SYSTEMATIC REVIEW

An international review of head and spinal cord injuries in alpine skiing and snowboarding

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Background: Alpine skiing and snowboarding are popular winter activities worldwide, enjoyed by participants of all ages and skill levels. There is some evidence that the incidence of traumatic brain injury (TBI) and spinal cord injury (SCI) in these activities may be increasing. These injuries can cause death or severe debilitation, both physically and emotionally, and also result in enormous financial burden to society. Indeed, TBI is the leading cause of death and catastrophic injury in the skiing and snowboarding population. Furthermore, there are severe limitations to therapeutic interventions to restore neurological function after TBI and SCI, and thus the emphasis must be on prevention.

Objectives: (1) To examine the worldwide epidemiology of TBI and SCI in skiing and snowboarding; (2) to describe and examine the effectiveness of prevention strategies to reduce the incidence of TBI and SCI in skiing and snowboarding.

Search strategy: Searches were performed on a variety of databases to identify articles relevant to catastrophic central nervous system injury in skiing and snowboarding. The databases included PubMed, Medline, EMBASE, CDSR, ACP Journal Club, DARE, CCTR, SportDiscus, CINAHL, and Advanced Google searches.

Selection criteria and data collection: After initial prescreening, articles included in the review required epidemiological data on SCI, TBI, or both. Articles had to be directly associated with the topic of skiing and/or snowboarding and published between January 1990 and December 2004.

Results: 24 relevant articles, from 10 different countries, were identified. They indicate that the incidence of TBI and SCI in skiing and snowboarding is increasing. The increases coincide with the development and acceptance of acrobatic and high-speed activities on the mountains. There is evidence that helmets reduce the risk of head injury by 22–60%. Head injuries are the most common cause of death among skiers and snowboarders, and young male snowboarders are especially at risk of death from head injury.

Conclusions: There should be enhanced promotion of injury prevention that includes the use of helmets and emphasizes the skier's and snowboarder's responsibility code.

The winter sport of alpine skiing was developed about 100 years ago, and, currently, about 40 million alpine skiers venture to the 300 alpine resorts in the world's major mountain chains, in approximately 40 different countries.[1] Within the past decade, there has been great growth in snowboarding as well. In 2000, the Canadian Ski Council listed snowboarding as one of the fastest growing winter sports, with a 4% decrease in skiing attributed to a 21% increase in snowboarding (www.canadianskicouncil.org). New activities, with modifications in equipment, such as snowblading, are now popular on the mountains as well.

Alpine skiing and snowboarding are sports that involve high velocity and, recently, an increased propensity for participants to jump and perform acrobatic maneuvers, factors that may result in injury. Increased participation in jumping and acrobatics has led to a large number of brain and spinal cord injuries, and hence there is a need for participants, sports associations, facilities operators, and sports governing bodies to become more aware of the risks and dangers associated with these activities.[2–8]

We reviewed the literature on traumatic brain injury (TBI) and spinal cord injury (SCI) in alpine skiing and snowboarding. The objectives of the review were to: (1) examine the epidemiology of TBI and SCI in skiing and snowboarding; (2) describe and examine the effectiveness of prevention strategies to reduce the incidence of TBI and SCI in skiing and snowboarding. The review examines the responsibilities of alpine participants, sports associations, facilities operators, and sports governing bodies worldwide.

METHODS

Inclusion criteria

The articles included in the review had to be epidemiologically based and could be case–control, cohort, or cross-sectional studies. The types of study design included both retrospective and prospective analyses, some of which came from trauma registries and databases. In addition, two studies were included that used death certificates and coroners' reports for retrospective analysis. We also included retrospective reviews that provided independent analyses separate from the other included articles.

Search strategies

The following electronic databases were searched using standardized terms: the original search was performed with PubMed (performed December 2004), followed by updated searches in October 2006 in Medline (1966 to September Week 4 2006), EMBASE (1980 to 2006 Week 40), CDSR, ACP Journal Club, DARE, CCTR, SportDiscus, and CINAHL (1982 to October Week 1 2006). Brain and spinal cord injuries of all severities were included, and search terms and outputs are available upon

Abbreviations: SCI, spinal cord injury; TBI, traumatic brain injury request. In addition, Advanced Google searches were performed to locate conference proceedings and any additional websites.

Study selection and inclusion criteria

Articles were prescreened to determine their inclusion in the review. Articles had to be agreed upon by two reviewers (AA and CHT) and had to have one or more of the following MeSH headings: traumatic brain injury, spinal cord injury, head injury, CNS injury, winter sports, skiing, snowboarding. For inclusion in the review, the prescreened articles had to be on the topic of skiing, snowboarding, or both, and include epidemiological data on SCI, TBI, or both. Articles of all languages were included from the 15-year period of January 1990 to December 2004. We used a translator for the non-English articles to summarize their information. Lastly, with respect to the definition of TBI, we accepted all severities of injury, and thus concussion would have been included. However, it is acknowledged that the definition of head injury has changed during the last 10 years.[9] It is not known to what extent this change has affected the incidence data. Tables 1 and 2 contain summaries of the most informative of the 24 articles included.

Exclusion criteria

Excluded were case reports of TBI and SCI in skiing and snowboarding and studies that did not contain comprehensive epidemiological information on SCI and/or TBI.

RESULTS AND DISCUSSION

Search summary

From the 877 citations that were found, 51 were selected for citation in this review, and 24 met the inclusion criteria to be included in the epidemiological tables (tables 1 and 2). Of these 24 articles, 18 focused on TBI, 11 on SCI, and five on both SCI and TBI in skiing and/or snowboarding. Six were restricted to skiing, four were restricted to snowboarding, and 14 included both. One article included skiing, snowboarding, and snowblading.

Epidemiology of skiing and snowboarding injuries

The overall incidence of injuries of all types while skiing or snowboarding is relatively low.[10] For example, a review by Koehle *et al*[11] suggested that the overall injury rate for all types of skiing injuries declined from five to eight injuries per 1000 skier days in the 1970s, to the current rate of two to three injuries per 1000 skier days. This major reduction was attributed primarily to the improvement in equipment.

Levy *et al*[12] observed that, in the USA, snowboarders were more likely than skiers to sustain all types of injury (odds ratio 1.66:1; 95% CI 1.00 to 2.76; $p = 0.05$). A Norwegian report showed that snowboarders are 3–4 times more likely than skiers to incur all types of injury, and that these occur in a younger population.[13] Hagel *et al*[14] reported that, after adjustment for age, sex, and calendar year, snowboarders in Canada were 50% (95% CI 1.3 to 1.8) more likely to have head and neck injury than alpine skiers.

Risk factors for skiers and snowboarders

Traumatic brain injury

In both skiing and snowboarding, the leading cause of death and catastrophic injury is TBI.[12,15] Although head injuries comprise only 3–15% of all injuries in skiers and snowboarders, it appears that the incidence of TBI is increasing.[6,11–13,16–19] The risk of a ski fatality is estimated at 0.5–1.96 per million skier visits, with most deaths attributed to massive head, neck, or thoracoabdominal injury.[20] The review by Levy *et al*[12] estimated that TBI accounted for 50–88% of the fatalities seen at various ski resorts. The denominator data used to report head injury have varied in the literature. A study conducted between 1980 and 2001 in Colorado, USA reported that skiing death rates ranged from 0.53 to 1.88 per million skier visits, with a rising trend over the 21 ski seasons. In addition, they reported that 42.5% of these deaths resulted from TBI, and that this number increased to 67% in children.[21,22]

Levy *et al* reported 16 deaths among 1214 injured skiers and snowboarders (1.3%) admitted to a level I trauma center in Colorado, where TBI was the cause of death in 87.5% of those cases. Furthermore, of the 1214 patients, 28.8% had TBI; they had an average age of 26.9 years. Skiers and snowboarders under the age of 35 were 3 times more likely to sustain a head injury than older participants, and male skiers and snowboarders were 2.2 times more likely than their female counterparts to sustain a head injury.[12] Although most injuries were concussions (69.4%), 14.3% of these patients had various types of more serious brain injury.[12] Another report by Levy and Smith[19] showed that head injuries accounted for 28.0% of all injuries in skiers compared with 33.5% in snowboarders.

A prospective study of head injuries in skiers and snowboarders in Niigata, Japan between 1994 and 1999 reported that snowboard-related head injuries occurred at a rate of 6.33 per 100 000 snowboarder days, compared with a rate in skiers of 1.03.[17] The average age of the snowboarders was 3.6 years younger than that of skiers (22.2 and 25.8, respectively), and injuries to males were also more prevalent in the snowboard group (63% of all snowboard injuries were in males; 51% of all ski injuries were in males).[17]

Nakaguchi *et al*[23] reported the results of a prospective study on head injury in skiing and snowboarding in Chino, Nagano, Japan for the years 1995–1997. They found an incidence of head injury of 6.5 per 100 000 visits for snowboarders, compared with 3.8 per 100 000 visits for skiers. They also reported that beginner snowboarders were more likely to suffer head injuries and had a much higher incidence of severe head injuries than beginner skiers.

In 1996, Macnab and Cadman[24] reported the epidemiology of skiing and snowboarding injuries for Blackcomb Mountain, in British Columbia, Canada. They used ski patrol injury reports, and found that head and face injuries constituted 22% and 17%, respectively, of all injuries, and, of these injuries, 22% were serious enough to cause loss of consciousness. Ski days of high school outings were associated with a 25% higher likelihood of injury than outings involving participants aged 18 or older.

Another study, using ski and snowboarding injury statistics from the British Columbia Trauma Registry, reported head injury rates in skiers and snowboarders of 0.005 and 0.004 per 1000 participants, respectively. Although skiers had a greater proportion of concussions than snowboarders (60% vs 21%), snowboarders had a much higher proportion of more severe brain injuries (29% vs 15%).[25]

In a study of snow sport injuries in eastern Canada from Mt Tremblant, Quebec, concussions represented 11% of all injuries, and most head injuries (83%) were concussions.[26] Concussions represented 9.6% of all injuries in skiers, 14.7% of injuries in snowboarders, and 5.7% in snowbladers. Those with neck injuries also experienced significantly more concussions than those without, and there was no increase in neck injury in participants wearing a helmet. Most concussions occurred after 2–5 h of activity in intermediate participants and in those who had not had a lesson, as well as those who were skiing recreationally rather than competing. Moreover, the risk of sustaining a concussion on ungroomed and rough snow was 2.5 times greater than for soft snow. Male participants were more likely to sustain a head injury than female participants,

Table 1 Summary of epidemiology of head injuries in skiing and snowboarding: 1990–2004

Reference	Date of publication	Study design	Location	Activity*	Mechanism of injury†	Age (years)‡	Gender data	Most relevant statistic¶
Xiang *et al*[22]	2004	Retrospective study	Colorado, USA	Skiing	2/3 of all deaths were collisions	7–17	N/A	67% of all skier deaths in children resulted from TBI
Ambach *et al*[3]	1992	Retrospective study	Innsbruck, Austria	Skiing	N/A	N/A	N/A	Head injury is the most common cause of death from 1987–1990, in the 20–35 age group
Genelin *et al*[32]	1994	Retrospective study	Innsbruck, Austria	Both	Increasing speed and increasing deceleration	N/A	N/A	From 1982–1992 there was an increasing incidence of head injuries
Heim *et al*[4]	1993	Retrospective study	Davos, SUI	Both	N/A	N/A	N/A	Injuries are increasing, but head injuries are the same %, at 3–5%, of all injuries from 1974 to 1993
Hagel *et al*[14]	2004	Retrospective survey	Quebec, Canada	Both	Most common mechanisms for both was falls/jumps, 7% collisions	N/A	M 1671 injuries F 1141 injuries	Rate of head and neck injuries is 50% higher in snowboarders than in skiers
Xiang & Stallones[21]	2003	Retrospective study (death certificates)	Colorado, USA	Skiing	65% collisions with other skiers or stationary objects	32	M 81% F 19%	42.5% of skier deaths were due to head trauma
Bridges *et al*[26]	2003	Prospective study	Quebec, Canada	Both and snowblading	Snowboarders: 21% snowparks, 17.6% jumps	N/A	N/A	Concussions represented 9.6% of all injuries in skiers, 14.7% in snowboarders, and 5.7% in snowbladers
Levy *et al*[12]	2002	Retrospective study (trauma registry)	Colorado, USA	Both	61% collisions 37% falls	Snowboarders 21.5 Skiers 27.8	M 272 F 78	87.5% of all skiing and snowboarding deaths were head injuries
Nakaguchi & Tsutsumi[40]	2002	Prospective study	Nagano, Japan	Snowboarding	58% falls 21% jumping 21% collisions	24	M 30 injuries F 8 injuries	Predominant features of snowboarding head injuries included: falling backwards (68% of injuries), occipital impact (66% of injuries), and on a gentle or moderate ski slope (76% of injuries)
Hentschel *et al*[25]	2001	Retrospective study (trauma registry)	BC, Canada	Both	Most common mechanism for both was falls	Snowboarders 22 Skiers 32	N/A	Head injury rate in skiers was 0.005 per 1000 participants Head injury rate in snowboarders was 0.004 per 1000 participants Snowboarders had a higher rate of severe brain injury
Fukuda *et al*[17]	2001	Prospective study	Nigita, Japan	Both	Falls most common in both jumps: 30% snowboarders 2.5% skiers	Snowboarders 22.2 Skiers 25.8	M snowboarders 63% F snowboarders 37% M skiers 51%	6.33 head injuries per 100 000 snowboarder days 1.03 head injuries per 100 000 skier days Snowboarder head injury rate was 6.1 times higher than skier head injury rate
Levy & Smith[19]	2000	Retrospective review	Colorado, USA	Both	N/A	N/A	N/A	Head injuries accounted for 28.0% of all injuries in skiers compared with 33.5% in snowboarders

Table 1 Continued

Reference	Date of publication	Study design	Location	Activity*	Mechanism of injury†	Age (years)‡	Gender data	Most relevant statistic¶
Nakaguchi *et al*[23]	1999	Prospective study	Nagano, Japan	Both	Snowboarders had higher rates of falls when jumping	Snowboarders 23 Skiers 23	M snowboarders 103 F snowboarders 40 M skiers 94 F skiers 64	6.5 head injuries per 100 000 snowboarder days 3.8 head injuries per 100 000 skier days
Young & Niedfeltd[8]	1999	Retrospective analysis	Wisconsin, USA	Snowboarding	N/A	N/A	N/A	9.2% of all snowboarding injuries are to the head
Deibert *et al*[6]	1998	Retrospective analysis (database)	Vermont, USA	Skiing	N/A	Adolescents	N/A	Incidence of head injuries increased from 5.7% to 8.9% Frequency of concussions increased from 2.8% to 4.8% (comparing 1986–87 and 1993–94 ski seasons)
Macnab & Cadman[24]	1996	Prospective study	BC, Canada	Both	Wearing helmets: 48% falls, 10% collisions No helmets: 29% falls, 20% collisions	N/A	N/A	Head injuries accounted for 22% of all injuries Face injuries accounted for 17% of all injuries
Furrer *et al*[18]	1995	Retrospective analysis	Interlaken, Switzerland	Skiing	66% falls	N/A	N/A	The number of most severe head injuries from 1984 to 1992 increased from 11.6% to 19.3%
Myles *et al*[15]	1992	Retrospective analysis (coroner's office)	Alberta, Canada	Skiing	48% falls 27% collisions	23.8	Ratio M/F, 3:1	TBI involved in 88 of 145 deaths

*Skiing, snowboarding, or both.
†Falls, jumps, or collisions. Collision percentages were the sum of all types of collisions (including skier and object collisions).
‡Average or total number injured.
¶Incidence, prevalence, increased risk %.
F, female; M, male; N/A, not available; TBI, traumatic brain injury.

Table 2 Summary of epidemiology of spinal cord injury in skiing and snowboarding: 1990–2004

Reference	Date of publication	Study design	Location	Activity *	Mechanism of injury†	Age (years)‡	Gender data	Most relevant statistic¶
Heim *et al*[4]	1993	Retrospective study	Davos, Switzerland	Both	N/A	N/A	N/A	Trunk injuries including spinal injuries are increasing in incidence and increased from 4% to 10% over the 20 year period
Genelin *et al*[32]	1994	Retrospective study	Innsbruck, Austria	Both	Increasing speed and increasing deceleration	N/A	N/A	87% of winter sport spinal injuries were due to skiing and 3% to snowboarding Most common age group was 15–25 Skiing injuries were more common in the thoracolumbar region Snowboard injuries were more common in cervical region
Floyd[31]	2001	Retrospective review	Maryland, USA	Both	N/A	M 32 W 41	M 29 injuries F 12 injuries	Overall incidence of CSI is 1 every 3 990 664 participant days
Yamakawa *et al*[33]	2001	Retrospective analysis	Gifu Prefecture, Japan	Both	Snowboarders, mostly jumps Skiers, mostly fall	Snowboarders 22.3 Skiers 26.7	M snowboarders 163 F snowboarders 75 M skiers 58 F skiers 28	Overall incidence of spinal injury is 5.73 per 100 000 days for snowboarders and 0.69 per 100 000 days for skiers
Seino *et al*[34]	2001	Retrospective review	Sapporo, Japan	Snowboarding	Primarily from fall after a jump	23.7	M 6 injuries	6 cases showing injuries from intentional jumps and a fall backwards
Levy & Smith[19]	2000	Retrospective review	Colorado, USA	Both	falls: 61% skiers, 71% snowboarders Collisions: 34% skiers, 24% snowboarders	N/A	N/A	Incidence of SCI is 0.075 per 1000 skier/snowboarder days
Tarazi *et al*[7]	1999	Retrospective review (trauma registry)	BC, Canada	Both	Snowboarders: jumps 77%, falls 18% Skiers: falls 59%, jumps 20%	Snowboarders 22.4 Skiers 34.5	M snowboarders 100% M skiers 70% F skiers 30%	Incidence of CSI among skiers was 0.01 per 1000 skier days Incidence of CSI among snowboarders was 0.04 per 1000 snowboard days
Koo & Fish[35]	1999	Retrospective review	BC, Canada	Snowboarding	Primarily from fall after a jump	22.4	M 9 injuries F 1 injury	All but one of the SCIs were to expert snowboarders who were primarily injured on jumps ranging from 2 to 25 feet
Deibert *et al*[6]	1998	Retrospective analysis (database)	Vermont, USA	Skiing	N/A	Adolescents	N/A	Increase of skier SCI over a 21 year period in children by 130% and in adolescents by 407%
Prall *et al*[30]	1995	Prospective study	Colorado, USA	Skiing	60% falls, 36% collisions	32.5	Ratio M/F 3.4:1	0.001 SCI per 1000 skier days
Myles *et al*[15]	1992	Retrospective analysis (coroner's office)	Alberta, Canada	Skiing	N/A	23.8	Ratio M/F, 3:1	25 of 145 deaths from a spinal fracture alone 20 of 145 deaths from a SCI or nerve root injury

*Skiing, snowboarding, or both.
†Falls, jumps, or collisions. Collision percentages were the sum of all types of collisions (including skier and object collisions).
‡Average or total number injured.
¶Incidence, prevalence, increased risk %.
F, female; M, male; N/A, not available; SCI, spinal cord injury.

and a large proportion of concussions resulted from head-to-object or head-to-snow impacts.

A study from Sugarbush, Vermont, USA reported that the occurrence of head injuries and concussions in adolescents had risen during the 21-year period from 1972/1973–1993/1994. The proportion of head injuries increased from 5.7% to 8.9%, and concussions increased from 2.8% to 4.8%.[6]

In January 1999, the US Consumer Product Safety Commission evaluated the incidence of head injuries in skiing and snowboarding, in an attempt to develop solutions to reduce head injury.[27] They evaluated data collected between 1993 and 1997, and reported that the percentage of head injuries in skiing increased from 12% in 1993 to 15% in 1997. In snowboarding, they found that the estimated number of head injuries increased from 1000 in 1993 to 5200 in 1997. They concluded that the increase in head injuries was significant, even if it was only due to increased participation in the sport. Overall, they suggested that head injuries accounted for about 14% of all injuries in skiing and snowboarding among children (age 15 and under), and that this percentage increased to 22% of all injuries in the 4-year interval.[27]

Thus, it appears that TBI in skiing and snowboarding is a significant problem in many countries, and that the incidence is increasing. The reasons for the increase are not apparent, but may be related to increased recognition of the clinical signs of TBI, better surveillance, changes in the definition of TBI, increased risk taking such as jumping and acrobatic activities, and higher velocities. In addition, the increase may be linked with the proliferation of snowparks, and a possible increase in the risk of injuries associated with snowpark use where terrain is modified to accommodate acrobatic maneuvers.[28]

Spinal cord injury

A review by Levy & Smith[19] found that SCI in skiing and snowboarding was in the range 1–13% of all injuries, with a more probable rate (found in larger studies) of 2–4% of all injuries. Moreover, they indicated that the incidence of SCI is approximately 0.075 per 1000 skier/snowboarder days. Another study from Denver, Colorado, USA reported rates as low as 0.001 per 1000 skier days.[30]

The increasing incidence of SCI has also been demonstrated by a study in Sugarbush, Vermont, USA. The authors found that the rate of SCI in a 21-year period (1972/3–1993/94 ski seasons) increased in children and adolescent skiers by 130% and 407%, respectively.[6 19] A retrospective review by Floyd[31] reported spinal trauma in alpine skiing and snowboarding at a major American winter resort. During the 11-year period (1986–1997), there were 3 990 664 skier days, and an overall incidence of spinal trauma of 1 per 97 333 skier days. Surgical intervention for the SCI was required in 9% of the injured skiers, and permanent neurological sequelae or death occurred at a rate of 1 per 1 995 332 skier days.[31]

A study from the Innsbruck University Hospital reported that spinal injuries constituted 4.9% of all winter sports injuries. The authors collected data between 1982 and 1992 and found that there was an increase in injuries due to an increase in speed and an increase in collisions. Most winter sport spinal injuries (81.7%) were the result of skiing. The 15–25-year age group had the largest contingent of spinal injuries at 39.8%. The authors also commented that serious spinal injuries in snowboarding were most common in the cervical region.[32] They also noted that head injuries were escalating, but no other data about head injuries were given.

Tarazi *et al*[7] collected data on spinal injuries in skiers and snowboarders for two complete ski seasons at the Whistler and Blackcomb Ski Resorts in British Columbia, Canada (November 1994 to April 1996). They reported that the incidence of SCI was 0.01 per 1000 skier days for skiers and 0.04 per 1000 snowboarder days for snowboarders (data not adjusted for age). They found that 70% of all SCIs in skiing were to men, and SCI in snowboarding was found only in men. The mean age of skiers with SCI was 35.4 years, but the mean age of snowboarders with SCI was 22.4 years. Jumps (77%) were the main cause of SCI in snowboarders, followed by falls (18%). In contrast, in skiing, falls (59%) were the primary cause of SCI, followed by jumping (20%)[7]. Another study from Giru Prefecture, Japan showed that most SCIs in skiers were due to simple falls, whereas snowboarders suffered SCI because of jumping.[33] Thus, SCI in skiers and boarders is a significant problem, especially in young male snowboarders, and is increasing with the increased risk-taking behavior occurring on the mountains.[34 35]

Injury prevention

Helmets

Ski helmets are designed to resist impact. There is evidence that they can absorb energy at speeds up to ~19 km/h, and minimize damage to the brain.[36] Although controversy exists about the precise degree of efficacy of helmets in protecting against injury,[11] numerous studies support the use of helmets for both skiing and snowboarding.[8 11 12 19 23 27 37–43] Some studies of case series suggest a major protective effect of helmets by indicating that none or few of the head-injured skiers or snowboarders were helmeted.[12 44 45] Data from other case-series investigations allow additional comparisons to be made that offer better evidence for head injury protection by helmets.[46 47] However, only three case–control studies were conducted with the express purpose of determining whether helmets protect against head injuries.[38 43 48] Sulheim *et al*[48] found that helmet use was associated with a 60% reduction in the risk of a head injury. Another cohort study provided some evidence on helmet effectiveness, although the small number of participants makes interpretation of the results difficult.[49] The association of helmet use and reduction in head injury risk ranged from 22% to 60% in various reports.[38 43 46 47]

The US Consumer Product Safety Commission estimates that 44% of head injuries could be prevented by the use of helmets in skiing and snowboarding, and that the use of helmets for children aged 15 and under could reduce head injuries in this group by 53%.[27] In addition, this commission reviewed death certificates of skiers and snowboarders, and found that 11 deaths per year were attributed to head injuries that could have been prevented by the use of helmets.[27]

To date, there is no standard for ski helmets in many countries, including Canada. The most common standards used are the American Snell RS-98 test and Central European Standards EN1077 and UNI EN 812 (www.ski-injury.com/helmet.htm). The US Consumer Product Safety Commission reports that most helmets in the US are imported from Europe and cost approximately US$75–300. They also report that rental shops rent helmets for US$4–5 per day. Hennessey *et al*[50] conducted a survey of ski helmet availability in ski rental shops in Colorado, USA, and found that 2–38% of skiers and snowboarders rent equipment, but only 3.2% (range 1–8.6%) also rented a helmet. Fifteen of 24 (62%) ski resorts replied to the survey: 13 (87%) stated that they encouraged helmet rental regardless of age and ability; 12 (80%) indicated that children were most likely to rent a helmet, and the other three respondents did not answer. In a study conducted in multiple US ski resorts (data collected from mid January until early April of 2001), helmets were worn by 12.1% (95% CI 11.0 to 13.3) of the skiing population. Moreover, the highest prevalence of helmet use was in the expert skier/snowboarder category.[51]

There is some concern that helmet wearing is associated with an increased risk of cervical spine injuries in children (13 and under) in skiing and snowboarding. However, Macnab & Cadman[24] studied this phenomenon and found that helmet wearing did not increase the incidence or severity of neck injury in skiers and snowboarders in this age group. Bridges *et al*[26] studied an even younger group in their Mt Tremblant study, and also found that, when adjusted for age (<6, 6–12, >12), there was no increase in neck injury due to helmet use. Sulheim *et al*[48] found that helmet use did not increase the risk of neck injury in alpine skiing and snowboarding populations. Hagel *et al*[43] could not rule out the possibility of an increased risk of neck injury with helmet use, but estimates were imprecise. The issue of neck injury in relation to helmet use requires further study. However, given the equivocal evidence for neck injury risk and the greater incidence of head, compared with neck, injuries in these activities, we recommend helmet use for all skiers and snowboarders.

Helmet fitting is an important safety issue. For example, many parents buy helmets that are too large to allow ''room to grow'', and this is unsafe because a poor fit means reduced protection, vision, and hearing.[41] Helmet-fitting tips to ensure an optimal and proper fit include the following: (*a*) the helmet should fit snugly; (*b*) helmet sizing charts should be used for each helmet brand, and, if the helmet measurement is between two sizes, the larger size should be chosen; (*c*) several helmet brands should be tried; (*d*) there should be no red/pressure spots on the head after use. However, there is no direct evidence that a properly fitted helmet offers increased protection.

Risks and prevention

Advances in skiing/snowboarding equipment and techniques have produced increased velocities and jumping heights. Collisions occur with other participants on the slopes and with inanimate objects, such as trees, rocks, and chairlift poles, causing injury. An Alpine Responsibility Code has been disseminated in many countries and has been emphasized in many prevention programs such as ''Respect'' and ''A little Respect: ThinkFirst'', two Canadian injury prevention resources. The Code includes the following measures to minimize the chance of injury: (*a*) beginners should take lessons from a certified instructor; (*b*) never ski or snowboard alone; (*c*) maintain and check ski and snowboard equipment; (*d*) exercise and stretch before each day of skiing/snowboarding; (*e*) stay on marked trails; (*f*) follow the skiers/boarders responsibility code such as developed by the Canadian Ski Patrol; (*g*) be alert to physical and environmental hazards; (*h*) wear the appropriate gear, including helmets; (*i*) ski and snowboard on hills that are within your ability and skill level; (*j*) quit before becoming too tired.

Key points

- Alpine skiing and snowboarding cause a significant number of catastrophic head and spinal injuries.
- Rates of traumatic brain injury and spinal cord injury in skiing and snowboarding are increasing in all countries that have reported data, in parallel with the development and acceptance of acrobatic and high-speed activities on the mountains.
- Snowboarders, especially younger males, have higher rates of injury than skiers and are more likely to have head and neck injuries.
- Helmets are associated with a 22–60% decreased rate of head injury.

IMPLICATIONS FOR PREVENTION

Alpine skiing and snowboarding cause a significant number of catastrophic head and spinal cord injuries, and the incidence is increasing in most countries. There is some evidence that injury prevention measures, such as helmet use, are associated with decreased rates of injury. We strongly recommend the use of helmets by all skiing and snowboarding participants. We also recommend the promotion and enforcement of standards for ski and snowboarding helmets in countries in which these activities are common. The increased incidence of TBI and SCI may be due to increased risk-taking behavior in snowboard parks and/or jumping in terrain allowing acrobatic activities, leading to more falls and collisions, especially in the young male population. Injuries in this population have long-term sequelae that are usually devastating. These injuries are often irreversible with long-term physical, emotional, and socio-economic consequences. Prevention programs must target these populations because of these implications.

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Thanks to reviewers

Once again we return to the end-of-the-year ritual of thanking reviewers. I apologize for using that word because there is nothing ritualistic about this process other than the timing. As in past years, the engines of the journal were fuelled by the work of many scholars who, for the most part, carefully read and digested what we sent them. They then provided critiques that ranged from the rare ''It's fine; go ahead and publish'' (or words to that effect) to 10 pages of single-spaced comments, suggestions, and re-analyses! Reviews largely decide the fate of most papers; without them we could not function. It is as simple as that. Although the peer review process is often criticized, we are convinced that it is still the best way to judge what is worthy of being published, and what papers would fare better in another journal. As has been the case in past years, space does not permit us to list all the reviewers. Instead, the names are posted on our website. Almost every member of the Board submitted several reviews—some as many as seven (including re-reviews). Although this sort of devotion comes with the territory of being on the Board, we don't take this work for granted. Nor do we take for granted in the least the extraordinary services of others. A few non-Board members worked especially hard, providing three or more reviews: David Clark, Samuel Forjuoh, Kristian Filion, David Grossman, Kitty Hendricks, Rebecca Ivers, Sue Mallonee, Gerald McGwin, Lenora Olson, Will Pickett, Leon Robertson, David Schwebel, and Nancy Stout. We are deeply grateful to them, and to all 430 others who shared their wisdom with us this past year. The list of names is published online at http://ip.bmj.com/supplemental

Barry Pless, Editor