INFLUENCE OF EXTERNAL RISK FACTORS ON ALPINE SKIING INJURIES IN RECREATIONAL SKIERS

UTJECAJ VANJSKIH ČIMBENIKA RIZIKA NA OZLJEDE U ALPSKOM SKIJANJU KOD REKREATIVNIH SKIJAŠA

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SUMMARY

The main goal of this study was to identify potential external risk factors for injury in recreational skiers through a survey questionnaire. Subjects were divided into injured skiers and a control group who never had an injury. Injured skiers (N=212) answered questions that helped define potential risk factors. The control group (N=206) completed the same questionnaire but without questions about injury. Common questions were used to determine the possibility of injury using Chi-Square test, and additional questions were used to determine the influence on injury severity using Fisher's test. An analysis of external factors showed that formal ski school was not statistically related to the possibility and severity of injury, but significantly increased knowledge of skiing. Skiing with another person did not decrease the possibility of injury but did increase the severity of injury. Visibility, field of vision, condition of the slope, temperature, and weather conditions are not statistically related to injury severity, but when combined, they could be an important factor in the possibility of injury.

Keywords: *skiing, alpine skiing, ski injuries, causes of skiing injuries*

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INTRODUCTION

Skiing is a widespread recreational activity regularly practiced by approximately 200 million skiers per year (Ropret, 2014). With 2 skiers injured per 1000 ski days (Johnson, Ettlinger, & Shealy, 2008), skiing injuries are considered a public health problem, affecting the majority of the working-age population. For the purposes of this study, we defined a ski injury as one after which someone could not ski for at least one day. In recent years, the number of injured skiers has decreased significantly, mainly due to the better quality of equipment (St-Onge, Chevalier, Hagemeister, Van de Putte, & De Guise, 2004), but many external risk factors are still poorly explained, such as visibility, temperature, or company while skiing. In the literature, risk factors are defined (Ruedl, Ploner, Linortner, Schranz, Fink, Patterson, & Burtscher, 2011; Bahr & Krosshaug, 2005) and divided into internal and external. Some papers claim that attending a formal ski school has nothing to do with a lower likelihood of being injured while skiing (Bouter & Knipschild, 1991; Garrick & Requa, 1977). The opposite is argued by researchers from Canada (Macnab, Cadman, & Greenlaw, 1998), and France (Goulet, Régnier, Grimard, Valois, & Villeneuve, 1999).

A comprehensive analysis of previous research cites formal ski training as one of the biggest myths in reducing the likelihood of injury (Johnson, Ettlinger & Shealy, 2009). Recent research indicates little effect on injury prevention for individuals who learned from a professional (Ekeland, Rødven, & Heir, 2019). To date, no studies have described skiing in a group or with someone as an external factor in injury, while one study shows that children are less likely to be injured in ski school compared to skiing in a group, which is not the case for adults (Cadman & Macnab, 1996). The ski surface is a relatively frequently described risk factor in skiing (Moore & Knerl, 2013; Demirag, Oncan & Durak, 2004), but it is the greatest risk for young skiers (Dohin & Kohler, 2008). It is noted that there are so-called "AOC - areas of concern" areas on the trail where up to 40% of all trail injuries occur (Shealy, Scher, Johnson, & Rice, 2015), and that the number of injuries decreases proportionally to the number of hours of trail fixation (Bergstrøm & Ekeland, 2004). Air temperature is a rarely researched and dubious risk factor for injury. Aschauer concluded that low air temperature favours injury, but attributes this to poor weather and visibility (Aschauer, Ritter, Resch, Thoeni, & Spatzenegger, 2007).

Comparing intra-articular to skin temperature at the knee after 60 minutes of skiing, the mean intra-articular temperature was 19.6% higher than the skin temperature at the knee. The reason for this is a decrease in skin temperature, as well as thigh muscle temperature after one hour of skiing (Becher, Springer, Feil, Cerulli, & Paessler, 2008). Meteorological conditions as a risk factor have not been significantly described. It is stated that women are twice as likely to suffer a knee injury in snowfall compared to other injuries (Ruedl, Fink, Schranz, Sommersacher, Nachbauer, & Burtscher, 2012). In a sample of 3512 casualties, the risk of injury was twice as high on sunny days than on precipitation days, but the authors linked this to poorer visibility (Aschauer, Ritter, Resch, Thoeni, & Spatzenegger, 2007). In addition, one study failed to demonstrate an

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association between weather conditions and the occurrence of LCA injuries in women (Ruedl, Linortner, Schranz, Fink, Schindelwig, Nachbauer, & Burtscher, 2009). The influence of weather conditions on injuries has also been analysed by Japanese researchers, but no association was found, so weather conditions remain a doubtful risk factor for injuries. Visibility has been described in the literature mostly as an influence of weather conditions on injury and rarely as an individual factor. Aschauer stated that poor visibility is the main cause of injury in bad weather (Aschauer, Ritter, Resch, Thoeni, & Spatzenegger, 2007), while Ekeland claimed that poor visibility is one of the main causes of injury in new equipment (Ekeland & Nordsletten, 1994), whose quality is evolving at a rapid pace (Davey, Endres, Johnson, & Shealy, 2019). Ruedl found that poor visibility increased the likelihood of LCA injury in skiers tenfold (Ruedl, Fink, Schranz, Sommersacher, Nachbauer, & Burtscher, 2012). Finally, one study found that the incidence of injury was lower with good visibility (Bouter, Knipschild, & Volovics, 1989). It can be concluded that visibility, like many others, is a questionable risk factor for injury. Obscuration of the field of view by some of the equipment has not been studied in previous work but has been consistently observed as visibility for the duration of certain weather conditions. An interesting 2011 study described those polarized glasses recommended for motorcycling or bicycling are not suitable for skiing because they prevent the occurrence of glare that could be a sign of a potential threat (person or object) (Lingelbach & Jendrusch, 2010), as well as that there are no significant differences between filters for glasses of different colors (Jendrusch, Senner, Schaff, & Heck, 1999). The helmet is cited as an insignificant factor in reducing the field of view (Hagel, 2005). To our knowledge, there is no study with so many external risk factors related to environmental conditions and also compared with a control group. Therefore, the purpose of this study was to analyse the data of some external risk factors in injured recreational skiers during the winter season 2013-2018 and their influence on the possibility and severity of injury.

MATERIALS AND METHODS

Procedure

This study was conducted as a retrospective, questionnaire-based study during five winter seasons (2013-2018). Data were collected from injured recreational skiers of all ages and both sexes in special rehabilitation hospitals and included in the study. The survey was conducted in accordance with the ethical guidelines for surveys approved by the Ethics Committee of the Faculty of Kinesiology, University of Zagreb, at its meeting on 23 April 2013. All participants were informed about the purpose of the study before completing the questionnaire. Data from the control group of uninjured

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skiers were collected by random recruitment at ski resorts after a full day of skiing after leaving the ski slopes, also over a five-year period. The planned sample size was 200 injured skiers and the same number of uninjured skiers. Considering the statistical significance level (0.05), the targeted statistical power (0.95), and the moderate impact factor (effect size d = 0.5), the minimum sample size for the Mann Whitney U test was 186 subjects divided into two groups, whereas the student's t test required 176 subjects and the multiple regression analysis, e.g., with three predictors, required 119 subjects. Therefore, the planned sample size was sufficient for reliable analysis, even though some skiers did not answer all questions. The required sample size was calculated using the freely available software G * Power Software (Heinrich-Heine-University Duesseldorf, Duesseldorf, Germany).

Questionnaire

Both groups (injured and uninjured) completed a validated questionnaire, as a test-retest review of the questionnaire was performed on 20 subjects who completed the questionnaire again, and it showed a satisfactory reliability of r=0.857 with p 0.001. More than 90% of the invited patients and 50% of the uninjured skiers agreed to participate in this study. Skiers were also asked about their self-reported skiing level (expert, advanced, intermediate, beginner) according to Sulheim et al. (Sulheim, Ekeland, & Bahr, 2007). While the injured group completed the entire questionnaire, the uninjured group completed an identical questionnaire without questions about the conditions of the injury (vision, visual field, track condition, temperature, and weather conditions). All study participants were informed about the aims of the study and gave their written consent to participate.

Statistical analysis

To compare the distribution of individual characteristics between injured and uninjured groups of skiers, the chi-square test was used, i.e., Fisher's exact test in the case of a small number of occurrences of individual values of a given category variable. In addition to the test of statistical significance and in order to examine the strength of the correlation between the variables, the results also include the size of the effect or the measure of correlation in the form of Cramer's coefficient V. In the case of injured skiers, the influence of certain factors on the severity of the injury was analysed, measured by three ISS categories (mild, moderate and severe injury) estimated by the authors (Stevenson, Segui-Gomez, Lescohier, Di Scala, & McDonald-Smith, 2001). Ordinal logistic regression, corresponding to a larger number of categories of the dependent variable compared to standard logistic regression, examined the influence of a single factor on injury severity. Statistical analysis was performed using the SAS System software package (SAS Institute Inc., North Carolina, USA).

RESULTS

A total of 418 surveys were collected, an equal number of injured (212 surveys; 51%) and uninjured (206 surveys; 49%) skiers. According to the results, of the total number of respondents, 11% were beginners, 36% were average skiers, 28% were advanced skiers, and 25% were excellent skiers. Based on the observed values and previous research, the ISS numerical variable, i.e., the injury severity indicator, was transformed into a categorical variable with three categories (Table 1).

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Table 1. *Distribution of categorized ISS indicators*

ISS_{kat}	N	%
Minor injury	70	33.0
Moderate injury	47	22.2
Severe injury	95	44.8
Total	212	100.0

1. Minor injury (0> ISS> 8)
2. Moderate injury (8> ISS> 15)
3. Serious injury (ISS> 15)

Attending a ski school or learning to ski from a licensed instructor was not statistically significantly associated with injury (Chi-Square test; p = 0.721) (Table 2). Most skiers surveyed learned to ski from a licensed ski instructor (71.5%).

Table 2. *The association between injuries and learning to ski from a licensed ski instructor.*

Variable	Total	Injured	Uninjured	p-value[a]	Cramer V
Ski school				0.721	0.018
Learning from a licensed ski instructor	71.5 %	70.8 %	72.3 %		
Didn't learn form a licensed ski instructor	28.5 %	29.3 %	27.7 %		

[a] *P-value of the Chi-Square test to compare the distribution of characteristics between injured and uninjured groups of skiers.*

Ski school or learning from a licensed ski instructor was not statistically significantly associated with injury severity (Chi-Square test; p = 0.505) (Table 3).

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Table 3. *The association between severity of injury and learning from licensed ski instructor*

Varijable	Minor injury (ISS ≤ 8)	Moderate injury (8 < ISS ≤ 15)	Severe injury (ISS > 15)	p-value[a]	Cramer V
Ski school				0.505	0.081
Learning from a licensed ski instructor	75.7 %	66.0 %	70.2 %		
Didn't learn from a licensed ski instructor	24.3 %	34.0 %	29.8 %		

[a] *P-value of the Chi-Square test to compare the distribution of characteristics between three groups of skiers.*

It is also interesting to note that skiers who attended an official ski school had significantly better self-assessed skiing skills (32% excellent, 33% advanced, 31% intermediate, and only 4% beginner) compared to those who did not attend a ski school (8% excellent, 32% advanced, 35% intermediate, and even 25% beginner). Skiing with someone or in a group (Chi-Square test; p = 0.834) showed no statistically significant association with skier injuries (Table 4).

Table 4. *The association between injury and skiing with other person*

Varijable	Total	Injured	Uninjured	p-value[a]	Cramer V
Company during skiing				0.834	0.030
Alone	10.8 %	10.4 %	11.2 %		
In a group	79.6 %	79.2 %	80.0 %		
In ski school	9.6%	10.4%	8.8%		

[a] *P-value of the Chi-Square test to compare the distribution of characteristics between injured and uninjured groups of skiers.*

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Company during skiing was statistically significantly associated with injury severity (Fisher's test; p = 0.005). A higher proportion of skiers with company was found among severely injured skiers (88%) than among moderately injured skiers (78%) and slightly injured skiers (67%) (Table 5).

Table 5. *The association between injury severity and skiing with other person*

Varijable	Total	Minor inury (ISS ≤ 8)	Moderate injury (8 < ISS ≤ 15)	Severe injury (ISS > 15)	p-value[a]	Cramer V
Company during skiing					0.005	0.182
Alone	10.8 %	17.1 %	15.2 %	3.2 %		
In a group	79.6%	67.1%	78.3 %	88.3 %		
In ski school	9.6%	15.8%	6.5%	8.5%		

[a] *P-value of the Fischer's test test to compare the distribution of characteristics between three groups of skiers.*

Most of the injured skiers had no visual field defects (92%). The trail was usually in good condition (according to 39% of the injured skiers), while 24% of the injured skiers skied on a trail with ice surfaces, 15% on a trail with bumps, 11% on a wet trail, 9% on deep snow, and 2% on an uneven (broken, narrow) trail (Table 6).

Visibility was mostly good (68%), 18% of skiers rated it as average and 14% as poor. Almost one in two injured skiers (47%) rated the temperature as comfortable, while 44% said it was cold, 8% said it was warm, and 1% said it was hot. Most of the injured skiers skied in sunny weather (58%), one in five skied in snow, 14% skied in fog, and 4% skied in cloudy weather or reduced sunlight (Table 6).

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Table 6. *Slope and weather condition*

Visual disturbance	No 92%	Yes 8%
Track conditions	Good 39%	Other (ice surfaces, bumps, wet trail, deep snow, broken trail) 51%
Visability	Good 68%	Other (average and poor) 32%
Temperature	Comfortable 47%	Other (cold, warm, hot) 53%
Weather conditions	Sunny 58%	Other (snow, fog, cloudy, dusk) 42%

Weather and other disturbances, such as limited field of vision (Chi-Square test; $p = 0.744$), track conditions (Chi-Square test; $p = 0.105$), visibility (Chi-Square test; $p = 0.453$), temperature (Fisher's test; $p = 0.340$), and other meteorological conditions (Fisher's test; $p = 0.649$), were examined only in the injured group and showed no statistically significant correlation with injury severity (Table 7).

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Table 7. *Correlation between weather and slope condition with the severity of a skiing injury.*

Variable	Minor injury (ISS ≤ 8)	Moderate injury (8 < ISS ≤ 15)	Severe injury (ISS > 15)	p-value[a]	Cramer V
Visual disturbances (fog, tears, darkness, cap, glasses, flash or poles)				0.744	0.053
No	89.9 %	93.5 %	92.6 %		
Yes	10.1 %	6.5 %	7.5 %		
Track condition				0.105	0.178
Good	47.8 %	28.3 %	37.2 %		
Wet	4.4 %	17.4 %	11.7 %		
Ice	23.2 %	21.7 %	26.6 %		
Deep snow	8.7 %	17.4 %	5.3 %		
Uneven surface	15.9 %	15.2 %	19.2 %		
Visibility				0.453	0.093
Good	61.4 %	69.6 %	72.3 %		
Mediocre	22.9 %	19.6 %	12.8 %		
Bad (fog, dark)	15.7 %	10.9 %	14.9 %		
Temperature				0.340	0.130
Cold	51.4 %	37.0 %	42.6 %		
Comfortable	44.3 %	47.8 %	47.9 %		
Warm	4.3 %	10.9 %	8.5 %		
Hot	0.0 %	4.4 %	1.1 %		
Weather conditions				0.649	0.121
Snow or rain	23.5 %	26.1 %	15.1 %		
Sun (sunny, windy)	54.4 %	56.5 %	61.3 %		
Fog	16.2 %	8.7 %	15.1 %		
Cloudy	2.9 %	6.5 %	3.2 %		
Reduces sunlight	2.9 %	2.2 %	5.4 %		

[a] *P-value of the Chi-Square test / Fisher's test to compare the distribution of characteristics between the three ISS categories*

DISCUSSION

The main finding of the present study was that external risk factors, such as official ski school and company during skiing, do not influence the possibility of injury, nor do environmental conditions influence the severity of injury in recreational skiers. As it has been found, professionally trained ski instructors have a doubtful influence on the likelihood of injury (Bouter & Knipschild, 1991; Macnab, Cadman, & Greenlaw, 1998; Johnson, Ettlinger & Shealy, 2009; Davey, Endres, Johnson, & Shealy, 2019). This study confirms the thesis of most studies that a trained ski instructor has no effect on injury likelihood or severity. However, when we

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examine the self-assessment of skiing skills compared to attending a formal school, we find that those who have attended a ski school are excellent skiers 32% of the time and beginners 4% of the time, while those who have not attended a ski school are beginners 25% of the time and excellent skiers only 8% of the time.

And this gives us the information that the official ski school fulfils its main purpose, which is to increase the knowledge of skiing and therefore probably to have more fun. Accompaniment while skiing is a factor that had no effect on the possibility of injury in the present study (the injured were accompanied by another person 79% of the time, the uninjured 80% of the time), whereas skiing in a group increased the severity of injury, which might be explained by increased relaxation.

Visual disturbance has not been previously studied, unless limited by bad weather, and thus was not a significant risk factor except at high speeds (Carus & Castillo, 2021). This study failed to demonstrate the influence of visual field impairment on injury severity, suggesting that other factors still have a much greater influence on injury severity. The influence of slope condition on injury has been extensively addressed in previous work and according to Dohin (Dohin & Kohler, 2008) is a risk particularly for younger and less experienced skiers. In this analysis, it had no statistically significant effect on injury severity. Considering that only 39% of injured skiers responded that the slope was good, it can be concluded that a poor slope, although not influencing the severity of injury, can likely increase the possibility of injury. Visibility has been presented as a dubious factor in previous work, although it has been shown to increase the possibility of injury in poor weather (Aschauer, Ritter, Resch, Thoeni, & Spatzenegger, 2007).

This work showed that visibility had no effect on the severity of injury. Temperature is the next factor that has been studied only in the injured population and had no statistically significant effect on the severity of injury. It has been little studied in previous research and is mainly associated with weather conditions and poor visibility (Aschauer, Ritter, Resch, Thoeni, & Spatzenegger, 2007). According to previous research, cold weather leads to greater heat loss in women, so this could be a predisposing factor for injury, which has been shown specifically for the knee but was not investigated in this study. Meteorological conditions (sun, precipitation, etc.) were also only examined in the injured group and had no effect on injury severity.

Although the condition of the slope and the weather conditions were only studied in the injured skier group, so the possibility of injury itself was not studied for these factors, it can be concluded that they still have an influence on injury, as visibility was only good in 68% of skiers, only 47% of skiers rated the temperature as comfortable, and only 39% of injured skiers answered that the slope was good, so together they could be an important factor in the possibility of injury.

Limitations

The disadvantage of this study is primarily the rather small sample compared to some other analyses, but the advantage is that a control group was also selected. Most of the existing

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studies have not included a control group. Also, this study has an important condition for participation, which is the inability to ski for at least one day after the injury. Although this seems to be irrelevant data, other studies show that many injuries are contusions, abrasions, sprains, after which one could ski that day and the next and still be defined as a ski injury.

Finally, another real shortcoming of the study is the objectivity of the responses for some factors. The most obvious example is the subjective assessment of air temperature and slope conditions, so the above example may lead to an exaggeration or downplaying of the importance of external factors in describing conditions or assessing the cause of injury.

CONCLUSION

By examining the external risk factors, they were found to have an impact on injuries in recreational skiers. However, the impact is exclusive in relation to improving skiing skills when attending formal ski school and increasing injury severity when skiing in a group. Environmental conditions do not increase injury severity, but could be an important factor in the possibility of injury. The results should be presented to recreational skiers, as well as professional coaches during their training sessions. Subsequent research should include additional self-assessments of injury causes as new variables and compare with the results obtained.

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INFLUENCE OF EXTERNAL RISK FACTORS ON ALPINE SKIING INJURIES IN RECREATIONAL SKIERS

SAŽETAK

Glavni cilj ovog istraživanja bio je identificirati potencijalne vanjske čimbenike rizika za ozljede rekreativnih skijaša putem anketnog upitnika. Ispitanici su podijeljeni na ozlijeđene skijaše i kontrolnu skupinu koja nikada nije imala ozljedu. Ozlijeđeni skijaši (N=212) odgovarali su na pitanja koja su pomogla definirati potencijalne čimbenike rizika. Kontrolna skupina (N=206) ispunila je isti upitnik, ali bez pitanja o ozljedi. Zajednička pitanja korištena su za utvrđivanje mogućnosti ozljede pomoću Chi-Square testa, a dodatna pitanja za utvrđivanje utjecaja na težinu ozljede Fisherovim testom. Analizom vanjskih čimbenika pokazalo se da pohađanje službene škola skijanja nije bilo statistički povezano s mogućnošću i težinom ozljede, ali je značajno povećalo znanje skijanja. Skijanje u društvu nije smanjilo mogućnost ozljeda, ali je povećalo težinu ozljede. Vidljivost, vidno polje, stanje staze, temperatura i vremenski uvjeti nisu statistički povezani s težinom ozljede, ali kombinirano mogu biti važan čimbenik u mogućnosti ozljeda.

Ključne riječi: *skijanje, alpsko skijanje, skijaške ozljede, uzroci skijaških ozljeda*

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