

Factors affecting injury severity among recreational skiers and snowboarders: an epidemiology study

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Abstract Different results have been reported for skiing and snowboarding injuries worldwide. Few studies consider the injury severity score (ISS) for the evaluation of differences among injured skiers–snowboarders. The aim of this study is to identify possible risk factors that affect the severity of skiing and snowboarding injuries in three winter seasons (2002–2005) in South Tyrol. For every injured skier or snowboarder referred to our emergency department in three consecutive seasons, the following data were collected: date of birth, gender, self-declared technical skills level, place of residence (local/non-local), as well as the date, time, and place of the accident. Type of injury and ISS were retrospectively assigned. Data concerning the snowfall in the last 24 h, average snow level, and outdoor air temperature values were obtained from four weather stations that were located inside the ski resorts. A multiple linear regression model was used to evaluate the association between ISS and potential determinants. In the

analyzed seasons, 2,511 injured skiers and 843 injured snowboarders were evaluated at our emergency department. There was a significant change in the ISS value for subjects with different self-reported skills levels ($P < 0.001$). Men and non-local residents experienced more severe injuries than women and local residents, respectively ($P < 0.013$, $P < 0.001$). The ISS was higher for people aged over 60 ($P < 0.001$). Snowfalls brought about a decrease in accident severity ($P = 0.009$). The severity of the injuries increases with age. Prevention and information programs should be targeted to people who are at high risk of severe injury. A 24-h fresh snowfall seems to reduce the severity of injuries. Very little is known about snow conditions and winter sports injury. Further studies are needed to explore this field.

Keywords Skiing injury · Snowboarding injury · Injury severity score · Snowfall

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Introduction

Skiing and snowboarding are popular winter sports and are enjoyed by several hundred million people worldwide [13]. Although downhill skiing is a well-established sport, snowboarding is relatively recent. Equipment and performance technology have been improved over the years, and their accessibility to the general public has increased. Therefore, it is not surprising that a greater number of traumatic injuries have been observed, some of which are very severe or even life threatening. The Province of Bolzano-Bozen (Italy), better known as South Tyrol, encompasses a large mountain area in the northern part of Italy with 16 ski resorts that attract winter sports fans from all over the world. Five of these ski resorts (Alpe di Siusi,

Obereggen, Frazione San Martino, Val Gardena, Renon) refer to our ED for primary and secondary care. The most common way to study skiing- and snowboarding-related injuries is based upon ski-lift ticket sales (skier-days) and ED admissions or ski-patrol reports. Although there are plenty of reports of skiing and snowboarding injuries, very few studies use the Injury Severity Score (ISS) to analyze possible associations with risk factors [2, 17, 20]. The aim of this study was to evaluate which variables are associated with a moderate-high level of ISS and also to estimate risk factors for skiing and snowboarding injuries in the four ski resorts referring to our ED. The aim of this study was to confirm the association between ISS value and probable risk factors for injuries.

Materials and methods

For every patient referred to our emergency department (ED) after a skiing or snowboarding accident in three consecutive seasons (from 2002 to 2005), the following data were collected on admission: date of birth, sex, self-declared technical experience, place of residence, as well as the date, time, location, and type (collision/fall) of accident.

These data were collected without taking the national health system documentation into account, and they were only used for the purpose of this study, according to the Italian law on privacy. Ethical committee approval was not required for this kind of study. Type of injury and injury severity score (ISS), according to Baker [1], were retrospectively assigned: their values were calculated upon ED and hospital charts. In order to calculate the score, the body is divided into six regions: (1) head/sore neck; (2) face; (3) chest; (4) abdominal or pelvic contents; (5) extremities of pelvic girdle; (6) external. An Abbreviated Injury Score (AIS) is attributed to each of these body regions, using the scoring chart proposed by Greenspan [10]: (1) minor, (2) moderate, (3) serious, (4) severe, (5) critical, (6) lethal injury. The ISS is then calculated by taking the sum of the square root of the three most severe injuries (with the highest AIS score).

Data concerning snow condition were gathered from four weather stations related to the five ski resorts. The weather stations daily recorded the average snow level, the amount of fresh snowfall, and the minimum outdoor air temperature values.

Statistical analysis

We performed statistical descriptive analyses by producing box plots and frequency tables for the variables involved in the study. After verifying the normal distribution on the

variables (Shapiro–Wilk’s test), we used parametric (Student’s *t* test, Chi-squared test, ANOVA test) and non-parametric (Wilcoxon–Mann–Whitney’s test, Kruskal–Wallis rank sum test) tests to verify the statistical hypotheses. The linear correlation between continuous variables was analyzed via the Spearman’s linear correlation test. Risk factors for ISS values were evaluated using multilevel linear regression adjusting for potential confounders (age, sex, type of skier, weather condition, self-reported experience level) and level (ski resorts). To normalize the ISS, we used a logarithmic transformation. The limit of significance for tests and model parameters was fixed at $P < 0.05$.

All the analyses were performed using R statistical open source software (version 2.8.1) [18] and its MASS package [23].

Results

During the period of the study, 2,511 injured skiers and 843 injured snowboarders were evaluated at our ED. The ISS level has an asymmetric distribution; median = 2 (I.Q.R. 2–4), and mean 3.4 (SD 4.3). In the three considered seasons, there was neither a significant difference in the ISS distribution (n.s.) nor among the proportion of moderate-severe (ISS ≥ 4) versus mild ISS (ISS < 3) levels (n.s.). We did not detect any significant difference either between the ISS level and type of sport or between accident types (collision/fall) (n.s.; Table 1). We detected a significant difference between the ISS classes and different self-declared skills classes ($P < 0.001$) (Table 1). As reported in Fig. 1, the distribution of the ISS level seems to change with experience: beginners and first-time skiers–snowboarders reported lower ISS levels than other classes.

There was a significantly higher ISS among men (mean 3.62) compared to women (mean 2.91) ($P = 0.013$). A significant difference between the ISS values among local residents and non-local residents was found ($P < 0.001$; Table 1). Also for possible severe injuries (ISS ≥ 4), the non-local resident population showed more severe injuries ($P < 0.001$; Table 2).

A significant difference between ISS levels within different age classes was found ($P < 0.001$; Tables 1 and 2). In particular, the ISS is higher for under 20 and over 40-year-old people (Fig. 2). Moreover, we detected a positive association between ISS level and age (cor = 0.10; CI = [0.06; 0.13]; $P < 0.001$).

A snowfall seemed to bring about a decrease in accident severity. There was a slight but significant negative correlation between ISS and snowfall in the last 24 h (cor = -0.05 ; CI = $[-0.01; -0.08]$; $P = 0.009$; Fig. 3).

We had fitted a multilevel linear regression to evaluate the risk factors (Table 3). The significant risk factors were:

Table 1 Mean and SD of ISS values in the sample

	ISS (mean (SD))	P value
Sex		
Females	2.9 (3.1)	0.01*
Males	3.6 (4.9)	
Typology of rider		
Skiers	3.5 (4.6)	n.s.*
Snowboarders	3.0 (3.4)	
Self-reported skills level		
First time	2.7 (2.3)	<0.001**
Beginner	2.7 (2.5)	
Medium	3.3 (4.0)	
Expert	3.4 (4.3)	
Unknown	11.6 (12.8)	
Age		
0–20	3.1 (3.2)	<0.001**
21–30	3.1 (4.6)	
31–40	2.9 (4.1)	
41–50	3.2 (3.9)	
51–60	3.7 (4.5)	
Over 60	4.6 (5.6)	
Type of accident		
Fall	3.3 (4.3)	n.s.*
Collision	3.4 (4.1)	
Resident		
Local resident	2.6 (2.9)	<0.001*
No local resident	4.0 (5.2)	

* t test

** ANOVA test

age over 60 years old class ($P < 0.001$) with respect to the age class [0–20], men and snowboarders reported more severe injuries than women and skiers, respectively ($P = 0.010$ and <0.001). Age class [21–30] and age class [31–40] showed a low level of ISS with respect to age class [0–20] ($P = 0.024$ and $P = 0.006$). People who lived in Bozen showed a lower frequency of possible severe injuries ($P < 0.001$). The amount of snowfall in 24 h decreased the risk of a high ISS ($P = 0.034$). Beginners had a minor ISS value with respect to experts ($P = 0.016$), and people who did not report the experience level data had a greater ISS than experts ($P < 0.001$). There was no significant association between the ISS and others self-reported experience levels (Table 3).

Discussion

The most important finding of the present study was that there is a positive association between ISS and determinant variables such as: age, sex, and track conditions.

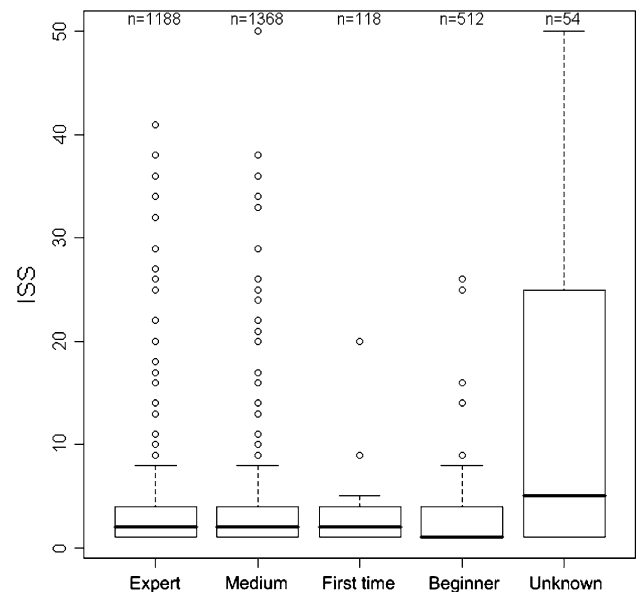


Fig. 1 Box plot with the distribution of the ISS values for each self-reported skills level class (Expert, Medium, First time, Beginner, and Unknown). Class sizes are indicated above each box plot (ANOVA test P value < 0.001)

Table 2 Distribution of ISS level (high/low) in the sample (percentages unless stated otherwise)

	ISS < 4	ISS ≥ 4	P value
Total (absolute frequency)	1,783	1,457	
Age (years) (median (I.Q.R.))	30 (18–43)	33 (17–48)	<0.001*
Males	61	63	n.s.*
Type of accident (fall)	87	88	n.s.**
Typology of rider (snowboarder)	25	27	n.s.**
Local resident	56	38	<0.001**
24-h snowfall (cm) (mean (SD))	3 (6)	3 (5)	n.s.*
Self-reported skills level:			
First time	3	4	0.001**
Beginner	16	16	
Medium	42	42	
Expert	38	35	
Unknown	1	3	

* t test

** Chi-squared test

The severity of worldwide snowboarding injuries seems to be higher compared with skiing accidents [6, 25]. Although we could not calculate the relative incidence of injuries connected to the two sports activities, in the linear regression estimation (adjusted for age, sex, weather conditions, and self-declared skills level), we detected a significant higher injury severity risk for snowboarders.

Snowboarding has become increasingly popular over the past several years, and the different pattern of injury

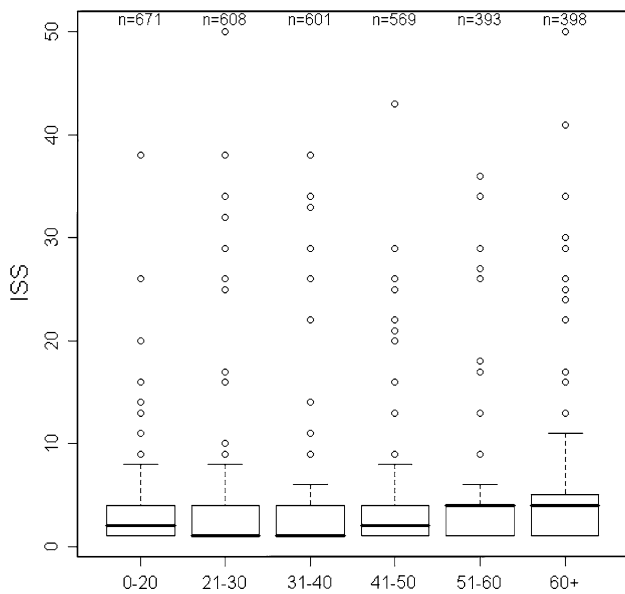


Fig. 2 Box plot with the distribution of ISS values for each age class. Class sizes are indicated above each *box plot* (ANOVA test P value < 0.001)

between ski and snowboard is well known [4, 6]; but whether this sport is more dangerous than skiing is still under debate. Early reports [20] showed that snowboarding injuries were less severe than those connected to skiing. The increasing popularity of this sport among younger participants has meant that the incidence and the severity of snowboarding-related injuries have also grown [6, 25]. More recent reports show that the incidence of snowboarding injuries is higher than the incidence of skiing injuries [12, 16, 21]. However, contrasting results have been reported for severe injuries, in particular for those regarding the central nervous system [8, 24].

Previous studies have reported that 10–24-year-old individuals are at a higher risk of experiencing skiing and snowboarding injuries than other age groups [9, 12, 15]. An epidemiological study completed in the USA [25] showed that the incidence of intermediate-severe injuries was higher among skiers aged 55–64. Our results showed that for intermediate-severe injuries, the age class with higher risk is over 60-year-old one. These results confirm both the well-known fact that younger participants are at a higher risk for severe injuries [11], and the more recently reported data regarding senior skiers [25]. Seniors have been shown to be at a higher risk of experiencing severe injuries for other outdoor winter activities as well [5].

It is not yet clear whether the gender of the injured person can be considered a potential risk factor for skiing and snowboarding injuries. Although men are generally reckless, published data on the subject gather different

conclusions. Our analysis shows that men suffer from more severe injuries than women. This conclusion was also reported in a previous survey in our region [4].

The most ubiquitous finding in ski literature is that the subjects with a lower ability or less experience are at a greater risk of injury. This is particularly relevant for children and adolescent population-based epidemiological studies [9, 14]. If we do not consider the 54 unconscious patients, the self-declared technical skills level does not affect the ISS (only beginners reported a significant minor ISS level).

The finding that non-local residents experience more severe injuries is probably associated with technical expertise. The difference between Bozen resident/non-resident ISS levels of injuries is statistically significant. Local residents generally start practicing winter sports at a very young age; they are better acquainted with steep slopes and they ski throughout the whole season, maintaining a good average training level. Tourists, on the other hand, practice for a shorter period and often ski enthusiastically, regardless of slope harshness, weather conditions, and their technical abilities.

One of the main limitations of almost all studies in this field is that minor injuries that do not require immediate care are rarely detected, because they are treated after a relevant amount of time they occur and sometimes in facilities that are located far from the ski resorts. The analysis of intermediate-severe injuries ($ISS \geq 4$) is more reliable than the one for the mild ones ($ISS < 4$), since these kinds of lesions are unlikely to be treated in locations other than those closest to an ED.¹

We noticed that in the presence of a small amount of freshly fallen natural snow, the number of severe injuries decreases (Fig. 3). In extremely dry periods, ski slopes are covered with artificial snow only, with a bottom layer of icy snow covered by a thin layer of daily produced and powder-like groomed artificial snow. In these conditions, the slope is faster and easier to ride, compared to when it is covered with a thick layer of natural snow. This enhances the possibility of high-speed accidents. Moreover, on the trail side, the scarcity or absence of snow does not offer the same natural protection as in off-trail snow. To our knowledge, only one previous study has dealt with slope grooming, trail design, and incidence of injuries [3]. This

¹ This is related to the rescue system operating in South Tyrol. All the patients that after an accident cannot ski anymore are helped downhill by the ski-patrols. No medical facilities are available at the base of the five ski resorts referring to our ED. Ambulance transport is easily available in all ski resorts, it is financially supported by the Provincial Government and it is free of charge for Italian and European Community citizens. Severely injured patients rescued by helicopters anywhere in South Tyrol are referred by protocol to our ED. Therefore, it is unlikely that patients with intermediate or severe injury are treated in other facilities.

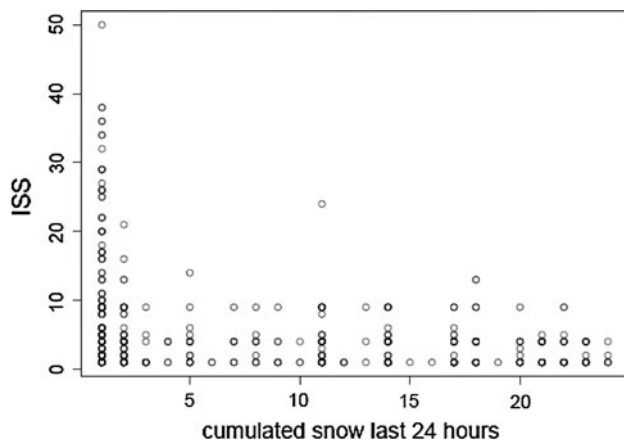


Fig. 3 Scatterplot of ISS values and cumulated 24-h snowfall (cm)

Table 3 Multilevel linear model for log (ISS) versus trauma risk factors* considering the five ski resorts as level factor

	Parameter	<i>t</i> test	<i>P</i> value
Intercept	0.88	8.45	<0.001
Age and sex			
21–30	−0.11	−2.25	0.02
31–40	−0.13	−2.73	0.01
41–50	−0.03	−0.61	n.s.
51–60	0.09	1.46	n.s.
Over 60	0.21	3.71	<0.001
Sex (Male)	0.10	3.32	<0.001
Weather condition			
24-h snowfall (cm)	−0.01	−2.12	0.03
Average snow level (cm)	0.00	0.23	n.s.
Temperature Min.	−0.01	−1.64	n.s.
Type of skier			
Local resident	−0.32	−10.45	<0.001
Snowboard	0.10	2.57	0.01
Type of accident (fall)	0.03	0.71	n.s.
Experience level			
First time	−0.05	−0.59	n.s.
Beginner	−0.12	−2.42	0.02
Medium	−0.04	−1.45	n.s.
Unknown	0.44	3.53	<0.001

* Reference profile is an expert woman skier age [0–20], non-local resident

study showed that inappropriate trail design and slope grooming increases the frequency of injuries. There is probably a connection between snow, trail condition, incidence, and severity of injuries, but further research is needed to explore this field.

Few measures are known to be effective in preventing skiing injuries: helmet for head injuries [22], wrist-guards

for wrists injuries among snowboarders [19], and training programs using videotaped knee injuries scenes [7]. The Italian law enforces the use of helmet only for under 14-years-old skiers. Since other age groups are at risk of severe injuries and traumatic brain injuries represent one of the main features for severe skiing and snowboarding accidents [25], the use of helmet should be strongly recommended to all skiers and snowboarders and not only to children. Moreover, information about wrist-guards protection should be targeted to snowboarders. The use of videotaped injuries scenes could represent a useful approach not only to prevent knee injuries, but also to spread information about skiing and snowboarding injuries and to promote safe behaviors on the slopes. To confirm the effectiveness of such preventive measures, further studies are needed.

From the clinical point of view, it is particularly relevant that people aged 60 or more are at high risk of severe injuries. It is well known that the death rate of elderly patients with poly-trauma approximately doubles compared to the one of younger subjects. This is due both to the lack of homeostatic reserve and to pre-existing medical conditions, some of which may be subclinical. The management of severely injured old patients is sometimes challenging; therefore, a particular effort should be made to prevent severe injuries among this group.

Conclusion

Although severe injuries may occur, skiing and snowboarding are generally considered safe sports by several hundred million people worldwide. Among these, some seem to be at higher risk of severe injury. We found that the severity of the injuries increases with age. Elderly skiers report more severe injuries when compared to other age classes. Pre-existing medical conditions and lack of physiological reserve challenge the management of severe injuries in elderly patients. A particular effort should be made to prevent injuries in this population.

A 24-h fresh snowfall seems to reduce ISS level. Very little is known about snow conditions and winter sports injuries, but a correlation between snow, slopes conditions, and injuries is emerging. Further studies are undoubtedly needed to explore this field. Non-local residents report more severe injuries compared to local residents; this probably reflects the different knowledge of the slopes and the average higher skiing capabilities of the local population.

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