

# Risk Factors Associated with Serious Ski Patrol-reported Injuries Sustained by Skiers and Snowboarders in Snow-parks and on Other Slopes

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## ABSTRACT

**Background:** Over the past years, the rate of injuries sustained at the alpine ski hills in Québec significantly increased. This raises concern over a possible increase in risk of severe injuries associated with snow-park use. The main objective of this study was to examine the severity of injuries sustained by skiers and snowboarders in snow-parks compared with other slopes from 2001 to 2005.

**Methods:** A case-control study design was used. Subjects were injured skiers and snowboarders who reported to the ski patrol with an injury. Two sets of severely injured cases were defined based on the type of injury and ambulance evacuation. Injured controls were those who did not sustain severe injuries. 50,593 injury report forms were analyzed. A logistic regression analysis was performed to relate the severity of injury to the type of slope used when the injury occurred. All analyses were controlling for age, sex, skill level, helmet use, season, and type of activity.

**Results:** There was evidence to suggest that, for skiers (adjusted OR = 1.36; 95% CI: 1.21-1.53) and snowboarders (adjusted OR = 1.14, 95% CI: 1.05-1.23), participation in a snow-park increased the risk of being evacuated by ambulance. Severe injuries in skiers were also more likely to occur in snow-parks, but snowboarders had similar risk of severe injury in snow-parks and on other slopes.

**Conclusions:** These results provide evidence that the type of activities performed in snow-parks may increase the risk of sustaining a severe injury compared with participation on other slopes.

**MeSH terms:** Athletic injuries; snow sports; skiing; case-control studies; risk factors

*La traduction du résumé se trouve à la fin de l'article.*

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Alpine skiing and snowboarding are two of the most popular winter sports in Québec (population 7.5 million), with an estimated 995,000 participants, 83 stations in operation, and 6 to 7 million visits registered every season.<sup>1</sup> Unfortunately, from 1995 to 2000, the rate of injury increased from 0.91 to 1.36 injuries per 1000 outings in Québec.<sup>2</sup> There was also a steady increase in the rate of injury with younger age (12-17 years).<sup>2</sup>

The increase in the rate of injuries coincides with an increase in the number of ski areas where snow-parks are available, suggesting an association between these areas and increased risk.<sup>2-4</sup> Snow-parks are specific areas of the slopes where terrain is modified to accommodate acrobatic maneuvers. Modules such as rails, boxes, tables, jumps or half-pipes can be found in snow-parks. The objectives of this investigation were to examine the associations between some risk factors and serious injuries, and the body region injured by skiers and snowboarders in snow-parks compared with other slopes.

## METHODS

### Data source

All subjects of this study were injured skiers and snowboarders who reported to the ski patrol at a ski station in Québec with an injury sustained in a snow-park or another slope during the seasons from 2001-2002 to 2004-2005. The methods used for data collection respected the dispositions of two provincial statutes.<sup>5,6</sup>

The injury data were based on ski patrol reports. In Québec, a law requires that every individual undergo a structured program of first aid education to qualify for the ski patrol and that all ski hills complete a standard injury report form when ski patrollers are asked to treat an injury.<sup>6</sup>

The ski areas are also required to send their ski patrol injury reports to the Québec Ministry of Education, Leisure, and Sport. Although this requirement has been in place since 1988,<sup>6</sup> not all ski hills comply every year. For this reason, and because not all skiing and snowboarding injuries get reported to the ski patrol,<sup>7-9</sup> the number of injury reports received will underestimate the total number of injuries sustained at the Québec ski stations.

## Definitions

### Cases

Two sets of cases based on the severity of the injury were defined: 1) those who suffered from a severe injury classified according to the type and body region of injury based on the opinion of emergency clinicians, as defined in Table I;<sup>10</sup> 2) those evacuated by ambulance (evacuation by ambulance or medical referral has been used in other studies using ski patrol injury report data to define potentially severe injuries<sup>11-14</sup>).

### Controls

Controls were those injured skiers and snowboarders who did not have severe injuries as defined previously.

### Body regions

Four body regions of injury were categorized: 1) head-neck, 2) trunk, 3) upper extremity, 4) lower extremity.

### Data analysis

Logistic regression analyses were performed independently for each set of cases to relate the severity of injury to the different risk factors studied. Other logistic regression analyses were used to examine the associations between the type of hill where the injury occurred (snow-park vs. other), the type of activity, the body region injured, and the severity of the injury. To obtain valid estimates, odds ratios were adjusted for age, sex, helmet use, season, type of activity, and skill level (beginner/intermediate, expert). We also examined the interaction between type of activity and type of hill on the risk of injury.

All logistic regression models were constructed with SAS statistical software.<sup>15</sup> The data were also analyzed using Multi-Level models, with the MLwiN statistical software,<sup>16</sup> and Generalized Estimating Equations<sup>17</sup> with SAS statistical software,<sup>15</sup> accounting for potential season and ski area effects.

## RESULTS

The proportion of ski areas contributing reports ranged from 80% in the 2004-2005 season to 86% in the 2003-2004 season. Those ski areas contributing reports represent between 96% and 98% of the total Québec visits to ski areas.<sup>18</sup> Only

**TABLE I**

### Severe Injuries Based on Clinical Opinions\*

Type of Injury	Body Region Injured
Compound fracture	Head Arm, forearm, elbow, wrist, hand, thumb Cervical, dorsal, lumbar spine Shoulder blade, collar bone, thorax, ribs, hip-pelvis Thigh, knee, lower leg, ankle, foot
Simple fracture	Head Cervical, dorsal, lumbar spine Hip-pelvis
Any fracture	Neck
Dislocation	Cervical, dorsal, lumbar spine Hip-pelvis Elbow
Internal injury	Knee Abdomen, thorax
Concussion	Head
Burn	Head
Cut	Face, head, nose, mouth Eye

\* Adapted from Lipskie<sup>10</sup>

injury report forms where all the characteristics of interest were recorded were analyzed (n=50,593 reports; 94% of reports received).

### Severe injuries

No significant contributions to overall variation were found when data were analyzed using Multi-Level models,<sup>16</sup> and Generalized Estimating Equations.<sup>17</sup> Therefore these analyses are not reported here.

The results presented in Table II show that the older age groups were more at risk of sustaining a severe injury and being evacuated by ambulance. Compared with skiers, snowboarders were less likely to be evacuated by ambulance (adjusted odds ratio [AOR] = 0.92; 95% confidence interval [CI]: 0.87-0.97), but more likely to suffer from a severe injury (AOR = 1.55; 95% CI: 1.45-1.66). Snow-park injuries were more likely to require ambulance evacuation (AOR = 1.26; 95% CI: 1.17-1.35) and be severe (AOR = 1.12; 95% CI: 1.04-1.21) than other slope injuries. Experts were more likely to be severely injured (AOR = 1.22; 95% CI: 1.14-1.31) than beginners/intermediates.

### Snow-park injuries

The interactions between the type of activity and the type of hill are presented in Figure 1. When skiers (AOR = 1.36; 95% CI: 1.21-1.53) and snowboarders (AOR = 1.14; 95% CI: 1.05-1.23) were injured in snow-parks, they were more likely to be evacuated by ambulance than skiers injured on other slopes. For severe injuries, the interaction was significant (p<0.001)

indicating that skiers injured in snow-parks (AOR = 1.50; 95% CI: 1.30-1.73) and snowboarders injured on both other slopes (AOR = 1.66; 95% CI: 1.55-1.79) and in snow-parks (AOR = 1.69; 95% CI: 1.57-1.82) were more likely to be severely injured compared with skiers on regular slopes.

For skiers, the proportion of head or neck injuries was greater in snow-parks (AOR = 1.35; 95% CI: 1.22-1.50). For skiers (AOR = 1.82; 95% CI: 1.58-2.09) and snowboarders (AOR = 1.37; 95% CI: 1.25-1.50), the proportion of trunk injuries was greater in snow-parks, while the proportion of lower-extremity injuries was lower for skiers (AOR = 0.62; 95% CI: 0.57-0.68) (Table III).

Combining injury severity and body region for snowboarders (Table III), the risk of sustaining a more severe injury was increased in snow-parks, if the injury affected the upper extremity (AOR = 1.45; 95% CI: 1.25-1.68), or the lower extremity (AOR = 1.26; 95% CI: 1.05-1.51). For skiers, when an injury occurred to the head or neck (AOR = 1.21; 95% CI: 1.01-1.45), there was evidence that the risk of sustaining a more severe injury was increased in snow-parks (Table III).

## DISCUSSION

This study suggests that participation in a snow-park increases the risk of being evacuated by ambulance; however, the relation for injuries classified as severe based on injury type and body region is less clear for snowboarders. Other factors related to a greater risk of one of these outcomes

TABLE II

Selected Characteristics of Cases and Injured Controls, Injury Event, and Results of the Regression Analyses, or Odds of Sustaining a Severe Injury for Skiers and Snowboarders, Québec, Canada, 2001-2005

Characteristics	Ambulance			Type of Injury		
	Evacuated No. (%)	Not Evacuated No. (%)	Adjusted OR (95% CI)*	Severe Injury† No. (%)	Not Severe Injury No. (%)	Adjusted OR (95% CI)*
Sex						
Male	4218 (13.3)	25,493 (86.7)	1.03 (0.98-1.09)	3043 (10.2)	26,668 (89.8)	0.98 (0.92-1.05)
Female	2777 (14.2)	18,105 (85.8)	1 (Reference)	1932 (9.3)	18,950 (90.8)	1 (Reference)
Age (years)						
<12	1116 (11.9)	8243 (88.1)	1 (Reference)	699 (7.5)	8660 (92.5)	1 (Reference)
12-17	3253 (14.6)	19,051 (85.4)	1.23 (1.14-1.33)	2352 (10.6)	19,952 (89.5)	1.21 (1.11-1.33)
18-34	1552 (13.5)	9940 (86.5)	1.12 (1.03-1.23)	1281 (11.2)	10,211 (88.9)	1.33 (1.20-1.47)
≥35	1074 (14.4)	6364 (85.6)	1.22 (1.12-1.34)	643 (8.6)	6795 (91.4)	1.27 (1.13-1.42)
Activity						
Alpine skiing	3661 (13.9)	22,658 (86.1)	1 (Reference)	2046 (7.8)	24,273 (92.2)	1 (Reference)
Snowboarding	3334 (13.7)	20,940 (86.3)	0.92 (0.87-0.97)	2929 (12.1)	21,345 (87.9)	1.55 (1.45-1.66)
Hill type						
Snow-park	1520 (16.2)	7839 (83.8)	1.26 (1.17-1.35)	1146 (12.2)	8213 (87.8)	1.12 (1.04-1.21)
Other slopes	5475 (13.3)	35,759 (86.7)	1 (Reference)	3829 (9.3)	37,405 (90.7)	1 (Reference)
Skill level						
Beginner/int.	5339 (13.5)	34,181 (86.5)	1 (Reference)	3670 (9.3)	35,850 (90.7)	1 (Reference)
Expert	1656 (15.0)	9417 (85.0)	1.05 (0.99-1.12)	1305 (11.8)	9768 (88.2)	1.22 (1.14-1.31)
Helmet use						
Yes	1041 (13.4)	6702 (86.6)	1 (Reference)	883 (11.4)	6860 (88.6)	1 (Reference)
No	5954 (13.9)	36,896 (86.1)	1.03 (0.95-1.12)	4092 (9.6)	38,758 (90.5)	0.93 (0.85-1.02)
Season						
2001-2002	1674 (14.1)	10,162 (85.9)	1 (Reference)	1051 (8.9)	10,785 (91.1)	1 (Reference)
2002-2003	1772 (13.9)	10,994 (86.1)	0.97 (0.90-1.04)	1142 (9.0)	11,624 (91.0)	1.00 (0.92-1.09)
2003-2004	1694 (13.5)	10,881 (86.5)	0.93 (0.87-1.01)	1225 (9.7)	11,350 (90.3)	1.08 (1.00-1.19)
2004-2005	1855 (13.8)	11,561 (86.2)	0.98 (0.90-1.05)	1557 (11.6)	11,859 (88.4)	1.29 (1.18-1.41)

\* OR, odds ratio; CI, confidence interval. Adjusted for all other characteristics in the table.

† Severe injury as defined in Table I.

TABLE III

Characteristics of Reported Injuries Sustained by Skiers and Snowboarders in Snow-parks and on Other Slopes, and Results of the Logistic Regression Analyses, or Odds of Sustaining an Injury in a Snow-park, Québec, Canada, 2001-2005

Characteristics	Alpine Skiing			Snowboarding		
	Snow-park No. (%)	Other Slopes No. (%)	Adjusted OR (95% CI)*	Snow-park No. (%)	Other Slopes No. (%)	Adjusted OR (95% CI)*
Body region†						
Head and neck	611 (26.2)	4436 (18.2)	1.35 (1.22-1.50)	1595 (22.7)	3783 (21.9)	1.00 (0.93-1.07)
Trunk	297 (12.7)	1675 (6.9)	1.82 (1.58-2.09)	896 (12.8)	1756 (10.2)	1.37 (1.25-1.50)
Upper extremity	666 (28.6)	5524 (22.6)	1.12 (1.02-1.24)	3744 (53.3)	9042 (52.4)	1.00 (0.94-1.06)
Lower extremity	940 (40.3)	14,317 (58.6)	0.62 (0.57-0.68)	1408 (20.0)	3833 (22.2)	0.94 (0.87-1.01)
Severity‡ and body region§						
Head and neck	274 (44.8)	1803 (41.4)	1.21   (1.01-1.45)	812 (50.9)	2052 (54.2)	0.95   (0.84-1.08)
Trunk	145 (48.8)	776 (47.3)	1.15   (0.88-1.49)	470 (52.5)	890 (50.7)	1.10   (0.92-1.30)
Upper extremity	63 (9.5)	541 (10.0)	0.98   (0.74-1.31)	376 (10.0)	577 (6.4)	1.45   (1.25-1.68)
Lower extremity	144 (15.3)	1729 (12.3)	1.13   (0.94-1.44)	240 (17.1)	539 (14.1)	1.26   (1.05-1.51)

\* OR, odds ratio; CI, confidence interval. Adjusted for age, sex, skill level, helmet use, and season.

† Proportions (%) are calculated for all injuries.

‡ Severe injury as defined in Table I or evacuation by ambulance.

§ Proportions (%) are calculated for all injuries of each body region.

|| Controls are non-severe injuries of each body region. That is, for each body region, severe injuries are compared to non-severe injuries for frequency of snow-park vs. other slope injuries.

included age 12 and older, snowboarding, higher skill level, and participation in a more recent season. The results also suggest that skiers were more likely to sustain any type of head or neck injuries and severe head or neck injuries in a snow-park than on other slopes. Snowboarders were more likely to sustain severe extremity injuries in snow-parks compared with other slopes.

The increased risk of severe injuries and the type of injury in snow-parks was probably linked to the nature of participation

in these areas. Indeed, the modules constructed in snow-parks favour acrobatic maneuvers as evidenced by the greater proportion of participants injured jumping compared with other slopes (37% vs. 4%, data not shown). Tarazi et al. noted that an intentional jump over two metres contributed to 20% of skier and 77% of snowboarder severe spinal injuries.<sup>19</sup> Similarly, a Japanese study found that jumps of over one metre resulted in an increased risk of spinal cord injuries for skiers and snowboarders.<sup>20</sup> The higher energy transfer dur-

ing the landing phase of a jump may contribute to increasing the risk of severe injury, and this risk may affect skiers and snowboarders differently given the greater risk of severe head injuries in skiers and severe extremity injuries in snowboarders.

The results of this study also suggest that the risk of serious injury was higher for experts and older participants (Table II). It could be that experts and older participants move faster and take more risks, as was shown for expert skiers.<sup>21</sup> These behaviours could lead to higher energy transfer during

crashes. Further studies are required to test these hypotheses.

When they were injured, snowboarders were less likely to be evacuated by ambulance than skiers (Table II, Figure 1). This could be explained by the fact that snowboarders were more frequently injured to the upper extremities and skiers to the lower extremities (Table III). Upper-extremity injuries interfere less with ambulation.

Since there are no standards on the design and the maintenance of the snow-parks in Québec, we suggest that some attention be given to this issue in further studies. As suggested for playground equipment standards,<sup>22</sup> the development and implementation of such standards may contribute to the reduction of the risk of severe injuries in snow-parks.

## Limitations

### Selection Bias

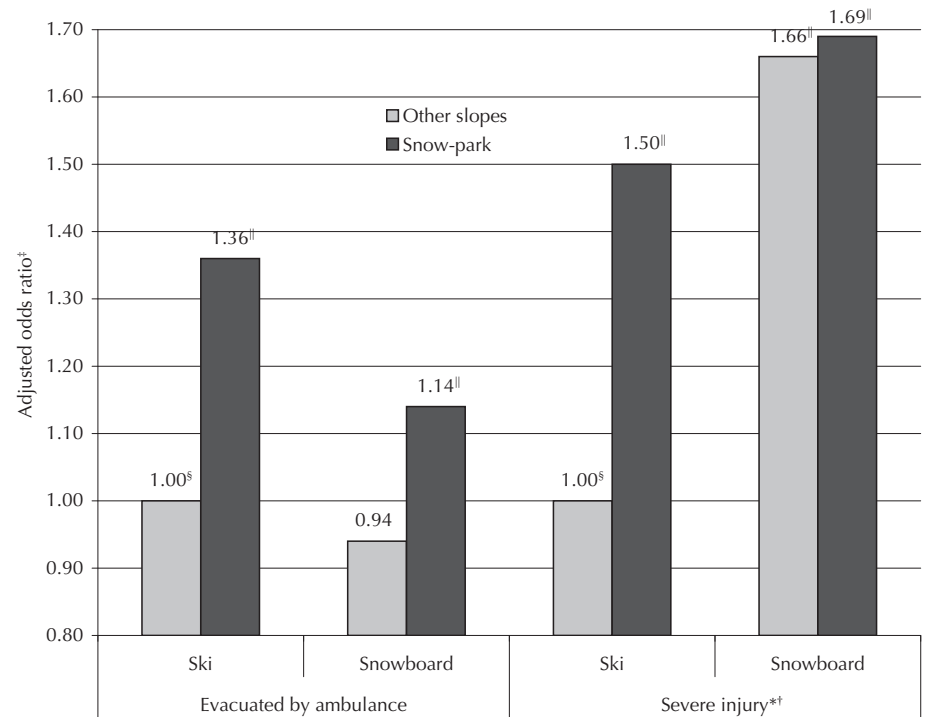
Not all skiing and snowboarding injuries are reported to the ski patrollers.<sup>7-9</sup> Injuries are probably more likely to be reported if they are serious, interfere with ambulation,<sup>7</sup> are sustained by females,<sup>7-9</sup> are sustained by children,<sup>7-9</sup> or are sustained by lower ability-level participants.<sup>7</sup> These problems affect any studies that are not focused on closed (i.e., cohort) populations but instead rely on presentation of injuries to the ski patrollers or medical facilities. However, there is no reason to believe that this bias would differentially affect injuries sustained in snow-parks compared with injuries sustained on other slopes.

Not all ski hills send their injury report forms to the Québec Ministry of Education, Leisure, and Sport. However, there is no reason to believe that respondents are significantly different from non-respondent ski hills to affect comparisons for type of hill, severity, type of activity, sex, skill level, season, and helmet use.

### Misclassification Bias

Accuracy of data on ski patrol reports can vary but Hagel et al. reported a moderate to almost perfect agreement between injury report forms and self-reported risk factor information.<sup>23,24</sup>

Some subjects evacuated by ambulance were included in the not severe injury con-



**Figure 1.** Results of the interaction between the type of activity and the type of hill for both indicators of severe injury

\* Severe injury as defined in Table I.

† Interaction significant at  $p < 0.0001$ .

‡ Adjusted for age, sex, skill level, helmet use, and season.

§ Reference.

|| Different from the reference at  $p < 0.05$

trol group ( $n=4,586$ ) and some cases of severely injured subjects were included in the not evacuated by ambulance injured control group ( $n=2,566$ ). Therefore, the estimates reported in this paper could be considered underestimates.

The interactions between the type of activity and the type of hill shows that snowboarders were more likely to sustain an injury requiring evacuation by ambulance when the injury occurred in a snow-park, but they had the same risk of sustaining a severe injury in a snow-park and on other slopes (Figure 1). More information regarding the nature of the injury would be needed to better understand the situation. But, it could also be hypothesized that our indicator of severe injury is not sensitive enough to the gravity of the injury. It could be that for snowboarders, the same type of severe injuries are sustained in snow-park (compound wrist fracture, for example), but the gravity of this injury (duration of activity limitation, for example) would be greater. This type of information is not available on the actual injury report forms.

### Confounding Bias

The increased risk of severe injuries observed in snow-parks cannot be fully explained by the age, the sex, self-reported skill level, type of activity, the use or non-use of a helmet, or season. Indeed, all the estimations produced by the statistical models were adjusted for these variables. As mentioned previously, these results suggest that the type of maneuvers performed in snow-parks increase the risk of severe injuries compared with injuries sustained on other slopes. However, further studies are needed to compare the circumstances and mechanisms of injuries sustained in snow-parks and on other slopes.

## CONCLUSIONS

The results of this study suggest that, for skiers and snowboarders, the type of activities or maneuvers performed in snow-parks may increase the risk of sustaining a serious injury compared with participation on other slopes. However, further research is needed to identify the factors influencing this difference and to better understand the characteristics of potentially effective prevention measures.<sup>25</sup>

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## RÉSUMÉ

**Contexte :** Au cours des dernières années, le taux de blessures subies dans les stations de ski alpin du Québec a augmenté significativement. Cette situation est préoccupante et soulève des interrogations quant aux risques de blessures graves associées à la fréquentation des parcs de surf acrobatique. L'objectif général de cette étude était d'analyser la gravité des blessures subies par les skieurs alpins et les planchistes dans les parcs de surf acrobatique, comparativement aux blessures survenues sur les autres pistes, de 2001 à 2005.

**Méthode :** Une étude cas-témoins a été réalisée. Les sujets étaient les skieurs et planchistes s'étant présentés à des pisteurs secouristes avec des blessures. Deux types de cas ayant subi des blessures graves ont été définis, selon le type de blessure et la nécessité d'évacuer le blessé par ambulance. Les témoins étaient les skieurs et planchistes dont les blessures n'étaient pas graves. Les données de 50 593 rapports de blessure ont été analysées. Par régression logistique, nous avons étudié la relation entre la gravité des blessures et le type de pentes où elles s'étaient produites. Toutes les estimations ont été ajustées selon le sexe, l'âge, le niveau d'habileté, le type d'activité pratiquée au moment de la blessure, le port du casque et la saison.

**Résultats :** Pour les skieurs (rapport de cotes ajusté = 1,36; IC de 95 % = 1,21-1,53) et les planchistes (RC ajusté = 1,14, IC de 95 % = 1,05-1,23), la pratique d'activités dans les parcs de surf acrobatique augmentait le risque d'être évacué par ambulance. Pour les skieurs, le risque de blessure grave était plus grand dans ces parcs, tandis que pour les planchistes, ce risque était le même dans les parcs de surf acrobatique et sur les autres pistes.

**Interprétation :** Les résultats de cette étude suggèrent que, comparativement aux blessures qui surviennent sur les autres pistes, les activités et les manœuvres que l'on pratique dans les parcs de surf acrobatique peuvent accroître le risque de subir une blessure grave.