Laban, 1991; Warne, 1995).

In the Australian Snowboard Injury Database, ankle injuries were more common amongst snowboarders wearing soft shell boots; these soft boots are typically worn by intermediate and advanced riders. Knee injuries and distal tibial fractures, on the other hand, were more common in snowboarders who wore hard shell boots, the type of boot favoured by novices (Bladin et al, 1993). Falls, often with a torsional movement component, are the most common mechanism of injury (Bladin et al, 1993). Only one injury was reported from a collision between a skier and snowboarder (Bladin et al, 1993, Biasca et al, 1995).

Another comparative study (Abu-Laban, 1991) found injured snowboarders were less likely than alpine skiers to have lacerations (0% versus 8%, respectively), boot-top contusions (0% versus 4%), thumb injuries (1% versus 10%) and knee sprains (14% versus 27%). Unfortunately, they were more likely to have spinal injuries (12% versus 4%), foot or ankle injuries (28% versus 5%) and distal radius fractures (10% versus 1 %). Most lower limb injuries occurred on the left side, presumably because snowboarders use a left-foot lead on the board. Like other studies, injured snowboarders were found to be

predominantly male and novices, and most reported being skiers as well. Seven per cent reported alcohol consumption before their injury (Abu-Laban, 1991).

In contrast to alpine skiing, where injuries to the knee and thumb are most common, the wrist (and forearm) and ankle are the most frequently injured body regions for snowboarders. Wrist injuries account for 27% of all injuries to snowboarders (Oberthaler et al, 1995). Distal radius fractures have been reported as accounting for 19% of all snowboarding injuries and 45% of all upper limb injuries (Janes and Fincken, 1993). In a European study, fractures of the distal radius accounted for 39% of all wrist injuries (Oberthaler et al, 1995)

Attention has also been drawn to an unusual injury - a fracture of the lateral process of the talus (McCrary and Bladin, 1996). This fracture is significant because it may be missed on routine X-rays and misdiagnosed as a severe ankle sprain, with subsequent delay in definitive treatment. If not managed correctly, there is the potential for complications such as non-union, malalignment and osteoarthritis (Nicholas et al, 1994; Bladin and McCrary, 1995; McCrary and Bladin, 1996).

The US Consumer Product Safety Commission (CPSC) has released statistics that showed a 42% increase in snowboarding injuries from 19,000 in 1993 to 27,000 in 1994. More than half of these injuries occurred in 15-24 year olds. Risk factors are considered to be a lack of skill or instruction for novices and high risk behaviour, and most injuries resulted from falls rather than collisions.

A number of European studies have been reported in the non-English literature. Based on their English abstracts, these studies describe similar injury patterns to those described above (Berghold and Seidl, 1991; Binet et al, 1994; Zollinger et al, 1994; Biasca et al, 1995; Oberthaler et al, 1995; Bjornstig and Bjornstig, 1996).

5. SNOWBOARDING EQUIPMENT

Snowboarding equipment differs from that of both alpine and cross-country skiing. A snowboard is a single board that is shorter and heavier than a ski, and resembles a small surfboard in shape (Victorian Ski Association, 1995). Whilst general construction of the snowboard is like a ski, it has two bindings for the feet so that the feet are placed at an angle across the board. The majority of snowboard bindings are designed to be non-release. It is not possible for the board to exert as much torque on an individual limb as in skiing, which is the commonest cause of lower limb injuries. Snowboarding boots allow increased flexibility at the ankle, and falls therefore tend to be in an anterior-posterior direction.

Unlike skiers, snowboarders do not hold ski poles. This may result in more falls to an outstretched arm and explain the relatively greater proportion of upper limb injuries and distal radius fractures and lower proportion of thumb injuries (Bladin and McCrory, 1995).

The technology of snowboarding equipment has progressed rapidly and snowboarders, like skiers, have a choice in equipment design. Changes in equipment are rapid and occurs as frequently as from season to season (Robinson, 1991). Readily accessible information on the Internet describes the range of equipment available (Australian Pro Ski Management, 1996). For example, there are boards specifically designed for certain styles such as freestyle, racing or half-pipe; and symmetrical or asymmetrically shaped snowboards.

The types of snowboarding boots fall into two categories (Bladin and McCrory, 1995):

Soft shell boots These are very popular and are typically made of soft leather or synthetic materials (eg 'Sorel' boots) with a stiff inner boot for ankle support. Half pipe boots are low-cut to enable greater movement and flexibility whereas free riding boots have more support and are higher cut (Australian Pro Ski Management, 1996). Moon boots, gym boots or hiking boots are occasionally worn by beginners. However, they do not provide stability to the lower limbs and are considered dangerous.

Hard shell boots These may be ski boots and, because they are interchangeable with skiing, they are often worn by beginners. Boots specifically for snowboarding are a recent development. They are typically either a modified ski boot (with a greater degree of ankle flex) or 'hybrid' boots with a hard shell base and a soft (synthetic or leather) upper portion that increases ankle flexibility.

Snowboard bindings are either:

Soft ('high back') a moulded plastic shell with a buckle system and extended Achilles support for use with soft shell boots.

Plate bindings a steel or plastic base plate with a heel and toe clip for hard shell boots.

All snowboard bindings are non-release. Ski boots can be used with plate bindings, which are particularly common on rental equipment, and allow participants to cross between the sports of skiing and snowboarding (Bladin and McCrory, 1995). Hard shell boots are designed for plate bindings and boots with a moderate degree of firmness can be used with the high back bindings (Victorian Ski Association, 1995).

6. AN INTRODUCTION TO INJURY COUNTERMEASURES FOR SNOWBOARDING

Injury 'countermeasures' are actions that can be taken to prevent or reduce the risk of injury. A number of researchers have described how countermeasures should be targeted at the different links in the chain of events leading to injury (Haddon, 1972; Ozanne-Smith and Vulcan, 1990; Watt and Finch, 1996). Such injury countermeasures can be equated with primary (pre-event), secondary (event) and tertiary (post-event) prevention in the chain of events associated with an injury.

Primary countermeasures, which act before the event to prevent the injury from occurring in the first place, may include:

- adequate supervision of young snowboarders
- adherence by snowboarders and other slope users to the safety and courtesy codes, the 'rules of the road'
- design features of snowboard parks or runs
- environmental factors (condition of ski slopes and marking or protection of natural obstacles, resort features or lifting equipment), grading of ski runs (green, blue and black) and run closure where necessary, design of ski runs and trails, prevention of congestion and overcrowded slopes
- equipment factors (snowboards, boots, bindings, eyewear, clothing, helmets)
- methods of falling
- pre-season conditioning and fitness programs and adequate warm ups
- separation of snowboarders and skiers
- ski patrollers and speed control measures
- snowboarder education programs
- snowboarding instruction and expertise of instructors
- use of safety equipment.

Kizer (1994) has provided a set of 15 tips or guidelines for making snowboarding and skiing safer. All of these are good examples of primary prevention countermeasures. Kizer's tips are (1994):

1. Before you ski or snowboard, find out what the snow conditions are.
2. Know your equipment. Make sure it fits.
3. Dress for the weather and your likely activity level.
4. Do not ski or board in deep powder unless you know how to.
5. Never ski or snowboard alone in deep powder.
6. When skiing on ice, make sure your edges are sharp and you know how to carve turns.

7. Don't ski or snowboard when you can't see, whether due to darkness or a snowstorm.
8. Stay on the main trails and groomed runs.
9. Avoid tree wells.
10. Pay close attention to warning and hazard signs, as well as special notices that may be posted at ticket booths or chair lifts.
11. In deep powder, always be on the lookout for avalanches or snow slides.
12. Be aware of the danger of hypothermia and frostbite.
13. Do not ski or shred if you are under the influence of alcohol or any other drug.
14. Be attuned to your body. Don't ski or shred when you are tired. Get conditioned.
15. Use common sense and be 'snow smart'. Do not overestimate your skill.

These basic principles of snow safety, amongst others, are also promoted by organisations such as the Victorian Ski Association (1995).

Secondary countermeasures act during the incident/event and either prevent the injury from occurring or reduce the severity of the resultant injury. They include:

- condition of ski slopes and environmental factors
- conduct and safety codes and speed control
- general sports equipment (snowboard, binding and boot design)
- protective equipment (wrist guards, helmets, eyewear, use of leg ropes).

Tertiary countermeasures act after the injury chain of events leading to injury and help to minimise the consequences of injury. They include:

- availability of first aid equipment
- Ski Patrol assessment, treatment and transport
- access to medical care
- Rest, Ice, Compression, Elevation, Referral of injuries
- adequate treatment and rehabilitation of injuries before resumption of snowboarding.

Unfortunately, demonstrating the effectiveness of injury prevention countermeasures for snowboarding has not kept pace with the popularity of the sport. Many countermeasures, particularly those relating to general snow safety have been translated from skiing, and rightly so. However, few countermeasures specific for snowboarding have been formally demonstrated to actually prevent injury.

The countermeasures to which some attention has been paid are boots, bindings, wrist guards, skill level and methods of falling. Boots and bindings are particularly relevant to lower limb injuries and wrist guards (and falling techniques) to wrist fractures, sprains and

other upper limb injuries. Skill level and the other injury countermeasures apply more generally across the sport.

A limited number of studies have evaluated the effectiveness of countermeasures for preventing snowboarding injuries. Support for these countermeasures is generally in the form of anecdotal evidence or informed opinion. Other studies have concluded that a particular countermeasure would be effective on the basis of an examination of injury trend or descriptive epidemiological data only. Neither of these types of 'evidence' can be considered to be a formal or controlled evaluation of the efficacy of the proposed countermeasures. For example, the large frequency of wrist fractures/sprains amongst snowboarders has prompted the recommendation that wristguards be worn. However, there has yet to be any evaluation of the effectiveness of wristguards for preventing these snowboarding injuries, and their use may increase the potential for injuries higher up the arm.

In the following section, the literature describing the use of some of the major countermeasures is described in detail. There are a number of methodological problems associated with much of the published snowboarding injury prevention research. These include study design, the difficulty of obtaining denominator population data and the lack of specificity in relation to equipment used. For example, it has been noted that an accurate method for determining the number of snowboarders at a resort over a specific period would improve the accuracy of injury rates (Abu-Laban, 1991). Abu-Laban (1991) recognised that specific information about speed, type of boot, foot position and injury mechanisms in his comparative study on injuries in snowboarders and alpine skiers would have strengthened the study results.

The studies that have provided the evidence for the effectiveness of wristguards, nonreleasable snowboard bindings and soft-shell boots (particularly for novices) are discussed in Section 7 and summarised in the Appendices. These studies provide either anecdotal evidence/informed opinion or data based evidence to support these claims. To date, however, there has been no formal evaluation of any of these countermeasures for preventing snowboarding injuries.

7. SUMMARY OF THE STRENGTH OF THE EVIDENCE FOR THE EFFECTIVENESS OF SNOWBOARD INJURY COUNTERMEASURES

7.1 WRISTGUARDS

The absence of ski poles and the fixed position of the feet in snowboarding means that the upper limbs absorb most of the impact of a fall (Bladin and McCrory, 1995). This is particularly so when the snowboarder is making a turn facing the slope. Injury commonly occurs as a result of falling onto outstretched arms with hyperextension of the wrist. Novice riders, who have not had the time to perfect their technique, are more prone to falling. Snowboarders do not use ski poles and the absence of these during a fall may explain the reduced frequency of 'skier's thumb' injuries (Abu-Laban, 1991).

An overview of snowboarding injury patterns (Bladin and McCrory, 1995) found that novice riders also experience more upper limb fractures, particularly to the wrist and forearm, than experienced snowboarders (13% of beginners' injuries). This review also reported that many instructors are now teaching beginners to fall with their hands clenched in a fist to attempt to avoid wrist injuries (Bladin and McCrory, 1995). As an injury prevention measure this practice has not been evaluated.

Two studies have presented detailed information about wrist injuries in snowboarding (Shealy, 1993; Calle and Evans, 1995). These are summarised in Appendix 1. The study by Shealy (1993) obtained descriptive epidemiological data of snowboarding injuries over 2 ski seasons from 15 areas in the USA. During this period there was a total of 1194 snowboard injuries of which 20% were to the wrist. Wrist injuries were also common amongst snowboarders in a study in Vermont (Calle and Evans, 1995). This study conducted a review of injuries sustained by 487 snowboarders over the 1991-93 winter seasons in Vermont and 565 injury cases in snowboarders nationally. Of the 144 fractures in the Vermont survey, 63 (44%) were wrist fractures, and in the national survey, 72 of the 209 fractures (34%) were wrist fractures. None of the injured snowboarders wore protective equipment. On the basis of descriptive epidemiology, these two studies have concluded that protective equipment for the wrist area should be worn.

The protection of the hand and wrist for snowboarders has also been recommended by a number of authors (Campbell et al, 1993; Biasca et al, 1995). Bjornstig and Bjornstig (1996) argue for waterproof gloves with reinforcement protecting the hand and wrist. An overview of snowboard injuries has recently reported that snowboard glove manufacturers have started producing gloves with wrist reinforcement, as a means of preventing wrist injuries (Bladin and McCrory, 1995). However, no formal evaluation studies or testing of these devices was identified in support of the effectiveness of these as countermeasures.

Wristguards have been suggested as a countermeasure for preventing wrist injuries but without formal evaluation of their effectiveness. They are designed to protect the wrist against sudden, forceful extension and contact with hard surfaces, as occur during a fall with outstretched arms (Scheiber and Branche-Dorsey, 1995). Some researchers have cautioned the use of wrist guards as a countermeasure for wrist injuries, lest they introduce other injuries occurring higher up the forearm, arm or shoulder (Shealy, 1993). The potential for wristguards to lead to other injuries such as fractures of the metacarpal or carpal bones also needs consideration before they are widely promoted.

The mechanism and frequency of wrist fracture injury in snowboarders is not dissimilar to that amongst in-line skaters and skateboarders (Scheiber and Branche-Dorsey, 1995). In both cases, the injury commonly occurs because of a fall on outstretched arms. It has been suggested that wristguards would be effective for preventing in-line skating and skateboarding wrist injuries (Banas et al, 1992; Scheiber and Branche-Dorsey, 1995; Heller et al, 1996). However, wristguards for these sports have not been fully evaluated. The preliminary results of a case-control study of injured in-line skaters being undertaken in the USA suggests that wristguards almost completely protect against lacerations, sprains and strains (Scheiber and Branche-Dorsey, 1995). Furthermore, the overall odd of a wrist injury occurring was reduced by more than 6-fold if wristguards were worn.

If snowboarders, like in-line skaters, are to be encouraged to wear wrist guards, it is important to know whether they will actually do what they were designed to do, that is, prevent wrist injuries. It would also be important to compare different types of wristguards to determine which style is most effective in preventing or reducing wrist injuries. Further research into the protective and unwanted effects of wristguards for snowboarders is clearly warranted.

7.1.1 Recommendations for research, development and implementation

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- Further detailed study of the nature and severity of snowboarding injuries is warranted with particular attention to wrist and forearm injuries. This information has the most potential for influencing the rate of injury, improved equipment design and new countermeasure development.
- Determine the current levels of protective equipment usage by snowboarders, particularly wristguards. This could be achieved by observational surveys-
- Determine current attitudes about, and barriers to, the use of wristguards in a cross-section of snowboarders.
- The effectiveness of wristguards for preventing wrist injuries needs to be evaluated as a matter of priority. This type of protective equipment is widely promoted. Its potential to increase fractures and other injuries further up the forearm, arm and shoulder needs to be examined in any evaluation. There may be other unwanted effects of wristguards that should also be explored.

7.2 FALL TECHNIQUE

Falls, often with a torsional component, are the main mode of snowboarding injury. Instruction in falling techniques has been suggested as an important countermeasure (Campbell et al, 1993; Bladin and McCrory, 1995).

Many snowboarders are also skiers and would be generally familiar with alpine conditions. Injured novice snowboarders, however, may exceed their limits of skill by snowboarding on slopes beyond their ability even though they may have felt comfortable on these slopes with skis (Abu-Laban, 1991). Lessons are recommended to develop proper technique and to introduce the general principles of slope safety that may reduce injuries to the self or others.

There have been no studies aimed at evaluating the impact of improved fall techniques or lessons as a snowboarding countermeasure.

7.2.1 Recommendations for research, development and implementation

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- The role of specific snowboarder training and lessons (particularly with regard to falling technique) should be explored.
- Determine the extent to which snowboarders undertake specific lessons in snowboarding and falling techniques before they participate in the sport-
- Develop education programs or lessons to teach snowboarders about correct falling and snowboarding techniques.

7.3 BINDINGS AND BOOTS

Snowboard bindings in common use are currently non-releasable, but releasable bindings have been developed. The non-releasable nature of bindings may account for the relatively fewer lacerations in snowboarding compared to skiing (Abu-Laban, 1991). This is because they would prevent the limbs coming into contact with the snowboard edges. A move towards the introduction of releasable bindings has been questioned in terms of their potential to introduce other injuries into the sport, particularly lower limb rotational injuries (Janes and Fincken, 1993; Bladin and McCrory, 1995). Another concern is that a board released during riding, which is attached to the rider by a rope, may remain in motion and cause injury to the rider or others. The use of a braking device, if releasable bindings are popularised, can be a substitute for a leg rope (Shealy and Sundman, 1989). Bjornstig and Bjornstig (1996) argue for the introduction of release mechanisms into the bindings. Appendix 2 summarises the data-based evidence suggesting that releasable bindings may aggravate injury.

Recently, a step-in boot/binding system, like that for skiing, has been introduced into snowboarding. It is too early to have reliable statistics about the role, if any, that this system has on injuries. It is essential to continue monitoring the injury trends over time to improve this information.

A further factor relevant to the type of bindings is the potential for it to limit the riding style (Bladin and McCrory, 1995). Being able to achieve extremes of movement and positioning with the board is one of the aspects of this sports which make it attractive, particularly to young riders. Releasable bindings would limit this range of movement because the potential for sudden release would make these manoeuvres very dangerous.

Suggestions have been made about the type of boot and bindings that should be worn on the basis of the nature of injuries (knee or ankle) that are associated with each (Bladin et al, 1993; Bladin and McCrory, 1995). It is important to consider this question carefully in relation to the severity and long term consequences of the injuries. Moreover, the implications of the potential for transferring the injury site from one area of the body to another, eg from knee to ankle or visa versa, needs to be considered.

A summary of the data-based studies that have considered the type of boot is summarised in Appendix 3. These studies suggest that novices should use soft-shell boots with a stiff

inner liner. However, there have been no formal evaluations of injury outcome with the different types of boots. Controlled studies are required to resolve these issues.

7.3.1 Recommendations for research, development and implementation

- Further detailed study of the nature and severity of snowboarding injuries is warranted with particular attention to knee and ankle injuries. This information has the most potential for influencing the rate of injury, improved equipment design and new countermeasure development.
- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- The effects of different types of equipment design (particularly the boots and bindings) on snowboarding injuries need to be fully evaluated in a controlled way. This also needs to keep pace with the rapid development of new snowboarding equipment, with new equipment being demonstrated to be 'safe'.
- The relative risks of injuries should be determined overall for those snowboarders wearing boots of varying stiffness in future studies, not only among injured snowboarders.
- Develop a Standard for snowboarding equipment that will 'guide' future design directions.
- Encourage snowboarders to maintain their equipment in good order.
- Ensure that rental equipment is properly fitted and adjusted by means of an accreditation scheme for hirers.

7.4 SPEED AND ENVIRONMENT CONTROL

It has been suggested that the lower rate of femoral fractures observed in snowboarders, compared to skiers, may be due to lower speeds (Abu-Laban, 1991). Environmental factors such as icy conditions, lack of slope grooming, presence of moguls and low skill level have also been suggested as risk factors for injury (Bladin et al, 1993). There have been no studies to formally support these observations, although they are supported by informed opinion.

7.4.1 Recommendations for research, development and implementation

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- Ensure that snowboarders are well aware of, and adhere to, general snow conduct and safety codes.

7.5 SEPARATION OF SNOWBOARDERS AND SKIERS

The separation of snowboarders from skiers is an approach taken by some overseas resorts. However, it is not generally the policy of Australian resorts (Alpine Safety Conference, 1995; Pelly, 1995). Separation is not generally favoured by the ski patrollers whose preference is to encourage understanding and cooperation amongst the various resort users.

The Ski Patrol Association is also introducing more ski patrollers to snowboarding as a means of transport on the mountain slopes.

An Australian study (Bladin et al, 1993) found that only one of 276 snowboarding injuries was reported as a collision between a snowboarder and a skier. A study from the University of Salzburg also could not find evidence of an increase in on-course collisions with increasing numbers of snowboarders (Berghold and Seidl, 1991). This suggests that snowboarder-skier collisions may not be a major cause of injury.

7.5.1 Recommendations for research, development and implementation

- Continue to give high priority to the design and maintenance of snowboard parks and runs.
- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury.

7.6 OTHER COUNTERMEASURES

Based on a case review at the Innsbruck trauma centre, Gabl et al (1991) concluded that attention needed to be directed towards educating snowboarders in proper technique.

A lack of appropriate technical, or properly tested equipment, was considered to be a major factor in injury causation in another study (Biasca et al, 1995). Rental equipment should be properly fitted and adjusted (Bladin et al, 1993; Bladin and McCrory, 1995). Snowboarders should choose their equipment carefully to suit their skill level and size (Australian Pro Ski Management, 1996). They should also not ride on slopes beyond their ability (Victorian Ski Association, 1995).

Retention systems are another important aspect of snowboarding safety, largely for preventing injury to others. Snowboards should be attached to the user by a leash to prevent injury to others on slopes (Robinson, 1991; Victorian Ski Association, 1995). Retention devices also ensure that the board does not 'run away' when it is not in use (Victorian Ski Association, 1995).

Other countermeasures relevant to injuries resulting from falls are the use of helmets and padding to reduce the impact during fall injuries (Pino and Colville, 1989; Campbell et al, 1993).

Appropriate clothing is an important aspect of snowboarding, both for 'image' and safety. Clothing should be both waterproof and breathable (Australian Pro Ski Management, 1996). Clothing that is a little baggy allows for ease of movement. Head covering should be used to prevent too much heat loss from the head.

Because the hands frequently come in contact with the snow, waterproof gloves should be worn (Victorian Ski Association, 1995; Australian Pro Ski Management, 1996; Bjornstig and Bjornstig, 1996)

7.6.1 Recommendations for research, development and implementation

Based on the literature review presented in this report and discussion with ski industry representatives, the following general recommendations for activities to reduce the occurrence and severity of snowboarding injuries in the future can be made. It is

recognised that some of these are long term goals but a number of these activities should be undertaken immediately. Improved and ongoing snowboard injury statistics are needed to inform the development of countermeasures and for their evaluation

- Conduct further epidemiological and biomechanical research into the mechanisms of snowboarding injury. Both approaches should be explored to provide information to guide countermeasure development.
- The effects of different types of equipment design on snowboarding injuries need to be fully evaluated in a controlled way. This also needs to keep pace with the rapid development of new snowboarding equipment, with new equipment being demonstrated to be 'safe'.
- Develop an education program to inform snowboarders about the need to be well prepared for snowboarding.
- Ensure that young snowboarders are fully supervised.
- Ensure that injured snowboarders receive adequate treatment and rehabilitation of injuries before resumption of snowboarding.
- Continue to promote the presence of ski patrollers as a major feature of snow safety programs.

8. RECOMMENDATIONS FOR IMPROVED DATA COLLECTIONS

Although not directly relevant to preventing snowboarding injuries, there is also a need to improve data collections. Injury data collections are useful for identifying emerging injury trends, for ongoing monitoring of injury patterns and for evaluating the effectiveness of countermeasures. The following recommendations are based on the data limitations noted in this review, as well as discussions with ski industry representatives-

- Establish a 'snowboarder' category of 'resort user' as an integral component of routine alpine injury data collections (eg Ski Patrol Injury Report forms).
- Data collections should collect information about specific equipment used by the injured snowboarders (eg type of boots) and the injury countermeasures (eg wristguards used).
- Injury data collections should routinely collect information about the mechanisms of snowboarding injury-
- Maintain ongoing injury surveillance in relation to snowboarding injuries. In Australia, the Australian Snowboard Injury Database should be maintained. Given the rapid pace at which new snowboarding equipment is introduced, the maintenance of ongoing injury surveillance is crucial.
- Where possible, data collection should conform to the requirements of injury surveillance standards and/or minimum data sets (eg the National Data Standards for Injury Surveillance). As sports injury versions are developed, the data should conform with these.

9. CONCLUSIONS

Snowboarding is quickly becoming a popular sport. General guidelines for snowboarding safety are available and are similar to the recommendations for general snow/ski safety. However, there has been little work done on formally evaluating injury countermeasures specifically for snowboarding such as snowboard bindings, boots and wrist guards and improved snowboarding techniques. This is an area that warrants immediate attention.

Some information about snowboarding statistics is available, (eg from the Australian Snowboarding Injury Database) and these data collections will continue to be valuable resources for injury prevention research.

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APPENDIX 1

THE EVIDENCE FOR WRISTGUARDS

Anecdotal/Informed opinion	Data-based evidence	Article reference
<p>Wrist support for snowboarders is an option that should be explored to try to reduce the high incidence of wrist fractures. Caution is needed, however, so that another injury such as a fracture of the forearm is not introduced. Wrist fractures in youth who have not finished their growth are potentially serious injuries, and can result in interrupted bone growth.</p> <p>Results: Wrist injuries comprised 20.2% of snowboarding injuries, but only 2.8% of downhill skiing injuries.</p>	<p>A study of downhill and snowboarding injuries over 2 ski seasons from 15 areas in the USA. Compared were 21817 downhill and 1194 snowboard injuries (with 2318 and 255 controls respectively).</p>	Shealy (1993)
<p>To reduce the number of injuries, all snowboarders should wear protective wrist and upper extremity pads.</p> <p>Results: None of the injured snowboarders wore protective equipment. Of the 144 fractures in the Vermont survey, 63 (43.8%) were wrist fractures, and in the national survey, 72 of the 209 fractures (34.4%) were wrist fractures.</p>	<p>A review of injuries sustained by 487 snowboarders over the 1991-93 winter seasons in Vermont and 565 injury cases in snowboarders nationally.</p>	Calle and Evans (1995)

APPENDIX 2

THE EVIDENCE AGAINST RELEASABLE SNOWBOARD BINDINGS

Anecdotal/Informed opinion	Data-based evidence	Article reference
<p>Non-release of bindings is beneficial for the prevention of lower limb injuries because it prevents rotational injury.</p> <p>Falls tend to be in an anterior-posterior direction in relation to the leg.</p> <p>Results: Rotational injuries, when they do occur, are less concentrated at the knee and less severe when compared to those in skiing. Releasable bindings are not recommended because of the risk of rotational injuries, and sudden release during the extreme positions of freestyle activities could be dangerous or limit this popular part of the sport.</p>	<p>An overview of snowboarding injury patterns, equipment, demographics, and a particular type of fracture "snowboarders ankle" (ie, a fracture of the lateral process of the talus), relationship of injuries to footwear and bindings.</p>	<p>Bladin and McCrory (1995)</p>
<p>Releasable bindings for snowboarders may present other problems, or change the pattern of injuries with an increased risk of other types of injuries.</p> <p>Results: Concerns are expressed about the recent development of a releasable binding because the snowboard may then act as a fulcrum for a rotational injury, the snowboard still attached to the rider may be dangerous to the rider and others, and sudden release during extreme freestyle manoeuvres may be dangerous.</p>	<p>A 4 year prospective epidemiological study from 1989-92 at 3 major Victorian resorts. Incidence and patterns of snowboarding injuries are presented, particularly in relation to footwear and level of skill. Ski injury data were collected for the same period.</p>	<p>Bladin et al (1993)</p>

APPENDIX 3

THE EVIDENCE FOR SNOWBOARD BOOT DESIGN

Anecdotal/Informed opinion	Data-based evidence	Article reference
	<p>An overview of snowboarding injury patterns, equipment, demographics, and a particular type of fracture "snowboarders ankle" (ie, a fracture of the lateral process of the talus), relationship of injuries to footwear.</p>	Bladin and McCrooy (1995)
<p>Results: Ankle injuries are more common in snowboarders wearing soft shell boots (the type of boot worn in 70% of ankle injuries). Knee injuries and fractures of the distal tibia ("boot top" fractures) are significantly more common in snowboarders wearing hardshell rather than softshell boots. Hardshell boots are more commonly worn by beginners, and rental shops encourage their use, as such shops prefer to use plate bindings. Because a knee injury is potentially more devastating than an ankle injury, and most ankle injuries (80%) are ankle sprains, it is recommended that beginners use a soft shell boot with a stiff inner boot for ankle support.</p>		
<p>To prevent injury, novices should use "hybrid" or soft shell boots and take lessons.</p>	<p>A 4 year prospective epidemiological study from 1989-92 at 3 major Victorian resorts. Incidence and patterns of snowboarding injuries are presented, particularly in relation to footwear and level of skill. Ski injury data were collected for the same period.</p>	Bladin et al (1993)
<p>Results: Ankle injuries are more common with soft shell boots (which are more commonly worn by intermediate and advance riders). Knee injuries and distal tibial fractures are more common with hard shell boots (that are mostly worn by novices).</p>		
<p>The solution to ankle injuries in snowboarders does not lie in stiffer boots as they exist at present. If the numbers of snowboarders using stiffer boots increases, the number of knee injuries is also likely to increase.</p>	<p>A study downhill and snowboarding injuries over 2 ski seasons from 15 areas in the USA. Compared were 21817 downhill and 1194 snowboard injuries (with 2318 and 255 controls respectively).</p>	Shealy (1993)
<p>Results: Information on boot stiffness was available in the case of 683 of the injured snowboarders, and 47 of the 683 (6.9%) used a boot with a stiff upper shaft. The incidence of ankle injuries in the 47 injured snowboarders using stiffer boots was 21.3% and that of knee injuries was 25.5%. The incidence of ankle injuries in the 636 injured snowboarders using softer boots was 23.8% and that of knee injuries was only 16.5%. The difference between the rate of knee injuries in the two groups was not significant at the 0.05 level (P-value 0.07). The authors acknowledge that the higher number of knee injuries in users of hard boots is a concern. The numbers for this category was small, and if the sample size was larger a statistically significant difference may become apparent.</p>		

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