

Risk Factors Associated With Alpine Skiing Injuries In Children

A Case-Control Study

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ABSTRACT

We investigated the relative contribution of four risk factors to the occurrence of injuries among alpine skiers aged 12 years and younger (3 to 12 years old; mean age, 9.43 years). The risk factors selected were deficient binding adjustment, absence of formal training, low skill level, and use of rented equipment. A group of injured skiers ($N = 41$) and a control group of uninjured skiers ($N = 313$) were recruited among young skiers at one major alpine ski center in the Québec City, Canada, area during the 1995 to 1996 season. No significant group differences were found for mean age or sex distribution. The adjusted odds ratios for injury were 7.54 (95% confidence interval [2.57, 22.15]) for skiers in the low level of skill category relative to highly skilled skiers, 7.14 (2.59, 19.87) for skiers who rented their ski equipment compared with skiers who owned their equipment, and 2.11 (1.02, 4.33) for skiers with ill-adjusted bindings compared with skiers with better-adjusted bindings. Only formal training did not meet the 0.05 significance level for entry into the model; this is probably because of methodologic limitations. Implications of these results for the development of a prevention program aimed at young skiers are discussed.

Alpine skiing is one of the most popular sports in the Canadian province of Québec (population 7 million), with

an estimated 800,000 participants, 92 centers in operation, and around 6 million skier-days registered every year.¹ Unfortunately, injuries treated by a ski patrollers on the slopes occur at a rate of 1.61 per 1000 skier-days.¹ This makes alpine skiing second only to ice hockey in terms of number of injuries in Québec.²⁹

Children aged 12 years and younger are overrepresented among patients with ski injuries in Québec.^{16,30} For example, during the 1992 to 1993 season, the percentage of injured children among the injured skiers (23.7%) was 1.86 times higher than the percentage of children among all skiers (12.7%).¹⁶ This overrepresentation of children has been observed in most of the other countries where alpine skiing is popular.^{2,5-7,15,20,26,27}

It has been suggested that the development of a tailor-made prevention program aimed at younger children (12 years and younger) would significantly contribute to the reduction of skiing injuries among this age group.^{4,23} Systematic planning of a skiing injury prevention program includes analyzing the magnitude of the problem and the behavioral risk factors, studying behavioral determinants, designing an optimal intervention, and implementing the intervention.²³ For most sports, there seems to be a strong need for further research on the origins and determinants of behavior before effective prevention can be implemented.²³

The concept of "behavior determinants" deserves further explanation. To manipulate demonstrated behavioral risk factors in a prevention program, it is important to find the origins or determinants of such behaviors. For example, if it is found that "not having taken ski lessons" increases the risk of injury among children, the next step should be to examine why some parents do not insist on formal ski training for their child. Some insight into such determinants of behavioral risk factors might be found in the parents' perception of what is considered "dangerous" for children in alpine skiing. The parents might underes-

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itimate important risk factors. A literature review, completed in a recently published report reviewing the effectiveness of injury countermeasures in alpine skiing,²² revealed the following four risk factors as worthy of further study: deficient binding adjustment, absence of formal training, low skill level, and use of rented equipment. A prevention program that raises the level of awareness of these factors for the safety of the children might represent an important first step in modifying the situation.

Deficient Binding Adjustment. The most documented risk factor for childhood ski injuries is the improper adjustment of bindings. Many authors have reported that bindings in poor condition or that are poorly adjusted are associated with a significantly increased risk of injuries for young skiers, especially injuries to the lower extremities.^{2, 6, 7, 20, 35, 36} A rigorous scientific evaluation of the effectiveness of a prevention program aimed at improving the quality of binding adjustment has also been previously suggested.⁵

Before developing and implementing a prevention program based on improving binding adjustment, it is important to demonstrate that an improper binding adjustment is associated with an increased risk of injury among young Québec skiers and that there are a significant number of young "Québécois" skiing with improperly adjusted bindings. The quality of ski binding adjustments of young skiers in Québec has not been well described.

Absence of Formal Training. The literature is less conclusive as to the risk of skiing without having received formal training in the form of ski lessons. At least two studies suggest that the risk of injury for children is increased by not having received any formal ski lessons,^{10, 32} whereas other studies have reported no difference.^{4, 31} Shealy et al.³³ concluded that the rapid skill acquisition through lessons when not coupled with much skiing experience was not sufficient for reducing the injury rate. Garrick and Requa¹⁴ argued that skiers appear to be in a paradoxical situation whereby they can ski more safely if they are better skiers, but rapidly gaining that expertise through lessons may mean an increase, although probably temporary, in injuries. Johnson and Pope²¹ consider "that rapid acquisition of skiing ability probably increases the risk of injury to relatively inexperienced skiers by allowing them to descend terrain which is more difficult than they would otherwise attempt until much later in their skiing careers." In Québec, the proportion of young skiers who have taken formal ski lessons is unknown.

Low Skill Level. The lack of experience and a low level of technical skill are two factors intuitively considered as risk factors for children. Garrick and Requa¹³ and Blitzer et al.² have found that skiers with less skill or experience have a higher incidence of injury compared with more experienced skiers or a control group of skiers. Two Australian studies of injury in young skiers concluded that less ability is a risk factor.^{15, 34} The injury rate for beginner or novice skiers has been reported to be as high as 9 or 10 times that of advanced or expert skiers.^{10, 31}

Although often considered indissociable, experience and skill have been demonstrated to have independent effects

on injury incidence.^{14, 19, 33} For example, Garrick and Requa¹⁴ and Hauser¹⁹ observed that more experienced skiers fall less and get injured less often, even if they remain at a low level of ability. "This decrease [in injury rates] appears to occur regardless of whether that skiing experience has resulted in an increase in expertise. For example as a general rule, the beginning skier skis more safely his fifth year than in his first year, regardless of the fact that he still classes himself as a 'beginner'."¹⁴ On the other hand, Ungerholm and Gustavsson³⁶ have shown that low skill level skiers aged 16 or younger are injured more often than highly skilled young skiers, regardless of their respective level of experience. Ekeland et al.⁷ reported the same findings for a group of skiers of all ages. In the present study, we will consider the influence of low skill level, since it is an element that can be addressed by a prevention program, whereas experience cannot.

Use of Rented Equipment. It has been suggested that equipment (skis, boots, bindings) not well-adapted or well-adjusted to the child skier could increase the risk of injuries.^{2, 6, 7, 25} Along these lines, and considering that there is no specific standard on shop practices in force in Québec, it seems reasonable to hypothesize that the use of rented equipment, as opposed to equipment belonging to the skier, would increase the risk of injury for a young skier. The quality of operations in rental shops is also a factor that could be addressed by a prevention program in the event that it was shown to be associated with increased risk of injury.

Objectives of the Study

The first objective of the present study was to investigate the relative contribution of four selected risk factors to the occurrence of injuries among alpine skiers aged 12 years and younger (3 to 12 years old). The risk factors under study are factors that could be modified through a prevention program. Thus, no environmental factors such as snow conditions or temperature were selected. Psychological factors such as risk-taking attitude were also not selected in view of the difficulties faced when trying to modify them in a short period.²⁷ We also attempted to document the prevalence of potential risk factors among young skiers in Québec. These results should be helpful in designing a prevention program for this population.

MATERIALS AND METHODS

Subjects and Setting

A total of 387 skiers aged 12 years and younger (mean age, 9.43 ± 2.24) were recruited at one major alpine ski center in the Québec City area during the 1995 to 1996 season (from November 1995 to April 1996).

Design

A group of injured skiers ($N = 41$) and a control group of uninjured skiers ($N = 346$) were collected among young skiers aged 12 years and younger. The "injured" group

included skiers treated by a ski patroller for an injury suffered on the slopes. Skiers in the control group were selected at random at different periods of the week and of the season among young skiers who had never suffered an injury resulting in a medical consultation or a first-aid intervention. The data collection procedure is described later.

Variables Measured

Data were collected on the following variables: age, sex, skill level, binding adjustment, formal training, and ownership of equipment. Except for binding adjustment, all data were collected through a questionnaire sent to parents.

Skill Level. The questions were designed to guard against the possibility of parents overrating the child's level of ability. Hence, instead of asking the parents to rate their child as either a beginner, an intermediate, or an expert skier, questions were asked as to the technique most often used and as to the level of difficulty of slopes most often frequented. More precisely, the parents first answered the following question: "The last time your child went skiing, how often was he/she skiing in easy, difficult, very difficult and most difficult slopes?" For each type of slope, the choices offered were always (1), often (2), sometimes (3), and never (4). Answers to the four questions were averaged to create a "Skill Level Index" ranging from 1 (low level of skill) to 4 (highly skilled). The Skill Level Index manifested a high level of reliability (Cronbach's $\alpha = 0.84$).

The parents were then asked to rate the skiing technique of their child on a four-point scale: "How would you describe the skiing technique of your child?" The choices offered were 1) makes all his or her turns in snowplow, 2) makes turns combining parallel and snowplow technique, 3) makes parallel turns on easy (green circle) and difficult (blue square) slopes, and 4) always makes parallel turns in all slopes, including moguls. This question was used to validate the Skill Level Index. Good convergent validity ($r = 0.75$) was found between the Skill Level Index and this rating. This suggests that the Skill Level Index is a good indicator of the real level of skiing ability of our sample of young skiers.

Formal Training. Considering 1) time constraints for completion of the questionnaires, 2) the difficulty for the parents to correctly estimate the number of hours of experience and the number of hours of lessons taken during the last few years, and 3) the difficulty in differentiating hours of lessons versus hours of experience,¹⁴ we judged that it was preferable to use a yes-or-no question simply indicating the subjects' exposure to a formal skill-learning process. In other words, the aim of this question was simply to evaluate if receiving basic notions of skiing techniques reduces the risk of injury. Therefore, formal training was measured by asking the parents if their child had ever had a ski lesson.

Ownership of Equipment. This was measured by asking the parents if their child owns his or her ski equipment. The answer was again a simple "yes" or "no."

Binding Adjustment. It has been suggested that to be effective, ski bindings should be adjusted through the use of binding testing machines.^{6,8,9,12,28} In Québec, binding testing machines are not easily available. Therefore, skiers and ski shop professionals have to use the release indicators as their only reference to adjust bindings. Considering the fact that binding testing machines are not easily available, we believe that the first step toward safety is to make sure that release indicators are set according to the standards. This was measured by comparing the release value observed on the bindings (release indicator) to the recommended value suggested by the manufacturer according to ISO IIO88 standard. This measure was selected to be representative of the Québec situation.

For skiers in the injured group, measurements of the release value were taken directly by ski patrol members specifically trained for the task. For skiers in the control group, the task was performed by a research assistant. The score used for analyses was the absolute discrepancy (in percentage) between the release value observed on the binding (observed adjustment [OA]) and the release value suggested by the manufacturer according to ISO IIO88 standard (recommended adjustment [RA]). The "weight method" (as opposed to the "tibia diameter method") was used for calculations, and the following parameters were considered to determine the recommended adjustment for each subject: age, weight, height, skill level, and length of boot sole. In view of the high correlation coefficient between measurements taken on the four bindings (forward, rear, left ski, right ski) ($r = 0.9$, $P < 0.001$), the mean of the four measurements was used as the value for the observed adjustment. The quality of the binding adjustment is thus expressed by the following equation: Percentage of discrepancy from the recommended setting equals $(|OA - RA|)/RA \times 100$.

Boldrino et al.³ suggest that a discrepancy of 20% or more between the recommended value and the observed settings represent the critical tolerance level. "The 'ISO IIO88' defines a tolerance of $\pm 15\%$. However, another recommended tolerance is $\pm 10\%$, listed in the foreword to 'ÖNORM-ISO IIO88' used in Austria. To suit the modern bindings, which allow a high tolerance, and in order to account for a relevant risk of injury, a release-value is considered tolerable if it differs by up to a maximum of 20% from the recommended value."³

Thus, for analysis purposes, skiers were grouped into two categories: "correct adjustment" when the discrepancy, in absolute value, between observed and recommended adjustments was 20% or less, and "incorrect adjustment" when the discrepancy was over 20%.

Data Collection Procedure

Injured Group. For each injured subject, a ski patrol member, specifically trained for the task, recorded the release value at which the binding was set. This procedure was done according to the protocol developed for this study and previously validated. After having obtained the ac-

companying parents' consent, the questionnaire was sent to the parents or guardians of the injured skier.

Control Group. A research assistant was positioned at the bottom of the slopes and randomly selected skiers coming from slopes of all levels of difficulty. After confirming that the skier was 12 years old or younger and had never suffered from a skiing injury, the assistant explained the objectives of the study to the accompanying parent(s) or guardian(s) and asked for his or her collaboration. If permission was granted, the assistant proceeded with the measurement of the release value of the binding according to the established protocol. The name and address of the accompanying parent(s) or guardian(s) was noted so that the questionnaire could be mailed 1 week later.

Children not accompanied by a parent or guardian were also stopped and asked to participate in the study. This procedure was designed to prevent a sample bias toward younger skiers, who were most likely to always ski with a parent. The unaccompanied children did not take the questionnaire home. The name and address of the subject was noted so that the questionnaire and the consent form could be mailed 1 week later. The consent form presented the aim and the methods of the study; it presented the same information that the research assistant was allowed to give at the ski station. Therefore, parents could judge by themselves the legitimacy of the study and decide whether to participate. Questionnaires were completed in the same conditions for all subjects. Moreover, the methods used respected the dispositions of two provincial statutes, that is, *An Act respecting safety in sports* (R. S. Q., chapter S-3.1) and *An Act respecting access to documents held by public bodies and the protection of personal information* (R. S. Q., chapter A-2.1).

Data Analysis

Complete data were obtained for 41 subjects from the injured group and for 313 subjects from the uninjured group. All statistical analyses were performed on these 354 subjects. A step-wise logistic regression analysis was performed to determine what combination, if any, of potential risk factors were predictive of the skiers' status (injured or uninjured). Initial analyses (analysis of variance and chi-square) were performed to test for group differences of mean age and sex distribution. No significant group differences were found for mean age ($F[1,352] = 1.22, P = 0.27$) and sex distribution (chi-square[1] = 0.094, $P = 0.76$) (Table 1), therefore the stepwise logistic

TABLE 1

Characteristics of the Injured and Uninjured Groups

Characteristic	Injured (N = 41)	Uninjured (N = 313)
Mean age (SD)	9.10 (1.97)	9.51 (2.30)
Sex		
%Male (N)	46.3 (19)	48.9 (153)
%Female (N)	53.7 (22)	51.1 (160)

regression analysis was performed without controlling for age or sex.

RESULTS

The distribution of injuries among the injured skiers is presented in Table 2. The most frequent injuries were fractures and sprains (78%) and the lower limbs were injured more often than the upper limbs.

Descriptive results for each predictive variable are shown in Table 3. Compared with the control group, the injured skiers seemed more likely to be low skilled, to rent their equipment, and to ski with ill-adjusted bindings.

Results of the stepwise logistic regression analysis, including odds ratios, are presented in Table 4. Skill level, equipment ownership, and binding adjustment (in that order) were the most significant predictors of the skiers' status (injured or uninjured). Only formal training did not meet the 0.05 significance level for entry into the model.

Adjusted odds ratios indicated that 1) skiers with a low level of skill were more likely to be injured compared with highly skilled skiers (7.54, 95% confidence interval [2.57, 22.15]); 2) skiers who rented their ski equipment were more likely to be injured than skiers who owned their

TABLE 2
Injuries by Body Part and Nature of Injury

Body part	Nature of injury	N	%
Ankle and foot	Fracture, sprain	4	9.76
	Frostbite	1	2.44
Leg	Fracture, sprain	11	26.83
	Fracture, sprain	8	19.51
Knee	Abrasion, laceration	2	4.88
	Fracture, sprain	6	14.63
Upper limbs	Concussion	1	2.44
Head and neck	Internal trauma	2	4.88
	Abrasion, laceration	1	2.44
Trunk	Fracture, sprain	3	7.31
	Internal trauma	1	2.44
Total	Abrasion, laceration	1	2.44
		41	100.00

TABLE 3

Distribution of Skiers among Injured and Uninjured Groups for Each Predictive Variable

Predictive variables	Class	Injured group (N = 41)	Uninjured group (N = 313)
		N (%)	N (%)
Skill level ^a	High	4 (9.8)	158 (50.5)
	Low	37 (90.2)	155 (49.5)
Formal training	Yes	36 (87.8)	282 (90.1)
	No	5 (12.2)	31 (9.9)
Equipment ownership	Owned	31 (75.6)	304 (97.1)
	Rented	10 (24.4)	9 (2.9)
Binding adjustment	Correct ^b	18 (43.9)	168 (53.7)
	Incorrect	23 (56.1)	145 (46.3)

^a Skill level index ranges from 1 to 4: "low level" = 1 and 2; "high level" = 3 and 4.

^b Observed adjustment is within 20% (over or under) of recommended adjustment.

TABLE 4
Results from the Stepwise Logistic Regression Analysis, or Odds of Being Part of the Injured Group

Risk factor	Coefficient	Standard error	df	P	Odds ratio	95% CI
Low skill level ^a	2.02	0.55	1	0.0002	7.54	2.57–22.15
Rented	1.97	0.52	1	0.0002	7.14	2.59–19.87
Incorrect binding adjustment ^b	0.74	0.37	1	0.0446	2.11	1.02–4.33
Intercept	–6.08	0.81	1	0.0001		

^a Skill level index of 2 or less.

^b Observed release value differs by more than 20% (over or under) from recommended value.

equipment (7.14 [2.59, 19.87]); and 3) skiers with ill-adjusted bindings (discrepancy over 20%) were more likely to be injured than skiers with better-adjusted bindings (2.11 [1.02, 4.33]).

To better understand the relationship between rented equipment and injury, two post hoc analyses were performed. The first one showed that skiers who rent their equipment were less skilled than skiers who owned equipment (*t*-test for unequal variance, $t[32.9] = -11.86$; $P < 0.001$; mean for owners, 2.17 ± 0.71 ; mean for renters, 1.26 ± 0.28). The second post hoc analysis showed that there was no difference in binding adjustment between renters and owners (*t*-test for unequal variance, $t[18.4] = -0.72$; $P = 0.48$; mean for owners, 0.25 ± 0.22 ; mean for renters, 0.33 ± 0.49).

DISCUSSION

Our results show that the occurrence of injury among young skiers, under 13 years old, is unrelated to age or sex. The small size of the injured group did not allow for testing of the hypothesis of a sex-based effect for severe injuries only. The absence of an observed sex-based effect could partly be explained by the fact that skiers under 13 are still preadolescents. This suggests that documented behavioral differences between male and female adolescent skiers on risk taking, and the expected increase in associated injuries, have yet to surface (G. Régnier, C. Goulet, G. Ouellet, unpublished data, 1996).

The aim of the question related to formal training was simply to evaluate if having received basic notions of skiing techniques reduces the risk of injury. As measured in the present study, our results show that it does not. However, no information was gathered on the number, the frequency, and the type of lessons received, nor do we know how long ago the lessons were taken. The simple question “Have you ever taken ski lessons?” might have been too general to discriminate between the injured and the control group as to the benefits of formal training. Close to 90% of subjects in both groups said they had previously taken ski lessons. Future researchers should examine more closely the intensity and the nature of ski training to better understand its effect on injuries.

The absence of an association between injury and formal training could also be explained by the fact that skill level is the most important factor in preventing injuries. It may not be important if the young skier reaches the required skill level through formal ski lessons, through relatives teaching him or her, or through natural ability

alone. Formal ski lessons should rather be viewed as one among several tools available to the parents to raise the level of skill of the young skier. It has also been suggested that lessons should include more information on skiing safety in general²¹ and more specifically on proper use and care of equipment and on proper falling techniques.^{9,11}

Logistic regression analysis revealed three factors that placed skiers more at risk of suffering an injury: having a low level of skill, skiing with ill-adjusted bindings, and skiing with rented equipment. Skiers in the low level of skill category were more likely to be injured compared with highly skilled skiers. Although the experience of the skiers was not considered in our model, it is most probable that highly skilled skiers were also the more experienced. Skiers do not necessarily develop more skills as they ski more often. The obvious solution to counteract this risk factor would be to recommend that “unskilled” skiers improve their skill level. However, some unskilled skiers may have already reached their full potential. Even so, any significant improvement would not be instantaneous. Future researchers should try to identify the circumstances under which low skill level skiers get injured. Preventive strategies could then be developed accordingly for the category of skiers that might remained “unskilled” for a long time.

The skiers with more than a 20% discrepancy between observed and recommended adjustments of their bindings were more likely to be injured compared with skiers with better-adjusted bindings. Even if the bindings are designed to eliminate injuries below the knee and not above that level,¹¹ inadvertent release of bindings is a possible cause of upper extremity or upper body injury. Therefore, all injuries were included in the analysis.

This higher risk of injury related to ill-adjusted bindings is consistent with a prospective study of German skiers of all ages in which it was found that proper binding setting and mounting reduced lower extremity equipment-related injuries by a factor of 3.5.²⁰ Considering that 46% of our control group had ill-adjusted bindings, it could be estimated that 47,840 young Québec skiers significantly raise their risk of injury on the slopes, even though a simple and inexpensive solution is readily available. That is, every skier should have his or her bindings regularly adjusted by a certified technician. Nevertheless, since there is no standard for retail or repair shop practices in effect in Québec, one cannot be assured that their own equipment is set up appropriately, even if it is done regularly.^{3,6,12}

In the present study we assumed that the binding release values recommended in the standards were appropriate for children. However, the charts used in the standards are based on biomechanical experiments conducted with adults. It has been suggested that, because children's bone substance is less brittle and has less ultimate strength than adult bone, children may need more sophistication than adults with regard to release modes and accuracy.^{17,18} More research is needed on this topic.¹²

Finally, the skiers who rented their ski equipment were more at risk of being injured than skiers who owned their equipment. One would expect that rented equipment should be adequately fitted, given the fact that most rental businesses will adjust the equipment (skis, boots, and bindings) each and every time it is rented. Our results show that binding adjustment is no different whether the equipment is owned or rented. It seems that other factors than binding adjustment could explain the higher risks of injury for renters of equipment. Two factors should be considered: 1) owners in our study were actually more skilled than renters and 2) the quality and sizing of bindings, boots, and skis might not be as good for renters as opposed to owners. Moreover, no standards for ski shop practices are currently enforced in Québec. The adoption and enforcement of such standards should be strongly encouraged.

Again, these results suggest that ill-adjusted equipment is a significant risk factor for young skiers. The safety provided by ski equipment depends on the correct interaction between skis, boots, and bindings adjustment. A preventive measure in this case could be twofold: 1) parents should be advised that improper skiing equipment can jeopardize the safety of their child and 2) efforts should be directed at ski shop operators to make sure the standards for fitting the equipment to the renter/skier are well-known and put into practice.⁶

CONCLUSIONS

This study provides valuable information for the development of a prevention program aimed at young skiers. Results suggest that such a program should include the promotion of well-adjusted equipment (including bindings) and the improvement of skill level. Moreover, efforts should be directed at education of parents in light of the control they have on the modification of both factors. Prevention programs should also encourage ski shop operators to apply recognized standards for adjusting rented equipment and to facilitate access to testing devices for bindings adjustment.

Ski injury prevention programs have often been aimed at modifying dangerous behaviors on the slopes (downhill skiing and other risk taking behaviors). This has been found to be a most difficult task.²⁷ Results of this study point very clearly toward direct, simple steps that could improve the safety of young skiers. It is not known what percentage of injuries could be prevented with such steps, but as Langley²⁴ urgently proposes, effective preventive measures should be used even if they are directed at reducing only a small percentage of injuries.

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