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Risk factors for injuries in alpine skiing, telemark skiing and snowboarding – case-control study

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ABSTRACT

Background Alpine skiing and snowboarding have a substantial risk of injuries, but precise risk factor estimates are limited.

Objective To determine the risk factors among skiers and snowboarders.

Study design Case-control study.

Methods Ski patrols reported cases (N=3277) in eight major Norwegian alpine resorts. Injury type and risk factors (age, gender, nationality, skill level, equipment, helmet use, ski school attendance, rented or own equipment) were recorded. An uninjured control group (N=2992) was obtained at the same resorts. A multivariate logistic regression analysis was used to assess the relationship between individual risk factors and risk of injury.

Results The overall injury risk was increased among beginners (OR 2.72; 2.12 to 3.47), children (OR 1.72; 1.41 to 2.13), adolescents (OR 2.16; 1.72 to 2.66) and non-Nordic skiers (OR 1.80; 1.37 to 2.36). Snowboarders had a higher overall injury risk than skiers (OR 2.11; 1.81 to 2.46). Alpine skiers (OR 2.65; 1.47 to 4.80), beginners (OR 2.50; 1.61 to 3.85), children (OR 11.1; 6.7 to 20.0) and adolescents (OR 4.17; 2.44 to 7.14) were prone to lower leg fractures. Knee injuries occurred more frequently among alpine skiers (OR 1.82; 1.39 to 2.38), females (OR 1.67; 1.38 to 2.03) and beginners (OR 3.13; 2.50 to 3.85). Males (OR 1.85; 1.45 to 2.38), telemark skiers (OR 1.70; 1.30 to 2.23), children (OR 2.22; 1.37 to 3.57) and adults (OR 1.64; 1.11 to 2.37) had an increased risk for shoulder injuries.

Conclusions Snowboarders, beginners, children and adolescents had an increased injury risk.

INTRODUCTION

Skiing and snowboarding are winter sports enjoyed by several hundred million people worldwide, and they are increasingly popular. However, they also represent activities with high potential for traumatic injury.[1 2] Alpine skiing has been the dominant discipline in Norwegian ski resorts. However, during the 1990s, telemark skiing and, in particular, snowboarding gained popularity.[3] The injury risk is high,[2] and serious injuries are common in both skiers and snowboarders.[4–6] Thus, downhill winter sports injuries represent a significant concern. Safety initiatives should be developed to target this population.

Several risk factors for injuries in these disciplines have been suggested, such as age, gender and skill level,[1–10] but the results are equivocal and there are few studies which include a representative control group of uninjured skiers and snowboarders.[1 7–9 11] Even less is known about the risk factors for specific injury types, and whether these differ between the disciplines of alpine skiing, telemark skiing and snowboarding.

The authors therefore conducted a case-control study to explore the effects of a number of assumed risk factors for injury, including age, gender and ability, on overall injury risk as well as the risk for knee injuries, shoulder injuries and lower leg fractures.

MATERIALS AND METHODS

Ski patrols at eight major Norwegian ski resorts registered injuries during the 2002 winter season (Geilo, Hafjell, Trysil, Norefjell, Hovden, Oppdal, Hemsedal and Ålsheia). These eight ski resorts account for about 55% of the ski lift transports in Norway, based on the number of tickets sold (personal communication, Andreas Rødven, Norwegian Ski Lift Association).

An injury was recorded when a skier or snowboarder was treated by or consulted with the ski patrol or first aid room staff after an accident in the skiing area during skiing or lift transport. To qualify for the ski patrol, the personnel are required to go through a structured programme of first aid education. A standard form was used to record personal data (age, gender, nationality), as well as information on the type of equipment (alpine skis, telemark skis (which permit a turning technique with free heel lift), snowboard, sleigh or other), use of helmet (yes/no), previous ski school attendance (yes/no), rented or own equipment (yes/no) and skiing ability. Skiing ability was classified into four categories (beginner, intermediate, good or expert) based on self-reported performance of turns.[12] In addition, the ski patrol recorded whether the injury occurred in prepared runs, in the snowboard park, off-piste (outside groomed runs), while taking the ski lift or getting on/off. The anatomical location (head, neck, shoulder, etc.) and injury type was recorded (classified as fracture, dislocation, sprain, contusion, skin wound or illness), as well as whether the patient needed transportation to a physician or hospital for further evaluation and treatment. Such patients were defined as potentially severe cases. For patients with multiple injuries (less than 1%), each injury was recorded as a separate case.

As a control group, uninjured skiers and snowboarders were interviewed in the same eight ski resorts during the same season (N=2992). The target number interviewed corresponded to the expected injury count from each resort, estimated from injury surveillance data from the previous years.[3] The interviews were conducted at the

Table 1 Distribution of injury cases in number and percentage by age, gender, nationality, skiing ability, equipment, used rented equipment, attained skiing instruction and helmet wear.

Characteristic	Controls (N=2992)	Injuries (N=3277)	p Values, injuries versus controls	Potentially severe injuries (N=1752)	p Values, potentially severe injuries versus other injuries
Age			<0.001		0.99
<13 years	295 (9.9)	453 (13.8)		87 (13.3)	
13–20 years	766 (25.6)	1392 (42.5)		27 (41.4)	
>20 years	1919 (64.1)	1393 (42.5)		269 (41.3)	
Missing	12 (0.4)	39 (1.2)		5 (0.8)	
Sex			0.88		0.75
Males	1801 (60.2)	1965 (60.0)		391 (62.0)	
Females	1185 (39.6)	1281 (39.1)		234 (37.0)	
Missing	6 (0.2)	31 (0.9)		6 (1.0)	
Nationality			<0.0001		<0.001
Norwegian	1639 (54.8)	1717 (52.4)		373 (59.1)	
Swedish	569 (19.0)	634 (19.4)		92 (14.6)	
Danish	615 (20.6)	661 (20.2)		96 (15.2)	
Others	162 (5.4)	260 (7.9)		70 (11.1)	
Missing	7 (0.2)	5 (0.1)		0	
Skiing ability			<0.0001		0.63
Expert	570 (19.1)	448 (13.7)		85 (13.5)	
Good	1055 (35.3)	946 (28.9)		195 (30.9)	
Intermediate	1005 (33.6)	963 (29.4)		182 (28.8)	
Beginner	348 (11.6)	846 (25.8)		156 (24.7)	
Missing	14 (0.4)	74 (2.2)		13 (2.0)	
Equipment			<0.0001		<0.001
Alpine skiers	1827 (61.1)	1607 (49.1)		267 (42.3)	
Snowboarders	757 (25.3)	1391 (42.5)		326 (51.7)	
Telemark	303 (10.1)	179 (5.5)		30 (4.8)	
Others	21 (0.7)	6 (0.2)		6 (1.0)	
Missing	84 (2.8)	94 (2.8)		2 (0.3)	
Used rented equipment			<0.0001		0.18
Yes	829 (27.7)	1058 (32.3)		189 (30.0)	
No	2157 (72.1)	2143 (65.4)		427 (67.7)	
Missing	6 (0.2)	76 (2.3)		15 (2.4)	
Skiing instruction			0.13		<0.001
Yes	993 (33.2)	1018 (31.1)		161 (25.5)	
No	1990 (66.5)	2053 (62.7)		444 (70.4)	
Missing	9 (0.3)	33 (5.5)		26 (4.1)	
Helmet wear			0.09		0.35
Yes	656 (21.9)	780 (23.8)		159 (25.2)	
No	2330 (77.9)	2443 (74.6)		461 (73.1)	
Missing	5 (0.2)	54 (1.6)		11 (1.7)	

Values are number (percentages) within the relevant group.

entry of the bottom main ski lift at each resort. Every tenth skier or snowboarder waiting in line was interviewed, to achieve a representative sample of the skiing population. The interviews were done every Wednesday and Saturday during the four winter months of 2002 by personnel, who were not told the purpose of the study. The registration was done when lifts opened in the morning and after lunch (ie, 10am–11am and 1pm–2pm). This is when most users enter the area, and the main lifts serve to feed a number of other lifts, which take the skiers further into the mountain area to ski the runs available. Except for the injury-related information, the questions asked were the same as for the injured skiers (ie, age, gender, nationality, equipment type, use of helmet, previous ski school attendance, rented or own equipment and skiing ability.

To study the relationships between potential risk factors and injury, the authors chose a multiple logistic regression model with injury as the dependent variable, and equipment, age, gender, ability, nationality, used rented equipment, attended skiing instruction and helmet use as the adjustment factors. The adjusted ORs were then compared with the crude ORs, and if the difference exceeded 20%, major confounding could be involved. The authors used SPSS (PASW Statistics 18) for the analyses.

Interaction between two risk factors on injury was tested on the relative scale by creating a product term between them as an added factor, which was tested for significance by the likelihood ratio method. None were found, and data are therefore not given. ODs are presented with 95% CIs. An α level of 0.05 was considered as statistically significant. All p values are two-tailed.

RESULTS

Of the 3277 injuries recorded, there were 1607 injuries among alpine skiers (49.1%), 1391 in snowboarding (42.5%)

Table 2 Crude and adjusted analyses of relationships between any injury and potential risk factors (N=3040). A total of 237 cases are excluded due to missing data.

	Crude			Adjusted		
Variables	**p Value**	**OR (95% CI: lower bound to upper bound)**		**p Value**	**OR (95% CI: lower bound to upper bound)**	
Equipment*	0.001			<0.001		
Alpine skiers		1.00			1.00	
Snowboarders		2.11	(1.80 to 2.46)		2.11	(1.81 to 2.46)
Telemark skiers		0.93	(0.70 to 1.22)		0.96	(0.77 to 1.19)
Skiing ability	<0.001			<0.001		
Experts		1.00			1.00	
Good		1.04	(0.88 to 1.23)		1.07	(0.88 to 1.31)
Intermediate		1.09	(0.92 to 1.30)		1.11	(0.90 to 1.38)
Beginners		2.70	(2.20 to 3.34)		2.72	(2.12 to 3.47)
Age	<0.001			<0.001		
< 13 years		1.00			1.00	
13–20 years		1.32	(1.02 to 1.71)		1.25	(1.00 to 1.54)
>20 years		0.66	(0.51 to 0.73)		0.58	(0.47 to 0.71)
Nationality	0.001			0.001		
Norwegian		1.00			1.00	
Swedish		1.10	(0.95 to 1.13)		1.16	(0.97 to 1.39)
Danish		0.98	(0.83 to 1.16)		0.95	(0.77 to 1.17)
Non-Nordic		1.58	(1.24 to 2.00)		1.80	(1.37 to 2.36)
Skiing instruction	0.68			0.30		
Attended		1.00			1.00	
Not attended		0.97	(0.84 to 1.12)		0.94	(0.83 to 1.06)
Rented equipment	0.30			0.44		
Not rented		1.00			1.00	
Rented		1.10	(0.93 to 1.30)		1.05	(0.92 to 1.22)
Sex	0.003			0.09		
Males		1.00			1.00	
Females		0.81	(0.70 to 0.93)		0.91	(0.81 to 1.02)
Helmet use	0.037			0.21		
Non helmet		1.00			1.00	
Helmet users		1.13	(1.01 to 1.28)		1.10	(0.95 to 1.28)

*Users with other equipment are excluded because there were few injuries in this group.

and 179 in telemark skiing (5.5%); 2.8% of cases missing due to unknown equipment. A total of 1752 (53%) were referred to a physician or hospital by the ski patrol for further assessment or treatment (potentially severe injuries). Table 1 depicts the distribution of injuries within subgroups of age, gender, nationality, skiing ability, equipment, rented or own equipment, skiing instruction and helmet wear compared to the control group. There were significant differences in the distribution of age, nationality, skiing ability, equipment type and rented/own equipment between injured skiers and controls. When comparing those with potentially severe injuries to the other injury cases, there were differences related to nationality, equipment and skiing instruction (table 1).

The results from a crude and adjusted logistic regression analysis of the relationship between any injury and the potential risk factors are shown in table 2. Age, nationality, skiing ability and the type of equipment were the significant risk factors. Snowboarding was associated with a two-fold higher risk of injury than alpine skiing, while there was no significant difference in injury risk between alpine and telemark skiing (table 2). Beginners were at a higher risk of injuries compared to the intermediate, good and expert skiers (OR ranging from 2.12 to 3.47), and non-Nordic skiers were at a higher risk than the Nordic skiers (OR 1.37 to 2.36). Compared to children up to 12 years of age, adolescents (13–20 years) suffered more injuries and adults (>20 years) fewer injuries. Female skiers and snowboarders had a significant lower risk of injuries in the crude model, but this was not statistically significant in the adjusted test. Helmet use, skiing instruction and ski rental did not influence the overall injury risk.

The adjusted ORs were then compared with the crude ORs, and the difference did not exceed 20%.

From a multiple logistic regression analysis of the relationship between the potentially severe injuries and controls, the authors detected that beginners (OR 2.50, 2.08 to 3.33; p<0.001), snowboarders (OR 2.11, 1.80 to 2.47; p<0.001) and non-Nordic skiers (OR 1.89, 1.37 to 2.32; p<0.001) had a higher risk, while adults over 20 years (OR 0.65, 0.51 to 0.85; p=0.001) and female skiers/boarders (OR 0.81, 0.70 to 0.93;p=0.003) had a reduced risk of potentially severe injuries.

Table 3 compares injury type to body region. The most frequently injured regions were the head (17.6%), knee (17.4%), wrist (13.8%) and shoulder (11.8%), while the most frequent injury types were contusions (35.2%), fractures (27.9%) and sprains (23.6%).

Table 4 shows the relationship between skiing equipment and the injured body region. In alpine skiing, knee injuries were the most frequent (27.3%), in snowboarding wrist injuries (25.9%) and in telemark skiing shoulder injuries (20.1%). Head injuries were frequent across all disciplines (17.8% to 17.9%).

Table 3 Comparison of injury types and body region (N=3189); in 88 cases there was no information on injured body region or injury type.

	Fracture	Dislocation	Sprain	Contusion	Wound	Disease	Total
Head	35 (6.1)	3 (0.5)	15 (2.6)	374 (64.5)	147 (25.4)	4 (0.7)	578 (17.6)
Neck	8 (13.1)	2 (3.3)	6 (9.8)	38 (62.3)	6 (9.8)	1 (1.6)	61 (1.9)
Shoulder	131 (34.7)	117 (31.0)	40 (10.6)	88 (23.3)	1 (0.3)	0	377 (11.8)
Arm	102 (56.0)	2 (1.1)	18 (9.9)	55 (30.2)	5 (2.7)	0	182 (5.7)
Hand	86 (36.3)	12 (5.1)	90 (38.0)	32 (13.5)	17 (7.2)	0	237 (7.4)
Wrist	284 (67.4)	2 (0.5)	124 (28.2)	24 (5.5)	5 (1.1)	0	439 (13.8)
Chest/abdomen	28 (27.2)	2 (1.6)	2 (1.9)	66 (64.7)	3 (2.9)	1 (1.0)	102 (3.2)
Back/buttocks	15 (7.8)	2 (1.0)	8 (4.2)	162 (84.4)	4 (2.1)	1 (0.5)	192 (6.0)
Thigh	14 (16.9)	0	7 (8.4)	55 (66.3)	6 (7.2)	1 (1.2)	83 (2.6)
Knee	20 (3.6)	45 (8.1)	321 (57.9)	151 (27.3)	17 (3.1)	0	554 (17.4)
Lower leg	121 (63.0)	1 (0.5)	11 (5.7)	42 (21.9)	17 (8.9)	0	192 (6.0)
Ankle/foot	45 (23.4)	1 (0.5)	111 (57.8)	34 (17.7)	1 (0.5)	0	192 (6.0)
Total (% of all injuries)	889 (27.9)	187 (5.9)	753 (23.6)	1123 (35.2)	229 (7.2)	8 (0.3)	3189 (100.0)

Values are number of cases (percentages) within the relevant group.

Table 4 Distribution of injured body region related to skiing equipment (N=3170). A total of 107 cases were excluded due to missing data on equipment type or body region.

	Alpine injuries N=598	Snowboard injuries N=1387	Telemark injuries N=179	Other injuries N=6	Total	p Value
Head	288 (17.9)	248 (17.8)	32 (17.9)	0 0	568 (17.9)	0.96
Neck	27 (1.7)	28 (2.0)	4 (2.2)	1 (17.7)	60 (1.9)	0.72
Shoulder	179 (11.2)	158 (11.4)	36 (20.1)	0	373 (11.8)	0.002
Arm	44 (2.8)	127 (9.2)	8 (4.5)	0	179 (5.6)	<0.001
Hand	140 (8.8)	76 (5.5)	16 (8.9)	1 (16.7)	233 (7.4)	0.003
Wrist	69 (4.3)	359 (25.9)	7 (3.9)	0	435 (13.7)	<0.001
Chest/abdomen	44 (2.8)	51 (3.7)	7 (3.9)	0	102 (3.2)	0.29
Back/buttocks	81 (5.1)	107 (7.7)	8 (4.5)	0	196 (6.2)	0.002
Thigh	56 (3.5)	23 (1.7)	2 (1.1)	0	81 (2.6)	0.002
Knee	437 (27.3)	94 (6.8)	26 (14.5)	1 (16.7)	558 (17.6)	<0.001
Lower leg	143 (8.9)	38 (2.7)	7 (3.9)	1 (16.7)	189 (6.0)	<0.001
Ankle/foot	90 (5.6)	79 (5.6)	25 (14.0)	2 (33.3)	196 (6.2)	<0.001
Total	1598 (100)	1387 (100)	179 (100)	6 (100)	3170 (100)	

Values are number (percentages) within the relevant group. The p value relates to the distribution of injuries in each body region among equipment categories.

The authors also performed multiple logistic regression analyses to examine the risk factors for some of the most common injury types; lower leg fractures (table 5), knee injuries (table 6), and shoulder injuries (table 7).

For lower leg fractures (table 5), beginners had a risk 2.5 times higher, compared to non-beginners, and children under 12 years had a risk four times higher than in adolescents and eleven times than in adult skiers. Alpine skiers had a significantly higher risk of lower leg fractures compared to snowboarders and telemark skiers.

For knee injuries (table 6), the authors found the highest risk among females, beginners, alpine skiers and non-Nordic skiers/boarders.

For shoulder injuries (table 7), telemarkers, children under 12 years and adults compared to adolescents, non-Nordic and males were at higher risk.

Crude analyses of injury risk concerning lower leg fractures, knee injuries and shoulder injuries did not differ more than 15% from the adjusted analyses, thus there is a low degree of confounding.

Collision with another person or obstacle was reported in 12.9% of all cases, and the remaining injuries were the result of a fall or a jump. Injury as a result of collision was seen more frequently among the alpine skiers (15.6%) than in the other disciplines (9.5%).

DISCUSSION

The main findings of the present study were that beginners, snowboarders, children and adolescents were at increased overall risk of injury.

Rented equipment and skiing instruction did not seem to influence the overall risk of injury, while skiing instruction decreased the risk of potentially severe injuries. The injury pattern varied between the three disciplines, snowboarding, alpine and telemark skiing, reflecting the inherent differences in user technique and equipment design. Being a beginner was associated with a 2.5 times higher risk of injury. The idea that beginners are at higher risk, is well established in the literature, but the risk estimates have been inconsistent, varying from 1.6 to 7 times higher risk.[9–11 13 14]

Whether the female skiers and snowboarders have the same injury risk and distribution as the men is controversial. Prodromos *et al*[15] found no gender differences in ACL (anterior cruciate ligament) tear risk for either recreational or expert alpine skiers in a meta-analysis investigating gender differences for ACL injury in different sports activities. Langran and Selvaraj[7] found no relation with gender in a case-control study during the winter of 2000, involving 674 injured skiers and snowboarders and 336 controls. However, Wasden *et al*[16] concluded that men are at a higher risk of injuries while skiing or snowboarding, based on a retrospective case series of

Table 5 Adjusted multiple logistic regression analyses of relationship between lower leg fractures and potential risk factors (N=113).

Variables	p Value	OR (95% CI: lower bound to upper bound)	
Equipment†	<0.001		
Snowborders		1.00	
Alpine skiers		2.65	(1.47 to 4.80)
Telemark skiers		1.07	(0.44 to 2.60)
Skiing ability‡	<0.001		
Non-beginners		1.00	
Beginners		2.50	(1.61 to 3.85)
Age	<0.001		
<13 years		1.00	
13–20 years		0.24	(0.14 to 0.41)
>20 years		0.09	(0.05 to 0.15)
Nationality*	0.008		
Nordic skiers		1.00	
Non-Nordic		2.50	(1.27 to 5.00)
Skiing instruction	0.058		
Attended		1.00	
Not attended		0.64	(0.41 to 1.02)
Rented equipment	0.64		
Not rented		1.00	
Rented		1.12	(0.77 to 1.79)
Helmet use	0.73		
Non helmet		1.00	
Helmet users		0.90	(0.50 to 1.63)
Sex	0.30		
Males		1.00	
Females		0.80	(0.52 to 1.23)

*Non-Nordic skiers are skiers and snowboarders from outside Norway, Sweden and Denmark.
†Users with other equipment are excluded because there were few injuries in these groups.
‡Non-beginners are experts, good and intermediate skiers.

Table 6 Adjusted multiple logistic regression analyses of relationship between knee injuries and potential risk factors (N=536)

Variables	p Value	OR (95% CI: lower bound to upper bound)	
Equipment†	<0.001		
Snowborders		1.00	
Alpine skiers		1.82	(1.39 to 2.38)
Telemark skiers		1.01	(0.64 to 1.59)
Skiing ability‡	<0.001		
Non-beginners		1.00	
Beginners		3.13	(2.50 to 3.85)
Age	<0.001		
<13 years		1.00	
13–20 years		0.89	(0.63 to 1.22)
>20 years		1.20	(0.90 to 1.61)
Nationality*	0.008		
Nordic skiers		1.00	
Non-Nordic		2.50	(1.27 to 5.00)
Skiing instruction	0.058		
Attended		1.00	
Not attended		0.81	(0.66 to 0.99)
Rented equipment	0.64		
Not rented		1.00	
Rented		1.24	(1.01 to 1.52)
Helmet use	0.73		
Non helmet		1.00	
Helmet users		1.14	(0.86 to 1.50)
Sex	0.30		
Males		1.00	
Females		1.67	(1.38 to 2.03)

*Non-Nordic skiers are skiers and snowboarders from outside Norway, Sweden and Denmark.
†Users with other equipment are excluded because there were few injuries in these groups.
‡Non-beginners are experts, good and intermediate skiers.

1142 skiers and snowboarders treated at the local medical center, but this study did not have a matching control group. In this study, the authors found a 19% lower overall injury risk for female skiers and snowboarders in the crude analysis, but this was not significant in the adjusted model. However, the authors did see a 67% higher risk for knee injuries among female skiers and snowboarders, as well as a 46% lower risk for shoulder injuries and 32% lower risk for head injuries. These gender differences are pointed out in a paper by Shealy and co-workers, 1996.[17] Female athletes are more prone to knee injuries in most sports (ACL ruptures in particular).[18] The injury often occurs as a combination of compressive loading and twisting of the knee.[19] This mechanism is typical in the alpine skiing discipline, when the skier loses balance or the ski edge catches during a turn.[20 21] Upper limb and head injuries are often associated with falling from a jump.[22 23] Thus, more cautious skiing may be an explanation for why female skiers and snowboarders have a lower risk for upper limb and head/neck injuries.

Sacco *et al*[24] found that alpine skiers and snowboarders were equally prone to injury in an evaluation of skiing and snowboarding injuries admitted to the local level 1 trauma center over a 6-year period, but without any control material their conclusion is difficult to interpret. Langran *et al*[7] based on their case-control study demonstrated that snowboarders were more likely to sustain upper limb or axial injury, while lower limb injuries were more common in the alpine group. However, they concluded that there is no difference in the overall risk between the two disciplines. In two other studies without control groups, Xiang *et al*[25] found no significant differences in overall injury risk or admittance to hospital between skiers and snowboarders, while Dohjima *et al*[6] found that snowboarders had a 6 times higher injury risk. In the present study, the authors found that snowboarders had twice the overall injury risk of alpine and telemark skiers, and a three times higher risk for potentially severe injuries. However, while snowboarders had a higher injury rate than skiers for injuries to the upper body, they sustained fewer lower limb injuries than alpine skiers. In fact, alpine skiers had more than twice the risk of knee injuries compared to snowboarders, and also a significantly higher risk than telemark skiers. The reason why snowboarders suffer fewer injuries to their legs and, in particular, their knees is probably because both feet are fixed to the board. The board is unable to act independently as a lever, thus reducing the twisting and bending forces on the individual knee.

Some authors claim that the injury rate for shoulder injuries is quite similar between disciplines,[7 26–28] while others have found a much higher incidence among snowboarders than alpine skiers.[29 30] These conclusions are mostly based on studies without control groups. McCall *et al*[30] debated this issue in a recent review, concluding that shoulder injuries account for 8% to 16% of snowboarding injuries and 4% to 11% of alpine skiing injuries. In this study, the proportion of shoulder

Table 7 Adjusted multiple logistic regression analyses of relationship between shoulder injuries and potential risk factors (N=365).

Variables	p Value	OR (95% CI: lower bound to upper bound)	
Equipment†	<0.001		
Snowborders		1.00	
Alpine skiers		1.16	(0.77 to 1.74)
Telemark skiers		1.70	(1.30 to 2.23)
Skiing ability‡	<0.001		
Non-beginners		1.00	
Beginners		1.28	(0.92 to 1.79)
Age	<0.001		
<13 years		1.00	
13–20 years		0.45	(0.28 to 0.73)
>20 years		0.74	(0.50 to 1.07)
Nationality*	0.008		
Nordic skiers		1.00	
Non-Nordic		1.82	(1.43 to 2.78)
Skiing instruction	0.058		
Attended		1.00	
Not attended		0.98	(0.75 to 1.26)
Rented equipment	0.64		
Not rented		1.00	
Rented		0.88	(0.53 to 1.18)
Helmet use	0.73		
Non helmet		1.00	
Helmet users		1.13	(0.84 to 1.53)
Sex	0.30		
Males		1.00	
Females		0.54	(0.42 to 0.69)

*Non-Nordic skiers are skiers and snowboarders from outside Norway, Sweden and Denmark.
†Users with other equipment are excluded because there were few injuries in these groups.
‡Non-beginners are experts, good and intermediate skiers.

injuries was highest among telemark skiers (20%) compared to alpine and snowboarders (11% each). Adjusted for other factors, telemark skiers had a 70% higher risk for shoulder injuries compared to snowboarders, while there was no significant difference between snowboarders and alpine skiers.

The authors also found that adults and children have a significantly higher risk of shoulder injuries than adolescents. Fractures in the shoulder were common in children, while adults sustained more dislocations.

Lower leg fractures are thought to be a particular risk among younger skiers, but exact risk estimates are missing. Data showed that children younger than 13 years had a four times higher risk than adolescents, and 11 times higher risk than adults. Langran *et al*[7] found that tibia/fibula fractures represented 5% of injuries to alpine skiers and 0.5% among snowboarders. The authors found that alpine skiers had about 2.5 times the risk of snowboarders and telemark skiers. Other risk factors for lower leg fractures were skiing ability and nationality. Since their introduction, ski release bindings are thought to have reduced dramatically the incidence of lower leg fractures among alpine skiers.[7 31] Nevertheless, lower leg fractures are still common in young alpine skiers (17% of all injuries in alpine skiers up to 12 years old). The high lower leg fracture rate among children is an issue which needs to be addressed, as release bindings alone do not seem to have solved the problem in this age group. The data used in this study were collected in 2002, and the authors do not know how changes in equipment or skier/snowboarder behavior over the past years may impact on the relevance of the study.

What this study adds

- Children, snowboarders and beginners are at increased injury risk.
- Female skiers and snowboarders have a lower risk for shoulder injuries, and higher risk for knee injuries.
- Telemark skiers have a higher risk for shoulder injuries.

LIMITATIONS

Recent studies on the risk factors of skiing and snowboarding injury have to some extent been inconclusive because they lack an appropriate control group or the number of injuries has been too small for multivariate analyses. The strength of the current study is that the authors could assess key risk factors in alpine skiing and snowboarding by comparing injured cases to an uninjured, representative control group, while correcting for important confounders.

Central to the injury reporting is also the definition of an injury. According to the authors' definition, an injury is whatever was reported to and registered by the ski patrol. Obtaining a control group representative of all skiers and snowboarders at risk is another difficult task. The controls were registered during 'rush-hour' in the morning and after lunch, when most users were entering the area through the bottom main ski lift. All users entered here, and many users would end up there after a run, even after going off-piste or in the snowboard park. The authors selected Wednesdays and Saturdays to sample the control group to compensate for differences in user characteristics between weekdays and weekends, and matched the number of controls to the expected injury count in each ski area. Potential confounding by type of run or weekday of injury may have been accounted for, at least in part, by factors adjusted for in the analysis, for example, nationality, skiing ability, rented equipment and skiing instruction.

The authors have not assessed the number of injured skiers and snowboarders that bypass the ski patrol for their injuries. Studies have shown that self-reported injuries may be up to ten times higher than recorded by ski patrols, but also that those missed by ski patrols were minor.[26 27] The results of these studies showed that injury risk factors were quite consistent between less and potentially more severe cases, which means that a reporting bias was unlikely.

Recall bias is not likely to have been a significant factor, since interviews were done on the spot, usually within a few minutes after the injury. Although the authors do not know how a stressful injury situation may have affected how skiers report their skiing ability or ski instruction, most other factors could be observed directly by the ski patrol.

CONCLUSIONS

Children, adolescents, beginners and snowboarders have an increased injury risk. Alpine skiers, beginners, males, children and adolescents are at a higher risk of lower leg fractures, telemark skiers, males and adolescents are at a higher risk of shoulder injuries, while knee injuries occur more frequently among alpine skiers, females and beginners.

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Competing Interests None.

Ethical approval The study was based on anonymised data from the Norwegian Ski Lift Association injury and marketing research databases, and ethical approval was not required by the Regional Committee for Medical Research Ethics.

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REFERENCES

1 **Johnson RJ**, Ettlinger CF, Shealy JE. Update on injury trends in alpine skiing. *Skiing Trauma and Safety*, 14th Vol. ASTM STP 1510. In: Johnson RJ, Shealy JE, Langran M, eds. West Conshohocken, PA: ASTM International 2009:3–10.
2. **Hunter RE**. Skiing injuries. *Am J Sports Med* 1999;**27**:381–9.
3 **Ekeland A**, Rødven A. Injuries in alpine skiers, Telemarkers and snowboarders at Norwegian ski resorts. In: Johnson RJ, Lamont MK, Shealy JE, eds. *Skiing, Trauma and Safety*,14th Vol ASTM STP 1440. Philadelphia, PA: American Society for Testing and Materials 2003:97–104.
4. **Nakaguchi H**, Fujimaki T, Ueki K, *et al.* Snowboard head injury: prospective study in Chino, Nagano, for two seasons from 1995 to 1997. *J Trauma* 1999;**46**:1066–9.
5. **Hentschel S**, Hader W, Boyd M. Head injuries in skiers and snowboarders in British Columbia. *Can J Neurol Sci* 2001;**28**:42–6.
6. **Dohjima T**, Sumi Y, Ohno T, *et al.* The dangers of snowboarding: a 9-year prospective comparison of snowboarding and skiing injuries. *Acta Orthop Scand* 2001;**72**:657–60.
7. **Langran M**, Selvaraj S. Snow sports injuries in Scotland: a case-control study. *Br J Sports Med* 2002;**36**:135–40.
8. **Made C**, Borg H, Thelander D, *et al.* Telemark skiing injuries: an 11-year study. *Knee Surg Sports Traumatol Arthrosc* 2001;**9**:386–91.
9. **Deibert MC**, Aronsson DD, Johnson RJ, *et al.* Skiing injuries in children, adolescents, and adults. *J Bone Joint Surg Am* 1998;**80**:25–32.
10 **Oliver BC**, Allman FL. Alpine skiing injuries: an epidemiological study. *Skiing Trauma and Safety*, 8th International Symposium, ASTM STP 1104. In: C.D. Mote Jr. and R.J. Johnson, eds. West Conshohocken, PA: American Society for Testing and Materials 1991:164–169.
11. **Goulet C**, Régnier G, Grimard G, *et al.* Risk factors associated with alpine skiing injuries in children. A case-control study. *Am J Sports Med* 1999;**27**:644–50.
12. **Sulheim S**, Ekeland A, Bahr R. Self-estimation of ability among skiers and snowboarders in alpine skiing resorts. *Knee Surg Sports Traumatol Arthrosc* 2007;**15**:665–70.
13. **Hauser W**, Asang E, Muller B. Injury risk in alpine skiing. In: Johnson RJ, Mote CD Jr, eds. *Skiing Trauma and Skiing Safety*, Fifth Internatoinal Symposium, ASTM STP 860. Philadelphia, PA: American Society for Testing and Materials 1985:338–348.
14. **Ekeland A**, Holtmoen A, Lystad H. Lower extremity equipment-related injuries in alpine recreational skiers. *Am J Sports Med* 1993;**21**:201–5.
15. **Prodromos CC**, Han Y, Rogowski J, *et al.* A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury-reduction regimen. *Arthroscopy* 2007;**23**:1320–1325.e6.
16. **Wasden CC**, McIntosh SE, Keith DS, *et al.* An analysis of skiing and snowboarding injuries on Utah slopes. *J Trauma* 2009;**67**:1022–6.
17. **Shealy JE**, Ettlinger CF. Gender-related injury patterns in skiing. In: Mote CD Jr, Johnsen 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.
18. **Hootman JM**, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train* 2007;**42**:311–9.
19. **Koga H**, Nakamae A, Shima Y, *et al.* Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. *Am J Sports Med* 2010;**38**:2218–25.
20. **Bere T**, Flørenes TW, Krosshaug T, *et al.* Mechanisms of anterior cruciate ligament injury in World Cup alpine skiing: a systematic video analysis of 20 cases. *Am J Sports Med* 2011;**39**:1421–9.
21. **Ettlinger CF**, Johnson RJ, Shealy JE. A method to help reduce the risk of serious knee sprains incurred in alpine skiing. *Am J Sports Med* 1995;**23**:531–7.
22. **Hagel BE**, Goulet C, Platt RW, *et al.* Injuries among skiers and snowboarders in Quebec. *Epidemiology* 2004;**15**:279–86.
23. **Sulheim S**, Holme I, Ekeland A, *et al.* Helmet use and risk of head injuries in alpine skiers and snowboarders. *JAMA* 2006;**295**:919–24.
24. **Sacco DE**, Sartorelli DH, Vane DW. Evaluation of alpine skiing and snowboarding injury in a northeastern state. *J Trauma* 1998;**44**:654–9.
25. **Xiang H**, Kelleher K, Shields BJ, *et al.* Skiing- and snowboarding-related injuries treated in U.S. emergency departments, 2002. *J Trauma* 2005;**58**:112–8.
26. **Davidson TM**, Laliotis AT. Snowboarding injuries, a four-year study with comparison with alpine ski injuries. *West J Med* 1996;**164**:231–7.
27. **Tuggy ML**, Ong R. Injury risk factors among telemark skiers. *Am J Sports Med* 2000;**28**:83–9.
28. **Bladin C**, McCrory P, Pogorzelski A. Snowboarding injuries: current trends and future directions. *Sports Med* 2004;**34**:133–9.
29. **Sutherland AG**, Holmes JD, Myers S. Differing injury patterns in snowboarding and alpine skiing. *Injury* 1996;**27**:423–5.
30. **McCall D**, Safran MR. Injuries about the shoulder in skiing and snowboarding. *Br J Sports Med* 2009;**43**:987–92.
31. **Johnson RJ**, Ettlinger CF. Alpine ski injuries: changes through the years. *Clin Sports Med* 1982;**1**:181–97.

Risk factors for injuries in alpine skiing, telemark skiing and snowboarding – case-control study

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