A Prospective Injury Surveillance Study on Ski Touring

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Background: Ski touring is an outdoor sport with growing popularity in alpine countries. Information about injuries in ski touring is limited.

Purpose: To determine injury rates, mechanisms, causes, and risk factors in ski touring.

Study Design: Descriptive epidemiology study.

Methods: Between November 2015 and May 2016, a total of 191 participants from the Alps region were prospectively tracked via personalized online questionnaires. Injury rates were calculated per 1000 hours of sports exposure. Risk factors were assessed per multivariate logistic regression analysis.

Results: A total of 3900 ski tours were performed, with 10,955 hours and 4,108,503 m in height ascension (uphill) recorded. The overall injury rate was 2.5 injuries per 1000 hours of ski touring. A total of 27 injury-events were reported, of which 18 (67%) were classified as mild, 7 (26%) as moderate, and 2 (7%) as severe. Hands (28%) and knees (16%) were the most commonly involved anatomic regions. Most injuries were limited to the soft tissue, such as bruises (31%) and abrasions (18%). Significantly more injuries happened during the descent (n = 17; 63%) than during the ascent (n = 6; 22%) (odds ratio, 5.96; P = .004), while poor weather conditions, icy surface, and inattentiveness were the most often reported reasons for injury. Sidecountry ski touring was identified as the only significant independent risk factor for injury (P < .001).

Conclusion: In this prospective injury surveillance study, the majority of ski touring injuries were mild and limited to the soft tissue. Ski touring injuries were more likely to happen during the descent of a tour, and sidecountry ski touring was the only significant independent risk factor for injury. Bad weather, icy surface, and inattentiveness were found to be the leading causes for an injury-event in this study.

Keywords: injury surveillance; sports injury; epidemiology; prevention; ski touring; alpine sports

Over the past few years, ski touring has become an emerging winter sport especially in alpine regions. According to current estimates of the German and Austrian Alpine Association, there are about half a million ski tourers in Germany and up to 700,000 ski tourers in Austria.9,27

Ski touring involves uphill and downhill travel without needing to remove the skis.6,39 It is a hybrid between alpine skiing and (snow) hiking and overlaps with both nordic and alpine forms. As such, a characteristic of ski touring is a free heel in an alpine ski binding, allowing for traversing and ascending flat or extremely steep terrain.6,39 Climbing skins or friction aids are typically used to provide sufficient grip during the ascent.6,39 The descent is similar to alpine skiing; however, the touring bindings are set to hold the boot heel firmly to the ski.8

Ski touring is generally distinguished as frontcountry, sidecountry, and alpine or backcountry.6,39 Frontcountry is defined as ski touring within the boundaries of a ski area, with ski lifts and emergency services close at hand.6,39 Sidecountry is defined as ski touring outside marked ski area boundaries yet accessible via ski lift, and backcountry ski touring is defined as navigating and skiing in remote areas outside the boundaries of the ski terrain.6,39 Backcountry ski touring is more time-consuming, owing to longer transportation to the high alpine terrain, thus explaining why frontcountry ski touring in a skiing area has become more popular in recent years as an after-work activity.1,17,28,40 In addition to the ability of skiing off-piste, backcountry ski touring requires navigation skills and knowledge to assess snow conditions to minimize the risk of avalanche-related accidents.6,39 Additional safety equipment, including

The Orthopaedic Journal of Sports Medicine, 7(9), 2325967119867676
DOI: 10.1177/2325967119867676
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avalanche- and rescue-specific equipment, is also recommended for ski touring in remote areas.23

Little is known about injury rates and causes in ski touring, and presently, only 1 cross-sectional questionnaire-based study about frequencies and causes of injuries in frontcountry ski touring is available.34 In that retrospective study, among a cohort of 451 so-called slope tourers, an injury rate of about 13% was calculated, with self-inflicted falls being the most common reported injury cause. Hence, the current study sought to determine common injury rates, patterns, causes, and risk factors in all ski touring disciplines.

METHODS

For this prospective observational study, institutional review board approval was obtained, and all participants gave written consent.

Study Population

For methodological purposes, participants were selected according to the STROBE (STrengthening the Reporting of OBServational studies in Epidemiology) criteria.28 The study was conducted during 1 ski touring season from November 2015 to May 2016. Participants had to be at least 18 years old and had to perform at least 1 ski tour in the observed season to be included. Initially 214 participants were prospectively being tracked; however, 23 were excluded as they did not perform any ski tour during the observed season. The final analysis included 191 participants.

Recruitment of participants was based on previous sports injury surveillance studies,11,12 and participants were contacted through the registries of the Austrian Skiing Association and the Austrian, German, and Swiss Alpine Clubs. Given the substantial geographic and climatic differences among several mountain chains, the aim was to include only participants who conducted their ski tours in the Alps region.

Data Acquisition

All data were obtained with an encrypted, anonymized, and personalized online-based questionnaire.22 General information—including age, sex, body dimensions, preferred skiing territory, years of ski touring experience, skill level, and skiing behavior—was gathered prior to the study. The definition of each skill level was established in a consensus session with a ski touring expert group. A modified classification was constructed according to previous sports epidemiology studies.11,12 Skiing behavior was categorized as “very careful,” “cautious,” “willing to take some risks,” and “risk taker.”11 Participants were divided into 3 groups, as beginner, advanced, and expert ski tourers. Further details are provided in Table 1.

At the end of each month within the ski touring season, participants filled out an activity-based online questionnaire.4 The information being obtained included number of hours of ski touring, number of tours performed, meters ascended, terrain and snow conditions, off-piste training, equipment employed, avalanche accidents, and sustained injuries. Participants could refer to the terrain as frontcountry, sidecountry, or backcountry tours. Snow conditions were classified into “fresh snow/powder,” “good grip,” “slushy/muddy,” and “icy.” Off-piste training was defined as any workout besides ski touring and included cardiovascular training, strength training or stretching, and balance training. Ski touring equipment was defined as every type of equipment used outside of conventional skiwear, such as a ski suit, skis, and ski poles (Figure 1).

In case of a reported injury-event, additional information regarding the circumstances, affected body part, type of injury, injury severity, and mechanisms of injury was assessed. Multiple responses regarding the injury circumstances and mechanisms were possible. Injury circumstances included information about the phase of the ski tour (ascent, descent, or between), time of day, weather and snow conditions, and the ski touring equipment employed. Questions about injury mechanism involved information about the ski touring accident, such as tilting, slipping, or colliding, and also material-related information, such as inadvertent release of the binding or technical failure (Figure 2).

With regard to injury mechanism, questions regarding the physical state during the accident were asked, as well as any influencing factors such as inattentiveness.

| Variable | Beginner | Advanced | Expert |
|----------|----------|----------|--------|
| Experience | ≤1 ski touring season | ≥2 ski touring seasons | Ski touring guide |
| Preferred terrain | Front- and sidecountry | Any terrain | Any terrain |
| Competition | None | Nonprofessional | International |

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The authors declared that there are no conflicts of interest in the authorship and publication of this contribution. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

Ethical approval for this study was obtained from the ethics committee for the province of Salzburg, Austria (415-EP/73/668-2016).
Furthermore, the participants were asked about their rescue, medical treatment, and the injury-related time of sports impairment.

Throughout the season, weekly checks of ski touring–related media were conducted to ensure that none of the ski tourers who had failed to follow up had suffered a fatal ski touring injury.

A ski tour was divided into ascent and descent and distinguished as frontcountry, sidecountry, or backcountry (Figure 3).

**Injury Rate Calculation**

According to the consensus statements of Fuller et al., an injury was defined as any physical complaint that resulted from training or competition, regardless of medical treatment requirement or absence from sports.

The injury rate was calculated per 1000 hours of sports exposure. The term exposure comprised everything between the start and the very end of a ski tour. An injury-event was defined as an incidence with possibly >1 injury type or affected anatomic location involved.

The severity of injury was defined according to the extent of sports impairment. Injuries causing no disruption to training or competition, such as bruises or contusions, were considered mild. Injuries resulting in a partial restriction from usual level of performance while still allowing participation in sports were defined as moderate. Injuries resulting in total absence from sports for a certain time span were classified as severe, and injuries leading to permanent disability or death were considered fatal.

According to Meeuwisse, risk factors were divided into 2 categorical types: intrinsic and extrinsic. Intrinsic factors included maturational stage, somatotype, and previous injuries, and extrinsic factors referred to equipment, type of tour, and environment. Intrinsic risk factors may predispose an athlete to an injury, whereas extrinsic risk factors are the trigger for an injury-event.

**Statistical Analysis**

Data were tested regarding normal distribution according to the Shapiro-Wilk test. Statistical significance between several means was assessed with an unpaired Student t test for normally distributed data and the Mann-Whitney U test for nonnormally distributed data. Chi-square tests and Fisher exact tests (if n < 5) were used to analyze categorical variables. Univariate risk factors were quantified with odds ratios and a corresponding 95% CI. Multivariate logistic regression analysis was conducted to determine independent intrinsic and extrinsic risk factors. Goodness of fit of the binary logistic regression models was assessed via the Hosmer-Lemeshow test. All statistical tests were 2-sided, and P values <.05 were considered statistically significant.
RESULTS

Study Population

Of the 191 included participants, 27 (14%) performed only 1 ski tour in the ski touring season. The mean age was 33.7 years (range, 18-70 years), and 112 participants (59%) were men. Participants originated from 8 countries. The skill level ranged from beginner to expert, including 48 beginners (25%), 120 advanced ski tourers (63%), and 23 experts (12%).

The mean experience in ski touring was 11.3 years (range, 0-40 years). More than two-thirds of the study participants (n = 131; 69%) stated that they performed regular off-piste training; most of those (n = 125; 65%) performed cardiovascular or strength training, whereas 60 (31%) did not work out regularly. The most frequently employed types of equipment were climbing skins or friction aids (n = 176; 92%), avalanche transceivers (n = 166; 87%), avalanche shovels (n = 161; 84%), probes (n = 160; 84%), gloves (n = 121; 63%), and helmets (n = 112; 59%).

Injury Rates, Patterns, and Severity

A total of 3900 ski tours were performed: 1446 as frontcountry, 2064 as sidecountry, and 390 as backcountry. During a total of 10,955 hours, 4,108,503 m in height ascension (uphill) was performed. The overall injury rate was 2.5 injuries per 1000 hours of sports exposure or 6.7 injuries per 1000 ski tours. There were 27 injury-events (14%), of which 18 (67%) were classified as mild, 7 (26%) as moderate, and 2 (7%) as severe. No fatal injuries were recorded. The 27 injury-events involved 32 anatomic regions and 40 types of injuries (Tables 2 and 3). The hand (28%) and knee (16%) were the most commonly injured anatomic regions.

Most injuries were limited to the soft tissue, such as bruises (31%) and abrasions (18%). No ligamentous knee injury was reported. Three participants (2%) suffered from skier’s thumb (lesion of the ulnar collateral ligament of the first metacarpophalangeal joint). All 3 participants were treated nonoperatively and returned to physical activity within 3 months. Two participants sustained a severe injury requiring surgical treatment: one to a syndesmotic malleolar fracture with return to physical activity after 90 days and the other to a radial meniscal tear with return to physical activity after 4 weeks. The participant with the syndesmotic malleolar fracture had to be rescued with a Ski-Doo (snowmobile); all other injured participants were able to descend independently.

Injury Circumstances, Mechanisms, and Risk Factors

The most frequently stated reason for an injury was icy surface (n = 14; 52%), followed by poor weather conditions (n = 10; 37%) and inattentiveness (n = 9; 33%). No accidents involving avalanches were reported. Participants were significantly more likely to get injured during the descent than the ascent of a tour (1.6 vs 0.5 injuries/1000 h; odds ratio = 5.96; 95% CI, 1.8-19.7; P = .004). Although not statistically significant, advanced ski tourers had a higher injury rate (3.0 injuries/1000 h exposure) than experts (1.1 injuries/1000 h; P = .17) and beginners (1.8 injuries/1000 h; P = .34). The injury rate during frontcountry (3.0 injuries/1000 h) and sidecountry (2.8 injuries/1000 h) ski touring was higher than that with backcountry ski touring (0.6 injuries/1000 h). These comparisons, however, did not reach statistical significance (P = .11 and .12, respectively).

In the most common scenario of an injury-event, an advanced ski tourer sustained an injury during the descent of an icy sidecountry ski tour (Table 4).

The only factor that significantly influenced the regression model was sidecountry ski touring (P < .001) (Table 5). The Hosmer-Lemeshow test confirmed the goodness of fit of the model (P = .656).

DISCUSSION

The key finding of this study is that ski touring is associated with an injury rate of 2.5 injuries per 1000 hours of sports exposure and injuries are, for the most part, mild and limited to the soft tissue. Another main finding is that the odds ratio for injury during the descent is 6-fold higher compared with the ascent of a tour. The only significant independent risk factor for injury was sidecountry ski touring.
The overall observed injury rate can also be calculated as 6.7 injuries per 1000 ski tours, which seems comparable with 6 injuries per 1000 ski tours in a previously published cross-sectional study on frontcountry ski touring. The reported injury rate in cross-country skiing was 0.5 per 1000 skiing days in the recreational field and between 0.02 and 0.1 per 1000 skiing days in professional cross-country skiing. The majority of the injuries described by previous cross-country skiing studies were also mild and limited to the soft tissue. Although the unit of the injury rate is different, the injury rates in cross-country skiing are much lower than the injury rates described in this study. In recreational alpine skiing, the previously described injury rate was also lower, with <1 injury per 1000 skiing days in the Alps region.

Table 2: Affected Anatomic Regions During Injury-Events (n = 32)

| Anatomic Region | n | % | Injury Rate |
|-----------------|---|---|------------|
| Hand            | 9 | 28| 0.8        |
| Knee            | 5 | 16| 0.5        |
| Foot/ankle      | 3 | 9 | 0.3        |
| Thigh           | 3 | 9 | 0.3        |
| Hip             | 2 | 6 | 0.2        |
| Arm             | 2 | 6 | 0.2        |
| Ribs/thorax     | 2 | 6 | 0.2        |
| Calf            | 2 | 6 | 0.2        |
| Adductors       | 1 | 3 | 0.1        |
| Head/face       | 1 | 3 | 0.1        |
| Neck            | 1 | 3 | 0.1        |
| Shoulder        | 1 | 3 | 0.1        |

Table 3: Types of Injuries During Injury-Events (n = 40)

| Type              | n | % | Injury Rate |
|-------------------|---|---|------------|
| Bruise            | 12| 31| 1.1        |
| Abrasion          | 7 | 18| 0.6        |
| Ligament rupture  | 5 | 13| 0.5        |
| Muscle strain     | 4 | 10| 0.4        |
| Joint sprain      | 3 | 8 | 0.3        |
| Cartilage injury  | 3 | 8 | 0.3        |
| Contusion         | 3 | 8 | 0.3        |
| Muscle tear       | 1 | 3 | 0.1        |
| Fracture          | 1 | 3 | 0.1        |
| Other             | 2 | 5 | 0.2        |

Table 4: Key Characteristics for an Injury

| Category         | Item          | n  | % |
|------------------|---------------|----|---|
| Skill level      | Advanced      | 21 | 78|
| Type of tour     | Sidecountry   | 18 | 67|
| Phase of tour    | Descent       | 17 | 63|
| Snow condition   | Icy           | 14 | 52|

A higher injury rate than in cross-country and recreational skiing seems in accordance with the fact that ski touring is an adventurous outdoor sport and involves skiing in off-piste terrain. Off-piste skiing appears to be associated with a self-reported risky behavior among skiers and
accidents nor injury-events related to an avalanche. Never-

results, albeit in a limited sample size, revealed no fatal

2016, there were 12 fatal avalanche accidents in ski touring

when performing sidecountry or backcountry ski

transceivers, shovels, and probes, should be a prerequisite

specific equipment, such as avalanche airbags, avalanche

edge in avalanche risk assessment, small group size, and

underestimation of the injury rate. Further studies analyz-
ing is underrepresented and might have contributed to

fact that off-piste skiing by means of backcountry ski tour-

study. These results should be interpreted in light of the

only significant independent risk factor for injury in our

Although in this study the majority of injuries were mild

limited and limited to soft tissue, ski touring is neither harmless nor

in a low-risk sport. In 2016, there were 28 fatal accidents

during ski touring in the Austrian Alps.26 The present

results, albeit in a limited sample size, revealed no fatal accidents nor injury-events related to an avalanche. Never-
theless, it is crucial to be aware of the risk of avalanches, as

backcountry skiers are the most common groups involved in

avalanche accidents and their lethal consequences.28 In

2016, there were 12 fatal avalanche accidents in ski touring

recorded in Austria.26 Geographical knowledge and knowl-
dge in avalanche risk assessment, small group size, and

specific equipment, such as avalanche airbags, avalanche transceivers, shovels, and probes, should be a prerequisite
when performing sidecountry or backcountry ski tours.16,41

Icy surface and bad weather were the main reasons for
injuries. On an icy surface, skiing grip is diminished, especi-

ally while squatting, which increases the risk of slipping, tilting, and falling. Accordingly, lower temperatures and
bad weather conditions are associated with a higher injury
risk on ski slopes.3,31 Obtaining information about the wea-
ther and snow conditions prior to touring could therefor-
be a preventive measure. Inattentiveness was found to
be another cause for injuries in this study. Athletes should
thus take regular breaks and have an adequate intake of
nutrition during ski touring to ensure a proper physical and
mental state. Although there was no significant association

in the present study, off-piste training might be a preven-
tive measure, as increased muscle strength reduces early
muscle fatigue and the concomitant risk of injury.15

While the difference was not statistically significant, the
injury rate in advanced ski tourers (3.0 injuries/1000 h) was
higher than in experts (1.1 injuries/1000 h) and beginners
(1.8 injuries/1000 h). Previous injury surveillance studies
have shown that more experience as such seems to be a preven-
tive measure, as poorer technical skills were associ-
ated with injuries.11,12 According to our definition of perfor-
ance level, advanced ski tourers are those who perform a high
number of ski tours on any terrain without restrictions
but remain on a nonprofessional level. Considering oneself
advanced might be associated with riskier skiing behavior
or an overestimation of one’s personal capabilities. Such
risk-taking behavior was reported to be associated with
higher skiing speeds and increased injury risk.35

In this study, about 16% of all reported injuries involved
the knee joint. Contrary to our assumption, no ligamen-
tous knee injuries were reported. In recreational skiing,
knee injuries make up the majority of injuries.18,20,33,37

Ligamentous knee injuries in alpine skiing frequently
involve the anterior cruciate ligament.19,21 In skiing, the
amount of torsion on the lower extremities is high, thus
exposing the knee joint to unphysiological high rotational
and shear forces, especially when the binding fails to
release during falling.21,32,36 Since the 1990s, the use of
carving skis has evolved, and recent studies have shown
that they have a positive influence on the overall injury
rate and the rate of knee injuries.7 In ski touring, skis are
broader, resulting in a larger contact area and radii, thus
allowing for better control while ascending or descending
in untouched areas with deep powder snow. The influence
of this different type of ski on the risk for injuries is yet to
be investigated. Another feature of ski touring is that pow-
der snow in remote areas makes skiing less aggressive,
with less racing character. Moreover, the rather small size
of touring groups and the lack of mass tourism bear a
lower risk of collision injuries.

A known injury in alpine skiing involves the ulnar col-
ateral ligament of the first metacarpophalangeal joint, also
known as skier’s thumb.10,20,25 We observed 3 cases of
skier’s thumb in this study. All 3 patients were treated
nonoperatively and returned to physical activity within 3
months. Prevention strategies are yet to be defined but
might involve additional support by gloves protective
against forced abduction and hyperextension of the thumb.

The main limitation of this study is that the sample size,
as compared with the large number of ski tourers in the
alpine region, was relatively small. Another limitation is
the questionnaire-based data collection, which might be
subject to recall and information bias. The influence of dif-
ferent ski binding systems was not analyzed, and may be a
focus for further investigations. Comparability with injury
rates of other winter sports was limited, owing to different
definitions of the injury rate. Since a ski tour includes an
ascent and a descent, the injury rate cannot be properly
described per runs and is more precisely expressed per
hour. In addition, the number of backcountry ski tours and
the subgroup analysis regarding skill levels might have

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### TABLE 5
Multivariate Logistic Regression Analysis of Intrinsic
and Extrinsic Risk Factors for Ski Touring Injury

| Item                          | Coefficient | SE  | P   |
|-------------------------------|-------------|-----|-----|
| Intrinsic risk factor         |             |     |     |
| Age                           | 0.032       | 0.025 | .637|
| Sex                           | -0.432      | 0.415 | .537|
| Level of performance<sup>b</sup> | -0.113     | 0.384 | .651|
| Off-piste training            | 0.443       | 0.424 | .292|
| Skiing behavior<sup>c</sup>   | 0.062       | 0.310 | .643|
| Ski touring experience, y     | -0.030      | 0.025 | .092|
| Extrinsic risk factor: ski touring |          |     |     |
| Frontcountry                  | -0.049      | 0.027 | .056|
| Sidecountry                   | -0.052      | 0.010 | <.001|
| Backcountry                   | -0.032      | 0.023 | .096|

<sup>a</sup> Bold indicates statistical significance (P < .05).

<sup>b</sup> Participants were divided into 3 groups: beginner, advanced, and expert ski tourers.

<sup>c</sup> Skiing behavior was categorized as “very careful,” “cautious,” “willing to take some risks,” and “risk taker.”
been underpowered. Further prospective studies with a higher number of participants comparing different alpine regions and territories and showing more detailed subgroup analysis of skill levels and injury severity would be of considerable interest. Finally, we did not have information about phase and snow condition during every ski tour reported. Therefore, we were not able to include those factors in our multivariate analysis.

Nevertheless, the current study is the first prospective trial to analyze injuries in >190 ski touring athletes of the Alps region over the period of 1 ski touring season. Injuries in the present study were defined according to the consensus statement of Fuller et al\(^{12}\) as any physical complaint resulting from ski touring, regardless of medical treatment requirement or absence from sports. Even injuries that did not result in disruption of ski touring were recorded. Thus, underestimation of injury rates may have been minimized.

CONCLUSION

In this prospective injury surveillance study, the majority of ski touring injuries were mild and limited to the soft tissue. Nevertheless, the overall injury rate was higher than in cross-country skiing and recreational alpine skiing. The most commonly affected anatomic regions were the hand and knee joint. In contrast with alpine skiing, ligamentous knee injuries were uncommon. Ski touring injuries were more likely to happen during the descent of a tour, and sidecountry ski touring was the only significant independent risk factor for injury. Bad weather, icy surface, and inattentiveness were found to be the leading causes for an injury-event in this study.

REFERENCES

1. Alpenverein Österreich. Skitouren auf Pisten. http://www.alpenverein.at/portal/news_archiv/2012/2012_01_19_pistentouren.php. Accessed February 16, 2018.
2. Africsson M, Werner S. Self-reported health, physical activity and prevalence of disabilities in elite cross-country skiers and matched controls. J Sports Med Phys Fitness. 2005;45(4):547-552.
3. Aschauer E, Ritter E, Resch H, Spatzenegger H. Injuries and injury risk in skiing and snowboarding. Unfallchirurg. 2007;110(4):301-306.
4. Bahr R. No injuries, but plenty of pain? On the methodology for recording overuse symptoms in sports. Br J Sports Med. 2009;43(13):966-972.
5. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. Br J Sports Med. 2005;39(6):324-329.
6. Branigan H, Jenna K. A Complete Guide to Ski Touring and Ski Mountaineering: Including Useful Information for Off Piste Skiers and Snowboarders. Bloomingon, IN: AuthorHouse; 2006.
7. Burtscher M, Gatterer H, Fritz M, et al. Effects of modern ski equipment on the overall injury rate and the pattern of injury location in alpine skiing. Clin J Sport Med. 2008;18(4):355-357.
8. Campbell JR, Scher IS, Carpenter D, Jahnke BL, Ching RP. Performance of alpine touring boots when used in alpine ski bindings. J Appl Biomech. 2017;33(5):330-338.
9. Deutscher Alpenverein. Skibergsteigen. https://www.alpenverein.de/bergsportaktiv-sein/aktiv-skitourengehen-snowboard-tourengehen-coaid_31017.html. Published 2018. Accessed October 10, 2018.
10. Engkvist O, Falkfors B, Lindsoe U. Thumb injuries in downhill skiing. Int J Sports Med. 1982;3(1):50-55.
11. Ernstbrunner L, Schulz E, Ernstbrunner M, et al. A prospective injury surveillance study in canyoning. Injury. 2018;49(4):792-797.
12. Ernstbrunner LM, Runer AM, Siegert PM, et al. A prospective analysis of injury rates, patterns and causes in cliff and splash diving. Injury. 2017;48(10):2125-2131.
13. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Br J Sports Med. 2006;40(3):193-201.
14. Fuller CW, Molloy MG, Bagate C, et al. Consensus statement on injury definitions and data collection procedures for studies of injuries in rugby union. Br J Sports Med. 2007;41(5):328-331.
15. Haslinger S, Blank C, Morawetz D, et al. Effects of recreational ski mountaineering on cumulative muscle fatigue—a longitudinal trial. Front Physiol. 2018;9:1687.
16. Hohlieder M, Mair P, Wuerli W, Brugger H. The impact of avalanche transceivers on mortality from avalanche accidents. High Alt Med Biol. 2005;6(1):72-77.
17. Jansen P, Weber K. Touren auf Skipisten in Deutschland—Betreutungsrecht und sonstige Aspekte. Österreichisches Kurat für Alpin Sicherheit. 2012;11:37-56.
18. Jordan MJ, Aagaard P, Herzog W. Anterior cruciate ligament injury/reinjury in alpine ski racing: a narrative review. Open Access J Sports Med. 2017;8:71-83.
19. Ketterl R. Recreational or professional participants in nordic skiing. Differences in injury patterns and severity of injuries [in German]. Unfallchirurg. 2014;117(1):33-40.
20. Kim S, Endres NK, Johnson RJ, Ettinger CF, Shealy JE. Snowboarding injuries: trends over time and comparisons with alpine skiing injuries. Am J Sports Med. 2012;40(4):770-776.
21. Koehle MS, Lloyd-Smith R, Taunton JE. Alpine ski injuries and their prevention. Sports Med. 2002;32(12):785-793.
22. Leiner D, Leiner S. SoSci Survey. http://www.soscisurvey.de/index.php?page=home. Published 2006. Accessed April 15, 2018.
23. Ludemann P. Ski touring guide: find the best equipment for your next ski tour. https://www.sport-conrad.com/blog/en/ski-touring-guide-find-the-best-skis-for-your-next-ski-tour/. Published 2018. Accessed December 18, 2018.
24. Meeuwisse WH. Assessing causation in sport injury: a multifactorial model. Clin J Sport Med. 1994;4(3):166-170.
25. Mohseni M, Graham C. Ulnar Collateral Ligament Injury. Treasure Island, FL: StatPearls Publishing; 2019.
26. Österreichischer Alpenverein. 2016 weniger Alpinunfälle in Österreich. http://www.alpenverein.at/portal/news/aktuelle_news_kurz/2017/2017_01_10_alpinunfallstatistik-2016.php. Published 2016. Accessed November 29, 2018.
27. Österreichischer Alpenverein. Skitouren auf Pisten. https://www.alpenverein.at/portal/news_archiv/2012_2012_01_19_pistentouren.php. Published 2011. Accessed October 10, 2018.
28. Probstl U. Skitourengeher auf Pisten—neue Zielgruppe oder Trainer-variante? Mountainmanager. 2012;4:54-55.
29. Rainer B, Firimel C, Sumann G, Brugger H, Kinzl JF, Lederer W. Correlation between avalanche emergencies and avalanche danger forecast in the alpine region of Tyrol. Eur J Emerg Med. 2008;15(1):43-47.
30. Ruedi G, Burtscher M, Wolf M, et al. Are self-reported risk-taking behavior and helmet use associated with injury causes among skiers and snowboarders? Scand J Med Sci Sports. 2015;25(1):125-130.
31. Ruedi G, Fink C, Schranz A, Sommersacher R, Nachbauer W, Burtscher M. Impact of environmental factors on knee injuries in male and female recreational skiers. Scand J Med Sci Sports. 2012;22(2):185-189.
32. Ruedi G, Helie K, Tecklenburg K, Schranz A, Fink C, Burtscher M. Factors associated with self-reported failure of binding release among ACL injured male and female recreational skiers: a catalyst to change ISO binding standards? Br J Sports Med. 2016;50(1):37-40.
33. Ruedi G, Philippe M, Sommersacher R, Dunnwald T, Kopp M, Burtscher M. Aktuelles Unfallgeschehen auf Österreichischen Skipisten—current incidence of accidents on Austrian ski slopes. Sportverletz Sportschaden. 2014;28(4):183-187.
34. Ruedl G, Poccecco E, Kopp M, Burtscher M. Frequencies of injuries and causes of accidents during ski touring on ski slopes—a pilot study. Sportverletz Sportschaden. 2015;29(1):46-50.
35. Ruedl G, Poccecco E, Sommersacher R, et al. Factors associated with self-reported risk-taking behaviour on ski slopes. Br J Sports Med. 2010;44(3):204-206.
36. Shea KG, Archibald-Seiffer N, Murdock E, et al. Knee injuries in downhill skiers: a 6-year survey study. Orthop J Sports Med. 2014;2(1):2325967113519741.
37. Stenroos A, Handolin L. Incidence of recreational alpine skiing and snowboarding injuries: six years experience in the largest ski resort in Finland. Scand J Surg. 2014;104(2):127-131.
38. STROBE criteria. https://www.strobe-statement.org/index.php?id=strobe-home. Accessed April 15, 2018.
39. Volken M, Schell S, Wheeler M. Backcountry Skiing: Skills for Ski Touring and Ski Mountaineering. Seattle, WA: Mountaineers Books; 2007.
40. Wadsack C. Pistentouren. http://www.alpenverein.at/portal/natur-umwelt/bergsport_umwelt/pistentouren.php. Accessed February 14, 2018.
41. Zweifel B, Procter E, Techel F, Strapazzon G, Boutellier R. Risk of avalanche involvement in winter backcountry recreation: the advantage of small groups. Wilderness Environ Med. 2016;27(2):203-210.