Injuries Among Skiers and Snowboarders in Quebec

Brent E. Hagel,[*†] *Claude Goulet,*[‡] *Robert W. Platt,*[*] *and I. Barry Pless*[*]

Background: Snow sports such as skiing and snowboarding are recognized as hazardous, but population-based injury rates or specific risk factors have been difficult to estimate as a result of a lack of complete data for both numerator and denominator.

Methods: We used data from 3 surveys to estimate the number of participants and annual number of outings in Quebec by age, sex, activity, and calendar year. Injuries reported by ski patrollers were used to estimate injury rates among skiers and snowboarders for the head and neck, trunk, upper extremity, and lower extremity.

Results: Head–neck and trunk injury rates increased over time from 1995–1996 to 1999–2000. There was a steady increase in the rate of injury with younger age for all body regions. The rate of head–neck injury was 50% higher in snowboarders than in skiers (adjusted rate ratio [ARR] = 1.5; 95% confidence interval = 1.3–1.8). Women and girls had a lower rate of head–neck injury (0.73; 0.62–0.87). Snowboarders were twice as likely as skiers to have injuries of the trunk (2.1; 1.7–2.6), and more than 3 times as likely to have injuries of the upper extremities (3.4; 2.9–4.1). Snowboarders had a lower rate of injury only of the lower extremities (0.79; 0.66–0.95). Snowboarder collision-related injury rates increased substantially over time.

Conclusions: Except for lower extremity injuries, snowboarders have a higher rate of injuries than skiers. Furthermore, collision-related injury rates have increased over time for snowboarders. Targeted injury prevention strategies in this group seem justified.

(*Epidemiology* 2004;15: 279–286)

There are many challenges in evaluating the role of risk factors for skiing and snowboarding. First, it is difficult to make accurate estimates of risk factors without an estimate of the population at risk (ie, a denominator). An often-used denominator is "hill user visits" based on the number of lift tickets sold throughout a season. However, lift tickets generally give little or no information on type of activity, age, and sex. Other limitations of lift tickets as a method for estimating denominators for injury rates have been discussed.[1]

Even when relative denominators are available through sampling like in a case–control study, it is rare that the investigators adjusted for the effects of other covariates in the analysis. This makes it difficult to assess the independent contribution of each risk factor to the likelihood of injury.

Finally, many studies of ski or snowboard injuries have not considered risk factors for injuries to specific body regions.

We used data collected in surveys contracted to the Print Measurement Bureau[2] by the Canadian Ski Council[3] to estimate the total number of male and female skiers and snowboarders in different age groups by calendar year. These data, combined with comprehensive ski patrol injury data from Quebec, allow for the calculation of injury rates per 1000 participants and per 1000 outings in various risk groups.

METHODS

The Canadian Ski Council contracts regular surveys to estimate the characteristics of the Canadian ski and snowboard population.[3] A new sample is drawn each year to represent the entire population of Canada over the age of 11 years with the exception of the far north, institutions, and reservations.[2] Canada is first stratified by region and city, within which census enumeration areas are randomly selected according to Statistics Canada definitions. Households within each enumeration area and individuals within each household are then randomly selected. Two weighting processes account for under- or oversampling as well as for Statistics Canada population estimates. An interviewer visits a selected respondent's home for a 30- to 90-minute interview and leaves a self-administered questionnaire with the respondent for 2 to 3 days. The average response rate is 65%; a minimum 60% response rate is required in all strata. The self-administered questionnaire has a 70% to 80% completion rate depending

Submitted 6 March 2003; final version accepted 12 January 2004.

From the *Department of Epidemiology and Biostatistics, McGill University, Montreal, Quebec, Canada; the †Alberta Centre for Injury Control and Research, Department of Public Health Sciences, University of Alberta, Edmonton, Alberta, Canada; and ‡Safety Research, Secrétariat au loisir et au sport, Québec Gouvernement.

Brent Hagel was supported by a Health Research Studentship from the Alberta Heritage Foundation for Medical Research.

Correspondence: Brent Hagel, PhD, Research Associate, Alberta Centre for Injury Control and Research, Department of Public Health Sciences, University of Alberta, 4075 RTF, 8308–114 Street, Edmonton, Alberta T6G 2E1, Canada. E-mail: brent.hagel@ualberta.ca

Copyright © 2004 by Lippincott Williams & Wilkins

ISSN: 1044-3983/04/1503-0279
DOI: 10.1097/01.ede.0000120044.62029.b4

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

on the demographic characteristics of the respondent. Further details regarding the sampling technique and measurement instruments are available on the Internet.[2]

We used data from 3 surveys conducted over a period of 5 years (October 1995 to September 1997; October 1997 to September 1999; January 2000 to December 2000) as estimates of the number of skiers and snowboarders in Quebec by calendar year, age, and sex. These data represent the denominators for our estimated rates. Estimates from the 1995–1997 survey of 7000 homes served as denominators for the 1995–1996 and 1996–1997 ski–snowboard seasons, estimates from the 1997–1999 survey of 7200 homes were used as denominators for the 1997–1998 and 1998–1999 seasons, and estimates from the 2000 survey of 7300 homes provided the denominator for the 1999–2000 season.

To capture participant exposure information, we used the survey data on the number of times the skiers and snowboarders engaged in their respective activities. Participation was categorized as low (once per month), medium (2–3 times per month), and high (4+ times per month). We arrived at a denominator of outings for each age, sex, activity, and calendar year grouping by weighting the participation levels as 1 (low), 2 (medium), and 4 (high).

We multiplied the total monthly outings by 3 months (average Quebec ski–snowboard season) to estimate a yearly number of outings. Separate participation-related questions were asked about skiing and snowboarding so that an individual who engaged in both activities would contribute to the denominator of both activities.

The numerators for injury rates are based on Quebec ski patrol reports. All ski areas in Quebec are required by law to send their ski patrol accident reports to the Secretariat of leisure and sport. Although this requirement has been in place since 1988,[4] not all ski hills comply every year. For this reason, and because not all skiing and snowboarding injuries get reported to the ski patrol,[5–7] the incidence rates reported here tend to underestimate the true rates of skiing and snowboarding injuries. However, the relative rates for the comparison of skiers with snowboarders, as well as comparisons by calendar year, age, and sex should not be affected. That is, we are assuming a constant rate of underreporting across all comparisons of interest.

Although the ski patrol accident report form provides space for up to 3 body regions of injury, we used only the first injury. With this approach, we are assuming that the first injury recorded represents the most significant injury, but this is not always the case. We categorized injuries as head–neck, trunk, upper extremity, and lower extremity to consider risk factors for particular body regions.

Injury incidence rates per 1000 participants and 1000 outings are presented by age group (12–17, 18–24, 25–34, and 35+), sex, activity (skiing vs. snowboarding), and calendar year (1995–1996, 1996–1997, 1997–1998, 1998–1999, and 1999–2000 or as a continuous variable). We used negative binomial regression to estimate adjusted rate ratios (ARRs) and 95% confidence intervals (CIs). Negative binomial regression is similar to Poisson regression but allows for extra-Poisson variation in the mean number of injuries (ie, the possibility that the variance is greater than the mean).[8]

RESULTS

Table 1 provides information on the number of ski stations reporting ski patrol injuries for skiers and snowboarders in each season. The proportion of ski areas contributing reports ranged from 56% in the 1997–1998 season to 76% in the 1996–1997 season. Based on an economic analysis survey conducted in Quebec, those ski areas contributing reports represent between 83% and 94% of the total Quebec visits (Audet S, personal communication, 2002, unpublished analysis extracted from the Étude Économique et Financière des Stations de Ski du Québec. Montreal: Chaire de Tourisme-University of Quebec at Montreal).

Head and Neck Injuries

After adjustment for age, sex, and activity, the rate of head and neck injury increased by approximately 50% over

TABLE 1. Number of Ski Patrol Injury Reports, Number of Stations Contributing Reports, and Number of Active Ski Stations by Activity in Quebec Since 1995–1996

Year	Active Stations	Contributing Stations (%)	Contribution to Total Quebec Skier Visits (%)*	Total Ski Injuries	Total Snowboard Injuries
1995–1996	94	69 (73)	84	5967	2488
1996–1997	92	70 (76)	94	6102	3050
1997–1998	86	48 (56)	86	5223	3634
1998–1999	84	61 (73)	89	5557	4953
1999–2000	84	60 (71)	83	5982	4871

*Audet S, personal communication, 2002, unpublished analysis extracted from the Etude Economique et Financière des Stations de Ski du Québecs. Montreal: Chaire de Tourisme–University of Quebec at Montreal.

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

the study period (Table 2). There was a decline in head and neck injuries with increasing age, with 12 to 17 year olds having a rate 5 times those older than 34 (ARR = 4.9; 95% CI = 3.9–6.2). Head and neck injuries were more common among snowboarders, and among girls and women after adjustment for all other covariates. No changes were evident after adjusting for level of participation.

Trunk Injuries

The rate of trunk injuries also increased over time with the 1999–2000 rate almost twice that of 1995–1996 (Table 2). Like with head and neck injuries, trunk injury rates were higher in the youngest age groups after adjustment for covariates. There was no evidence of a sex difference in the trunk injuries, but snowboarders were twice as likely to have trunk injuries as skiers (ARR = 2.1; CI = 1.7–2.6). Once again, estimates were not affected by adjustment for level of participation.

Upper Extremity Injuries

There was some evidence to suggest an increase in injuries of the upper extremity over time (Table 2). Those in the 12 to 17 year age group had a rate of injury 4.5 times (CI = 3.6–5.8) the rate in those 35 and older. There was no evidence of a sex difference in the rate of upper extremity injuries after accounting for covariates. Snowboarders were 3.4 times more likely than skiers to injure an upper extremity (CI = 2.9–4.1). There were few differences in the population-based and outings-based risk estimates.

Lower Extremity Injuries

There is some evidence to suggest an increase in the rate of injury to the lower extremities over time (Table 2). Twelve to 17 year olds were 3 times as likely to injure a lower extremity as those 35 and older. The rate of injury to the lower extremities was 1.5 times higher in females than males (CI = 1.2–1.7). Snowboarders were less likely to injure a lower extremity than skiers (ARR = 0.79; CI = 0.66–0.95).

Collision Injuries

Seven percent of all injuries were the result of a collision (with another person, a natural obstacle, or another obstacle). The remaining injuries were the result of a fall or a jump. There is no evidence to suggest that skier collision injury rates increased over time (Table 3). In contrast, the collision-related injury rate for snowboarders increased 16% per year (10–22%). Collision-related injury rates increased the most for head–neck (21%; range = 11–32%) and trunk (25%; range = 9–43%) per year.

DISCUSSION

This is one of the few studies to generate population-based estimates of injury rates in skiing and snowboarding per 1000 participants and per 1000 outings. We related risk factors to body region-specific injury rates and adjusted all comparisons for all other variables. We have directly compared the body region-specific rate of injury in skiing and snowboarding after adjustment for relevant covariates.

We find strong evidence for an increase in injuries of the head–neck and trunk over time. Our collision-related injury time trend analysis, however, only saw increases among snowboarders. The Canadian Ski Council data indicate that the proportion of snowboarders has increased from 1995 (22%) through 2000 (29%). The increasing proportion of snowboarders with their different pattern of movement could contribute to collisions within and between activities. There is some evidence to suggest an association between collisions and head injuries in snowboarders[9] and skiers.[10] Burtscher and Philadelphy noted a 60% increase in the frequency of collisions resulting in injury from 1986 through 1991.[10] In 1991, snowboarders represented 5% of all persons involved in skiing-related collisions, with 80% being the "collision-causer." However, the authors also noted that "collision-causers" tended to be younger and male, and therefore age, sex, or both could have confounded their results. If the interactivity-related hypothesis were correct, we would expect collision-related injury rates to increase in both skiers and snowboarders, which is not what we found.

Snowboarders represent the majority of users of snow parks, which are play areas with half-pipes, rails, and other slope modifications. Our collision-related injury trends could also reflect the proliferation of these areas. There could be a link between collision injury risk and the density of participants or the equipment or terrain in snow parks. Unfortunately, the survey provided no data on the prevalence of snow parks. However, based on separate surveys conducted by the Secretariat of Leisure and Sport, the number of Quebec ski areas with snow parks increased from 48 (73%) in 1999–2000 to 65 (86%) in 2001–2002. It is unlikely that more than a handful of Quebec ski areas had snow parks in the mid-1990s. It is also likely that, for a given number of snow parks, the actual number of users has increased with the increased acceptance of these areas and the growth of snowboarding.

The increases in head and neck injuries could also be associated with the introduction of snow parks because these areas encourage jumping. Tarazi et al.[11] noted that an intentional jump of over 2 meters contributed to 20% of skier and 77% of snowboarder severe spinal injuries. Similarly, a Japanese study[12] found a jump of over 1 meter had contributed to the hospital-treated spinal injuries of 55% of snowboarders but only 14% of skiers. An increase in the frequency of aerial maneuvers could be contributing to the increases in head and neck injury rates. Further research is required to determine if there is a relation between the type, rate or severity of injury, and snow parks.

New types of ski equipment could also contribute to the general increase in injury rates. For example, the super

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 2. Factors Related to Skier and Snowboarder Injuries, Quebec, 1995–2000

Factor	No. of Injuries	No. of Participants (000s)	Injuries per 1000 Participants		Outings per Season (000s)	Injuries per 1000 Outings	
			Rate per 1000	Adjusted* Rate Ratio (95% CI)		Rate per 1000	Adjusted* Rate Ratio (95% CI)
Head and Neck Injuries							
Calendar year							
1995–1996†	1243	1170	1.06	1.0	7284	0.17	1.0
1996–1997	1286	1170	1.10	1.1 (0.8–1.4)	7284	0.18	1.1 (0.9–1.4)
1997–1998	1466	1112	1.32	1.4 (1.1–1.8)	6981	0.21	1.3 (1.1–1.7)
1998–1999	1720	1112	1.55	1.5 (1.2–2.0)	6981	0.25	1.5 (1.2–1.9)
1999–2000	1637	1038	1.58	1.5 (1.2–2.0)	6207	0.26	1.6 (1.2–2.0)
Age (yrs)							
12–17	4101	1245	3.29	4.9 (3.9–6.2)	8925	0.46	4.2 (3.4–5.2)
18–24	1343	1187	1.13	1.9 (1.5–2.4)	7011	0.19	1.9 (1.5–2.3)
25–34	580	1073	0.54	1.0 (0.8–1.3)	6240	0.09	1.0 (0.8–1.3)
35+†	1328	2097	0.63	1.0	12,561	0.11	1.0
Sex							
Female	2661	2416	1.10	0.7 (0.6–0.9)	14,127	0.19	0.9 (0.7–1.0)
Male†	4691	3186	1.47	1.0	20,610	0.23	1.0
Activity							
Snowboard	3320	1337	2.48	1.5 (1.3–1.8)	9105	0.37	1.4 (1.2–1.7)
Ski†	4032	4265	0.95	1.0	25,632	0.16	1.0
Trunk Injuries							
Calendar year							
1995–1996†	412	1170	0.35	1.0	7284	0.06	1.0
1996–1997	447	1170	0.38	1.1 (0.8–1.5)	7284	0.06	1.1 (0.8–1.5)
1997–1998	491	1112	0.44	1.2 (0.9–1.6)	6981	0.07	1.2 (0.9–1.6)
1998–1999	636	1112	0.57	1.5 (1.1–2.0)	6981	0.09	1.5 (1.1–1.9)
1999–2000	826	1038	0.80	2.0 (1.5–2.6)	6207	0.13	2.0 (1.5–2.7)
Age (yrs)							
12–17	1547	1245	1.24	4.5 (3.5–5.8)	8925	0.17	3.8 (3.0–4.9)
18–24	566	1187	0.48	2.0 (1.5–2.6)	7011	0.08	2.0 (1.6–2.6)
25–34	209	1073	0.20	1.0 (0.8–1.3)	6240	0.03	1.0 (0.8–1.3)
35+†	490	2097	0.23	1.0	12,561	0.04	1.0
Sex							
Female	1141	2416	0.47	0.9 (0.8–1.1)	14,127	0.08	1.1 (0.9–1.3)
Male†	1671	3186	0.53	1.0	20,610	0.08	1.0
Activity							
Snowboard	1420	1337	1.06	2.1 (1.7–2.6)	9105	0.16	2.0 (1.7–2.4)
Ski†	1392	4265	0.33	1.0	25,632	0.05	1.0
Upper Extremity Injuries							
Calendar year							
1995–1996†	2217	1170	1.90	1.0	7284	0.30	1.0
1996–1997	2524	1170	2.16	1.1 (0.8–1.4)	7284	0.35	1.1 (0.9–1.4)
1997–1998	2762	1112	2.48	1.2 (0.9–1.6)	6981	0.40	1.2 (0.9–1.6)
1998–1999	3325	1112	2.99	1.4 (1.0–1.8)	6981	0.48	1.3 (1.0–1.7)
1999–2000	2933	1038	2.83	1.3 (1.0–1.7)	6207	0.47	1.3 (1.0–1.7)

continued on next page

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

TABLE 2. *Continued*

Factor	No. of Injuries	No. of Participants (000s)	Injuries per 1000 Participants: Rate per 1000	Injuries per 1000 Participants: Adjusted* Rate Ratio (95% CI)	Outings per Season (000s)	Injuries per 1000 Outings: Rate per 1000	Injuries per 1000 Outings: Adjusted* Rate Ratio (95% CI)
Age (yrs)							
12–17	8207	1245	6.60	4.5 (3.6–5.8)	8925	0.92	3.9 (3.1–4.9)
18–24	2408	1187	2.03	1.8 (1.4–2.4)	7011	0.34	1.9 (1.5–2.3)
25–34	1138	1073	1.06	1.2 (1.0–1.6)	6240	0.18	1.2 (1.0–1.6)
35+†	2008	2097	0.96	1.0	12,561	0.16	1.0
Sex							
Female	4851	2416	2.01	0.9 (0.8–1.1)	14,127	0.34	1.0 (0.9–1.2)
Male†	8910	3186	2.80	1.0	20,610	0.43	1.0
Activity							
Snowboard	8784	1337	6.60	3.4 (2.9–4.1)	9105	0.97	3.3 (2.8–3.9)
Ski†	4977	4265	1.17	1.0	25,632	0.19	1.0
Lower Extremity Injuries							
Calendar year							
1995–1996†	2754	1170	2.35	1.0	7284	0.38	1.0
1996–1997	3025	1170	2.59	1.2 (0.9–1.6)	7284	0.42	1.2 (0.9–1.5)
1997–1998	2602	1112	2.34	1.0 (0.8–1.4)	6981	0.37	1.0 (0.8–1.3)
1998–1999	2776	1112	2.50	1.2 (0.9–1.6)	6981	0.40	1.2 (0.9–1.5)
1999–2000	3071	1038	2.96	1.4 (1.0–1.8)	6207	0.50	1.4 (1.1–1.8)
Age (yrs)							
12–17	6036	1245	4.85	3.1 (2.4–4.0)	8925	0.68	2.7 (2.2–3.4)
18–24	2383	1187	2.01	1.5 (1.2–2.0)	7011	0.34	1.5 (1.2–1.9)
25–34	1773	1073	1.65	1.2 (0.9–1.5)	6240	0.28	1.2 (0.9–1.5)
35+†	4036	2097	1.93	1.0	12,561	0.32	1.0
Sex							
Female	8248	2416	3.41	1.5 (1.2–1.7)	14,127	0.58	1.7 (1.4–2.0)
Male†	5980	3186	1.88	1.0	20,610	0.29	1.0
Activity							
Snowboard	3318	1337	2.48	0.8 (0.7–1.0)	9105	0.36	0.8 (0.6–0.9)
Ski†	10,910	4265	2.56	1.0	25,632	0.43	1.0

*Adjusted for all other factors in the table.
†Reference category.

TABLE 3. Time Trends (per Calendar Year) in Collision-Related Injury Rates for Skiers and Snowboarders, Quebec, 1995–2000

	Skiers		Snowboarders	
	Population-Based* Adjusted† Rate Ratio (95% CI)	Outings-Based‡ Adjusted† Rate Ratio (95% CI)	Population-Based* Adjusted† Rate Ratio (95% CI)	Outings-Based‡ Adjusted† Rate Ratio (95% CI)
Total	0.97 (0.92–1.03)	0.98 (0.93–1.04)	1.15 (1.08–1.22)	1.16 (1.10–1.22)
Head and neck	1.0 (0.94–1.06)	1.01 (0.95–1.07)	1.19 (1.08–1.31)	1.21 (1.11–1.32)
Trunk	0.97 (0.88–1.08)	0.98 (0.89–1.09)	1.22 (1.06–1.40)	1.25 (1.09–1.43)
Upper extremities	1.0 (0.93–1.08)	1.01 (0.94–1.08)	1.08 (0.99–1.18)	1.10 (1.00–1.20)
Lower extremities	0.96 (0.88–1.04)	0.97 (0.89–1.05)	1.13 (1.03–1.24)	1.14 (1.05–1.24)

*Denominator for injury rates is participants.
†Adjusted for age (12–17, 18–24, 25–34, 35+) and sex.
‡Denominator for injury rates is outings based on a 3-month season.

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

sidecut (ie, carving) ski could increase the risk of injury.[13] Furthermore, there is evidence that skiboards (nonrelease binding skis under 130 cm in length[14]) increase the risk of lower leg injuries, particularly tibial fractures among younger participants, compared with alpine skis.[14,15] However, the rates of other types of injuries appear to be lower in skiboarders.[14,15] Increases in the prevalence of these new types of ski equipment could contribute to the increase in injuries over time, but more research is required.

There is some evidence that helmets provide protection from head injuries.[16] Although this study had limitations (inadequate control for confounding, small sample sizes, and so on), the results are encouraging. Increased use of helmets could help curb the worrisome trend in head injuries.

There was a sharp age gradient in injury risk for skiers and snowboarders, irrespective of the body region of injury. The youngest age group (12–17 years) is most at risk for any injury even after adjustment for activity, sex, and calendar year. This has previously been reported for skiers[17–19] and snowboarders.[14,20] At least part of this higher risk among younger participants could be the result of inexperience and a lower ability level.

The effect of lessons on the risk of injury in skiing and snowboarding is equivocal.[6,20–22] The benefits of instruction in these studies could have been counterbalanced by an increased opportunity for injury (increased number of outings), which was not always taken into account. It remains to be shown that adequate supervision of child and adolescent skiers and snowboarders will reduce the rate of injury.

Females were at less risk for head and neck injuries but at greater risk of injuries to the lower extremities compared with males. These findings are consistent with other investigations.[23,24] We found no sex differences for injuries to the upper extremities or trunk once other factors were controlled.

There is evidence that properly adjusted bindings reduce the risk of any injury in children,[22] and reduce the risk of certain lower extremity injuries in all age groups.[25] Although some investigators suggest that current release binding systems are optimal and cannot prevent serious knee injuries,[26] the French organization that sets standards for ski equipment suggests that binding standards for women and lighter men be lowered in response to a rise in the rate of injuries to the anterior cruciate ligament of the knee.[27] According to our results, women and those in younger age groups should be particularly vigilant in adjusting and maintaining their bindings. A modification of current release binding settings for these vulnerable groups could also help reduce injuries.

Snowboarders had a greater risk of injuries to the head and neck and upper extremities compared with skiers, and a lower risk of injuries to the lower extremities. This reflects the nature of the 2 activities. These findings are consistent with other reports,[28–30] with the exception of a greater risk of ankle injuries noted in snowboarders and thumb injuries in skiers.[30,31]

There is evidence that wrist-guard use in snowboarders is effective at preventing wrist injuries,[32,33] and does not increase the risk of other injuries to the arm or shoulder.[32,33] Wrist-guard use will likely prevent some of the upper extremity-related trauma in snowboarders.

Limitations

We compared our estimates of the number of outings with the number of Quebec hill visits in reports prepared by the Chaire de Tourisme–University of Quebec at Montreal for the Quebec Ski Areas Association.[34] We could have overestimated the number of visits relative to the estimates in the report. For example, we estimated 6.2 million outings in the 1999–2000 season compared with Chaire de Tourisme estimates of 5.7 million participation days. It is also possible, however, that the Chaire de Tourisme underestimated the number of visits attributable to a season pass because they ask each ski area operator to estimate for season pass holders the number of outings per year. It is unlikely there is a systematic over- or underestimate associated with either method.

Another limitation of the denominator data is that skiers and snowboarders from outside Quebec were not counted. It was impossible to remove nonresidents from the numerator because residency data were not available from the ski patrol reports. The net effect would be to overestimate injury rates. However, there was no evidence the proportion of injured skiers or snowboarders who were Quebec residents changed between 1994 and 1995 (77%) and 1999 and 2000 (78%), the only years these data were available from the Secretariat of Leisure and Sport. Similarly, there was no evidence the proportion of skier and snowboarder visits by Quebec residents changed between 1995 and 96 (77%)[35] and 1999 and 2000 (76%).[34] Therefore, although the absolute rates are presumably overestimated by including non-Quebec residents in the numerator, we do not believe that the relative rates in the different risk factor categories would be affected.

There are also some potential problems with our numerator data. First, not all injuries are reported to the ski patrol.[5–7] Injuries are probably more likely to be reported if they interfere with ambulation,[5] are sustained by females,[5–7] are sustained by children,[5,7] or are sustained by lower ability-level participants.[5] These problems affect any studies that are not focused on closed (ie, cohort) populations but instead rely on presentation of injuries to ski patrollers or medical facilities. Thus, the high rates reported by younger age groups could in part be the result of overreporting, but the higher rates of head and neck injuries among men and boys would not.

Not all ski areas in Quebec provided their injury reports to the Secretariat annually, which would tend to underestimate the absolute rates per 1000 participants or per 1000

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

outings. However, there is no reason to believe that the numerators would affect the rate comparisons for specific body injury regions by activity, age, sex, or calendar year.

Only the first injury recorded on the ski patrol accident report was used in the estimation of injury rates. The first injury represented most injuries recorded over the study period (85% in 1998–1999 and 86% in 1996–1997). Although limiting the analysis will not influence the rate of injury *events*, it will result in an underestimate of the body region-specific injury rate. There is no reason to believe, however, that 1 particular body region of injury was more often recorded first, second, or third depending on the different risk factor categories. Therefore, the relative rates should not be affected.

Our results also rest on the assumption that skiers and snowboarders have equal exposure in terms of time skied or snowboarded each day. If 1 group were to participate for more hours per outing, then their injury rates would be overestimated. It is likely that some of these possible differences in exposure between snowboarders and skiers would be captured by age and sex, variables we controlled in the analysis.

The adjustment for covariates did not substantially change the rate ratios from what was seen in the crude rates, suggesting that residual confounding by those covariates is not a problem. However, we did not account for other factors that could have had a bearing on injury rates such as ability or experience.

In summary, we found the highest rates of injury among the youngest group. Snowboarders had more injuries of the head and neck, trunk, and upper extremities, whereas skiers were more likely to injure their lower extremities. Males were more at risk for head and neck injuries, whereas females had a greater rate of injuries to the lower extremities. Importantly, the rates of injury to the head, neck, and trunk increased over the 5-year study period. Similarly, collision injury rates increased substantially in snowboarders, particularly for the head, neck, and trunk. This raises concern over the possible role of collisions with the continued proliferation of snowboarders, or a possible increase in risk associated with snow park use where the terrain is modified to accommodate jumping. Possible injury prevention measures include helmet and wrist-guard use, proper instruction, adequate supervision, and proper binding adjustment.

REFERENCES

1. Rønning R, Gerner T, Engebretsen L. Risk of injury during alpine and telemark skiing and snowboarding. The equipment-specific distance-correlated injury index. *Am J Sports Med*. 2000;28:506–508.
2. Print Measurement Bureau. Available at: http://www.pmb.ca/. 2001.
3. Canadian Ski Council. Canadian Ski & Snowboard Industry Facts & Stats. Available at: http://www.canadianskicouncil.org/. 2000.
4. Government of Québec. *An Act Respecting Safety in Sports*. Québec: Editeur Officiel du Québec; 1988.
5. Garrick JG, Kurland LT. The epidemiologic significance of unreported ski injuries. *J Safety Res*. 1971;3:182–187.
6. Machold W, Kwasny O, Gäβler P, et al. Risk of injury through snowboarding. *J Trauma*. 2000;48:1109–1114.
7. Requa RK, Toney JM, Garrick JG. Parameters of injury reporting in skiing. *Med Sci Sports Exerc*. 1977;9:185–190.
8. Rivara FP, Cummings P, Koepsell TD, Grossman DC, Maier RV. *Injury Control: A Guide to the Causes and Prevention of Trauma*, 1st ed. Cambridge: Cambridge University Press; 2001.
9. Prall J, Winston K, Brennan R. Severe snowboarding injuries. *Injury*. 1995;26:539–542.
10. Burtscher M, Philadelphy M. Skiing collision accidents: frequency and types of injuries. In: Mote CD Jr, Johnson RJ, Hauser W, et al., eds. *Skiing Trauma and Safety*, 10th vol. ASTM STP 1266. Philadelphia, PA: American Society for Testing and Materials; 1996:73–76.
11. Tarazi F, Dvorak MFS, Wing PC. Spinal injuries in skiers and snowboarders. *Am J Sports Med*. 1999;27:177–180.
12. Yamakawa H, Murase S, Sakai H, et al. Spinal injuries in snowboarders: risk of jumping as an integral part of snowboarding. *J Trauma*. 2001; 50:1101–1105.
13. Johnson RJ, Ettlinger CF, Shealy JF, Meader C. Impact of super sidecut skis on the epidemiology of skiing injuries. *Sportverletz Sportschaden*. 1997;11:150–152.
14. Greenwald RM, Nesshoever M, Boynton MD. Ski injury epidemiology: a short-term epidemiology study of injuries with skiboards. In: Johson RJ, Zucco P, Shealy JE, eds. *Skiing Trauma and Safety*, 13th vol. ASTM STP 1397. West Conshohocken, PA: American Society for Testing and Materials; 2000:119–126.
15. Langran M. Injury patterns in skiboarding: a 2-year study in Scotland. *Injury*. 2002;33:563–568.
16. Macnab AJ, Smith T, Gagnon FA, Macnab M. Effect of helmet wear on the incidence of head/face and cervical spine injuries in young skiers and snowboarders. *Inj Prev*. 2002;8:324–327.
17. Deibert M, Aronsson D, Johnson R, Ettlinger C, Shealy J. Skiing injuries in children, adolescents, and adults. *J Bone Joint Surg [Am]*. 1998;80: 25–32.
18. Goulet C, Régnier G, Valois P, Ouellet G. Injuries and risk taking in alpine skiing. In: Johnson RJ, Zucco P, Shealy JE, eds. *Skiing Trauma and Safety*, 13th vol. ASTM STP 1397. West Conshohocken, PA: American Society for Testing and Materials; 2000:139–146.
19. Shealy JE. Comparison of downhill ski injury patterns—1978–81 vs. 1988–90. In: Johnson RJ, Mote CD Jr, Zelcer J, eds. *Skiing Trauma and Safety*. Ninth International Symposium, ASTM STP 1182. Philadelphia: American Society for Testing and Materials; 1993:23–32.
20. Boldrino C, Furian G. Risk factors in skiing and snowboarding in Austria. In: Johnson RJ, ed. *Skiing Trauma and Safety*, 12th vol. ASTM STP 1345. West Conshohocken, PA: American Society for Testing and Materials; 1999:166–174.
21. Bouter LM, Knipschild PG. Behavioral risk factors for ski injury: problem analysis as a basis for effective health education. In: Mote CD Jr, Johnson RJ, eds. *Skiing Trauma and Safety*. Eighth International Symposium, ASTM STP 1104. Philadelphia: American Society for Testing and Materials; 1991:257–264.
22. Goulet C, Régnier G, Grimard G, Valois P, Villeneuve P. Risk factors associated with alpine skiing injuries in children: a case-control study. *Am J Sports Med*. 1999;27:644–650.
23. Bally A, Bonjour F. An investigation into ski injuries and equipment in Switzerland: objectives, means, and observations. In: Johnson RJ, Mote CD Jr, Binét M-H, eds. *Skiing Trauma and Safety*, 7th International Symposium, ASTM STP 1022. Philadelphia: American Society for Testing and Materials; 1989:51–62.
24. Shealy JE, Ettlinger CF. Gender-related injury patterns in skiing. In: Mote CD Jr, Johnson RJ, Hauser W, et al., eds. *Skiing Trauma and Safety*, 10th vol. ASTM STP 1266. Philadelphia, PA: American Society for Testing and Materials; 1996:45–57.
25. Hauser W, Asang E, Müller B. Injury risk in alpine skiing. In: Johnson RJ, Mote CD Jr, eds. *Skiing Trauma and Skiing Safety*, Fifth International Symposium, ASTM STP 860. Philadelphia: American Society for Testing and Materials; 1985:338–348.
26. Shealy JE, Ettlinger CF, Johnson RJ. What do we know? Things that we ought to know but may have forgotten about ski injury research that

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.

relates to binding function, knee and lower leg injuries [Abstract]. *Knee Surg Sports Traumatol Arthrosc*. 2002;10:389.
27. Laporte J, Bally A, Binet M-H. Why have standards for ski binding settings been modified in France [Abstract]. *Knee Surg Sports Traumatol Arthrosc*. 2002;10:388.
28. Levy AS, Hawkes AP, Hemminger LM, Knight S. An analysis of head injuries among skiers and snowboarders. *J Trauma*. 2002;53:695–704.
29. Matsumoto K, Miyamoto K, Sumi H, Sumi Y, Shimizu K. Upper extremity injuries in snowboarding and skiing: a comparative study. *Clin J Sport Med*. 2002;12:354–359.
30. Shealy JE, Ettlinger CF, Buonomo V. Epidemiology of snowboarding injuries: 1988 to 1995. In: Johnson RJ, Mote CD Jr, Ekeland A, eds. *Skiing Trauma and Safety*, 11th vol. ASTM STP 1289: West Conshohocken, PA: American Society for Testing and Materials; 1997:49–59.
31. Shealy J. Snowboard vs. downhill skiing injuries. In: Johnson RJ, Mote CD Jr, Zelcer J, eds. *Skiing Trauma and Safety*. Ninth International Symposium, ASTM STP 1182. Philadelphia: American Society for Testing Materials; 1993:241–254.
32. Machold W, Kwansy O, Eisenhardt P, et al. Reduction of severe wrist injuries in snowboarding by an optimized wrist protection device: a prospective randomized trial. *J Trauma*. 2002;52:517–520.
33. Rønning R, Rønning I, Gerner T, Engebretsen L. The efficacy of wrist protectors in preventing snowboarding injuries. *Am J Sports Med*. 2001;29:581–585.
34. Archambault M, Audet S, Morin J. *Étude économique et financière des stations de ski du Québec: Saison 1999–2000*. Montreal: Chaire de Tourisme–University of Québec at Montreal; 2000.
35. Archambault M, Audet S, Morin J. *Étude économique et financière des stations de ski du Québec: Saison 1995–1996*. Montreal: Chaire de Tourisme–University of Québec at Montreal; 1996.

© 2004 Lippincott Williams & Wilkins

Copyright © Lippincott Williams & Wilkins. Unauthorized reproduction of this article is prohibited.