

Accidents during Mountain Hiking and Alpine Skiing – Epidemiological Data from the Austrian Alps

Unfälle beim Bergwandern und Alpinskifahren – epidemiologische Daten aus den österreichischen Alpen

Summary

- › **This article presents** epidemiological data on traumatic accidents during mountain hiking in the summer season and recreational alpine skiing in the Austrian Alps.
- › **In mountain hiking**, the absolute number of fatalities remained stable from 2006-2014 (32 to 46 victims per year), whereas the number of non-fatal accidents increased by about 5% per year implying a decreasing mortality index. About 75% of all falls happened during the descent and 70% of the victims who sustained a fall-related injury showed defective vision. Mountain hikers should pay attention to sufficient regeneration before and breaks during descending. Additionally, a regular check of visual aids (glasses, contact lenses) can be recommended.
- › **In recreational alpine skiing**, the injury rate is estimated to be less than 1 injury per 1000 skier days and the traumatic fatality rate amounts to 0.36 traumatic deaths per million skier days. A tear of the anterior cruciate ligament is the most common diagnosis with about 15-21% of all injuries and the risk is 3 times higher in women than in men. Protective equipment and an appropriate skiing speed, depending on skill level, represent preventive measures to reduce injuries and traumatic deaths.

KEY WORDS:

Traumatic Accidents, Falls, Injuries, Anterior Cruciate Ligament

Zusammenfassung

- › **In diesem Beitrag** werden epidemiologische Daten von traumatischen Unfällen beim Bergwandern in der Sommersaison und beim Freizeitskilauf in den österreichischen Alpen präsentiert.
- › **Beim Bergwandern** blieb die absolute Zahl an tödlichen Unfällen im Zeitraum von 2006-2014 stabil (32 bis 46 Todesopfer pro Jahr), wohingegen die Zahl der nicht-tödlichen Unfälle um ungefähr 5% pro Jahr anstieg, was einen rückgängigen Mortalitätsindex ergibt. Ungefähr 75% aller Stürze ereigneten sich beim Abstieg und 70% der Sturzopfer waren mit einer Sehschwäche behaftet. Bergwanderer sollten auf eine ausreichende Erholung vor und auf Pausen während des Abstiegs achten. Zusätzlich wird eine regelmäßige Kontrolle von Sehhilfen (Brillen, Kontaktlinsen) empfohlen.
- › **Beim Freizeitskilauf** wird die Verletzungsrate auf unter 1 Verletzung pro 1000 Skitage und die traumatische Todfallrate auf 0,36 Todesfälle pro 1 Million Skitage geschätzt. Ein Riss des vorderen Kreuzbandes ist die häufigste Diagnose mit 15-21% aller Verletzungen, und das Risiko ist bei Frauen 3-mal höher als bei Männern. Schutzausrüstung und eine angepasste Geschwindigkeit stellen präventive Maßnahmen dar, um Verletzungen und traumatische Todesfälle zu reduzieren.

SCHLÜSSELWÖRTER:

Traumatische Unfälle, Stürze, Verletzungen, vorderes Kreuzband

Introduction

Mountain-sport activities are practiced by an increasing number of people including competitive events (e.g. one-day or multi-stage trial running events) or recreational activities among which alpine skiing and mountain hiking are assumed to be the most popular in the European Alps. Mountain hiking can be defined as recreational hiking on marked trails and can therefore include hiking on forest roads as well as passing rocky terrain or snow fields (33). By definition, mountain hiking does not include mountaineering such as glacier traverses, fixed

rope climbing or rock and ice climbing where specific equipment (e.g. rope) and skills are necessary (18). Therefore, mountain hiking is predominantly practiced at altitudes below 3,000 m in the European Alps. Recreational alpine skiing is typically performed during the winter season on snow-covered and groomed slopes of mountainous areas (11). The usual ambient conditions are characterized by cold temperatures and moderate altitudes up to 2,500 m (10). Alpine skiers use ski lifts and cable cars for the ascent, which is followed by downhill turns (10). >

REVIEW

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Table 1

Recommendations to prevent falls during mountain hiking and traumatic accidents (and related injuries) during alpine skiing.

	MOUNTAIN HIKING	ALPINE SKIING
Preparations	<ul style="list-style-type: none"> - Check regularly visual acuity and visual aids if necessary - Train lower extremities by eccentric muscle exercise - Reduce body weight if you are overweight 	<ul style="list-style-type: none"> - Check / adjust bindings annually - Perform ski gymnastics - Improve your technical skiing skills
During sports	<ul style="list-style-type: none"> - Don't waste your complete power during the ascent - Take regular breaks during descent - Consider descent by cable car if necessary and possible 	<ul style="list-style-type: none"> - Wear protective equipment (helmet, protectors) - Choose adequate skiing speed depending on your level - Avoid alcohol consumption

Both recreational mountain-sport activities are enjoyed by millions of people worldwide (12, 47) and have gained increasing popularity during the last decades (1, 14). On the one side, several studies have shown that mountain hiking and alpine skiing can provide health-related benefits (11, 23, 34, 35, 49). On the other side, these activities are associated with a certain risk of injury or even death. Data from the Austrian Alps revealed an annual rate of about 4 fatalities per 100,000 mountain hikers (9) and about 0.7 per million skier days (37). Falls, cardiovascular emergencies, getting lost, and exhaustion are the most frequent causes for emergencies requiring professional rescue during mountain hiking. Falls are responsible for nearly 50% of these emergencies independently of non-lethal or fatal outcome (17). Data of other regions in the Alps support the observation that falls are the leading cause of accidents in mountain hiking (22). With respect to alpine skiing, results of a study by Posch et al. (37) showed that 51.5% of all fatalities are traumatic deaths and 48.5% are non-traumatic deaths.

Therefore, the prevention of traumatic accidents plays a substantial role in the efforts to make mountain sports safer. For physicians and health professionals who advise persons performing recreational alpine skiing or mountain hiking, for example in medical routine checks and/or in preparation for holidays, knowledge of potential risks in these activities is of utmost importance. In addition, specific high-risk groups and potential risk factors should be considered before individual recommendations are given and preventive tools are suggested. However, it is also important to know the scientific background and the scientific evidence of provided recommendations and preventive tools.

From a scientific point of view, evidence-based injury prevention requires the identification of risk factors and mechanisms before preventive measures can be proposed. In a last step, the preventive effects of these tools should be proven in interventional studies (2). However, this more-step model can cause methodological problems in recreational mountain sports. For example, the complete documentation of non-fatal accidents or the determination of the population at risk (including exposure time) complicate high-quality data collection and its interpretation.

Nevertheless, several epidemiological studies in alpine sports have been conducted in the Austrian Alps. Data collection of these studies followed two general approaches: a) routine documentations of the Austrian Alpine Police, using a standardized data input procedure by trained staff, and b) questionnaire-based surveys and case-control-studies in victims and control persons. The detailed methodology is described in the original research articles (18, 19, 37, 46). Incidence of injuries and fatalities in recreational alpine skiing were calculated based on the number of skier days that represent collectively skiers and snowboarders. The present paper focuses on this series of investigations and presents scientific

data on traumatic accidents during mountain hiking during the summer season (May to October) and alpine skiing including accident-related circumstances, risk factors, and potential preventive measures.

Fall-Related Accidents during Mountain Hiking

Development of Injury and Fatality Risk

Based on routine documentation of accidents and emergencies in a mountain environment by the Austrian Alpine Police (part of the ministry of the interior) 700 fall-related accidents during mountain hiking activities have been documented in 2014 including 733 victims. Among the victims, 32 died because of the fall-related injuries whereas 701 survived with light to severe injuries indicating a mortality index of 4.4% for the year 2014. Interestingly, the absolute number of fatalities remained stable during the observed period from 2006 to 2014, whereas the number of non-fatal accidents increased by about 5% per year (Figure 1). This implies a decreasing mortality index during this period and therefore indicates that mountain hiking became safer with respect to fatal fall-related accidents (18). Since actual analyses are lacking it remains speculative if this trend is still going on.

Unfortunately, the absolute number of mountain hikers is not available and therefore a risk calculation based on the population at risk is impossible. However, the memberships of the largest Alpine Societies, the German and the Austrian Alpine Club, increased by about 45% in the observed time period. Assuming that this development represents the number of mountain hikers in general, the risk of non-fatal falls seem to be decreased (18). Based on a gender distribution in a general population of hikers in the Austrian Alps (16) an odds ratio (OR) for female compared with male hikers of 1.84 for non-fatal falls and 0.58 for fatal falls was estimated (18). These ratios indicate that female hikers are at increased risk for non-fatalities but have a clearly lower risk for fatalities in context of falls compared to their male counterparts.

Injury Locations of Non-Fatal Accidents

Considering non-fatally injured hikers who make an emergency call, most of them are seriously or life-threatening injured (45.4%) whereas 32.4% are unharmed or slightly injured (18). Among non-fatalities, the ankle is the most frequent injury location with about 40% of all injured body areas independent of gender (18, 19). However, injury locations significantly differ between genders: In females, nearly 50% of all injuries affect the ankle, in males, however, head injuries (17%) and multiple locations including polytrauma (12%) play an important role in addition to ankle injuries (27%) (18). Fractures (75%) and sprains (21%) seem to be the most frequent ankle injury types in mountain hikers and preliminary analyses of a case-control study revealed no differences in shoe types between hikers with ankle

injuries and controls. This analysis revealed a higher body mass index in ankle-injured hikers compared to controls (48). Although these results confirm previous findings from other sport activities (3), suggesting that the type of shoe plays a minor role in ankle injuries during mountain hiking in relation to other risk factors, these finding must be confirmed in subsequent evaluations before recommendations can be derived.

Causes and Potential Risk Factors for Non-Fatal and Fatal Accidents

Falls happen predominantly (about 75%) during the descent (18). The unfamiliar and high eccentric muscle contraction of downhill walking may be responsible for this observation (18). Additionally, the kinetic aspects of falling during downhill walking are likely to increase the risk of suffering injuries resulting in an emergency call and thereby in a documentation by the Austrian Alpine Police. Falls were in nearly 60% a consequence of slipping (36) but slipping on snow or ice seems to be relatively rare (6%) compared to slipping or stumbling on rubble or grass with 75% of all fall-related accidents (18). More than 70% of all fall-related accidents happened below 2000 m and less than 1% occurred above 3000 m indicating that altitude-related hypoxia does not play a relevant role in falls during mountain hiking (18). Furthermore, good weather without precipitation was recorded in about 90% of the accidents (18). The many times higher number of active mountain hikers in good compared to bad weather conditions may be responsible for this observation.

Victims of non-fatal accidents were on average significantly younger when compared to victims of fatal accidents (52.2 ± 17.5 versus 57.5 ± 16.5 years, $n=5632$) (age- and gender-specific accident data are presented in the original publication) (18) but much older than the general population of mountain hikers investigated by a survey in the Austrian Alps (41.8 ± 16.1 years, $n=1429$) (16). Therefore, these data strongly suggest age as a risk factor for fall-related accidents and for the severity of the resulting injuries.

Body mass Index (BMI) of victims of a fall-related accident was higher than BMI of a general hiking population in the same region (24.8 ± 3.5 vs. 23.3 ± 3.5 $\text{kg}\cdot\text{m}^{-2}$) with a significant higher proportion of overweight persons (52% vs. 34%) among men compared to women (16, 18). Considering the association between an increased BMI and dynamic walking stability in elderly persons (21), the higher BMI in the population who fell during hiking seems to indicate the impact of BMI on the fall-related accident risk during mountain hiking (18).

In fact, victims of falls were above-average in terms of their physical activity level compared with the general population (19, 24) but below the level of a population of uninjured mountain hikers in the Austrian Alps (16). Therefore, it can be assumed that a high amount of regular physical



Figure 1

Number of victims of fatal (light blue) and non-fatal (dark blue) fall-related accidents during mountain hiking in the Austrian Alps. Data based on (18).

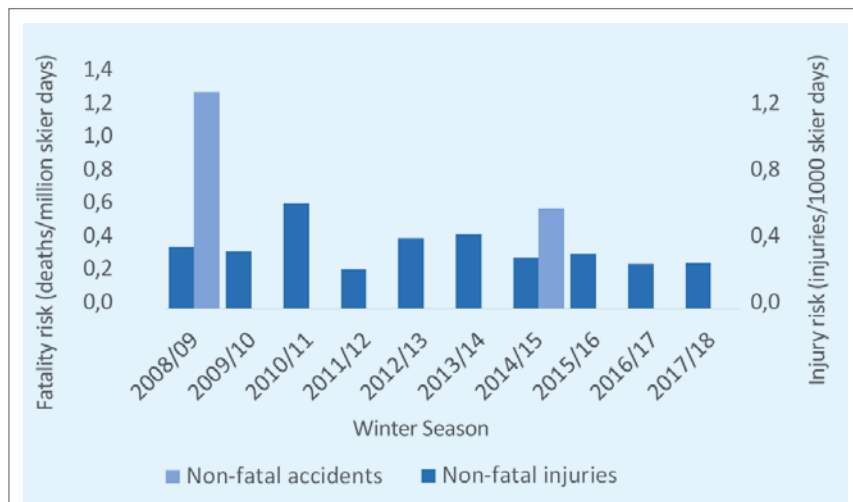


Figure 2

Fatality risk (dark blue) and injury risk (light blue) during alpine skiing in the Austrian Alps. Data based on (7, 37, 46).

activity has a preventive function on fall-related injuries during mountain hiking. However, information on hiking-specific and non-specific activities of the victims is still missing and therefore it remains unclear if different types of physical activity may have different impact on the accident risk of mountain hikers.

Seventy percent of male and female hikers who sustained a fall-related injury reported to suffer from a defective vision (with no significant difference between sexes), probably because of the above average age (19). Taking into account that the risk of falls in daily life is associated with the presence of visual impairment, e.g. visual field loss, within a population of elderly people of at least 50 years (20), also this variable could play a direct role as a risk factor for fall-related injuries among mountain hikers.

Considering that hikers involved in accidents in the Tyrolean Alps had a fluid intake of 1.0 ± 0.7 l during the hiking tour in which the accident happened and that on average 96% of them did not consume alcohol at the day of the accident (19), these factors probably play no or a minor role in the development of

accidents. Moreover, 80% of these hikers took one or more breaks during the hiking tour in which the accident happened, had a subjective level of fatigue of 2.4 ± 2.3 (on a scale of 0 (no fatigue) to 10) and 95% of them felt no muscle soreness at the time the accident happened (19). Thus, also fatigue seems not to be a risk factor for fall-related accidents among hikers in the Austrian Alps. However, a case-control study is needed to highlight more in depth the role of these parameters and it has to be taken into account that these parameters are prone to information bias.

Potential Preventive Measures to Reduce Injuries and Fatalities

The descent seems to be the riskiest part for falls in mountain hikers. Based on this observation, mountain hikers could be advised to pay attention to sufficient regeneration before and regular breaks during descending and, in addition, to consider cable cars, if available, to support the descent in case of fatigue. From a practical point of view, these recommendations could be distributed by folders in hotels or by information boards at the beginning of descents and supported by regular resting benches for example. In the preparation for mountain-hiking holiday, persons should perform regular physical activities including eccentric muscle contraction of the lower extremities. Additionally, a check of visual aids seems to be appropriate. Finally, falls during mountain hiking seem to be multifactorial and often occur when several factors are present at the same time. Therefore, a defensive planning of the trip according to individual skills and performance seem to play an important role in the prevention of falls and subsequent injuries.

Accidents During Alpine Skiing

Development of Injury and Fatality Risk

In past decades, the overall incidence of ski injuries has decreased from 5-8 injuries per 1000 skier days before the 1970s (28) to 2-3 injuries per 1000 skier days in the early 1990s (51, 55). Advances in ski equipment (7), e.g. in the ski-boot-binding system (50), and in slope preparation (4) are assumed to be the main reasons for this development. Especially with the introduction of the short and shaped carving skis, the overall injury rate decreased by 9% on Austrian ski slopes (7). Moreover, this decrease might be also due to an increase in use of protective gear, e.g. ski helmets (42, 47, 53). Consequently, the current evaluated injury rate in Austria is estimated to be less than one injury per 1000 skier days (46) (Figure 2).

In addition to non-fatal ski injuries, also traumatic ski fatalities occur on ski slopes. Generally, a rising trend of death rates could be shown between the period between 1980 and 2001 with death rates ranging from 0.53 to 1.88 deaths per million skier days (56). After the turn of the millennium, the number of traumatic deaths among recreational skiers has remained relatively stable (37), with incidences ranging from 0.37 (41) to 0.70 (6) and 0.75 deaths per million skier days (51). Recently a study by Posch et al. (37) showed that an average of 36.9 ± 7.9 fatalities per year were registered within a 10-year analysis (winter seasons 2008/09-2017/18) on Austrian ski slopes. The evaluated mean incidence during this 10-year period was 0.70 deaths per million skier days, with an incidence of 0.36 traumatic deaths per million skier days. Regarding the 10-year study period, incidence of traumatic deaths decreased by more than 25% (37).

Injury Locations in Non-Fatal Accidents

The knee joint represents the most frequent injured body part accounting for about one-third of all skiing-related injuries in recreational alpine skiing (7, 13, 46). Furthermore, a tear of the anterior cruciate ligament (ACL) is the most common diagnosis in injured recreational alpine skiers with about 15-21% of all injuries (29, 30) and approximately 50% of serious knee injuries in alpine skiing affect the ACL (31). The second most common injured body part in recreational alpine skiing is the shoulder/back accounting for 20% of all injuries (7). In the Austrian Alps, a constant head injury prevalence of about 10% has been observed in the last decades (7, 38, 44) and ski helmet use decreased head injury risk by 35% in adults and by 59% in children below 13 years of age, respectively (47).

Causes and Risk Factors of Non-Fatal and Fatal Accidents

The most common injury causes on ski slopes are self-inflicted falls with 80-90% and collisions in about 10-15% of cases, respectively (13, 45, 46). Generally, there are several risk factors contributing to the injury risk in recreational alpine skiing. Internal risk factors such as younger age, a lower skill level and inadequate skiing behavior increase injury risk in alpine skiing (54). Moreover, external risk factors as bad snow and weather conditions, not adjusted ski bindings according to the ISO 11088 standard, and not using any protective gear increase the injury risk (7, 25, 42, 43). With regard to ACL injuries, studies report a complex multiple interaction of intrinsic risk factors including age, sex, skill level and extrinsic risk factors including snow and weather conditions as well as the ski-boot-binding equipment (2, 8, 54). Especially sex represents an important risk factor, as female recreational alpine skiers have twice the knee injury prevalence of male skiers and the ACL injury risk is 3 times higher in female compared to male skiers (7, 8, 13). This distinctive sex difference of knee injuries among recreational alpine skiers may be partly related to hormonal, anatomical, and neuromuscular risk factors, which distinguish females from males (5, 26, 38).

The majority of the available literature shows collisions with solid objects and other skiers to be the most common scenario of traumatic deaths on ski slopes (37, 41, 52, 56). In general, mainly males are involved in fatalities and traumatic fatality risk is highest between 40-69 years of age (37). Male alpine skiers show a higher risk-taking behavior on ski slopes and are skiing faster compared to females (39, 40), leading to a potentially higher traumatic death rate. Mean altitude at death scene was 1552.0 ± 674.1 m and was further not significantly different between traumatic and nontraumatic deaths (37). Therefore, altitude-related hypoxia seems not to play a relevant role for fatalities on ski slopes (9).

Potential Preventive Measures to Reduce Injuries and Fatalities

According to a meta-analysis by Hume et al. (27), the injury risk in snow sports would benefit from using protective equipment like helmets and wrist guards. Moreover, improved signage, increased frequency and quality of weather reports, regulations for ski slope groomers and educational measures (e.g. FIS rules) represent potential preventive measures (27). The importance of risk awareness raising in recreational alpine skiing to prevent injuries was shown in a study by Ettliger et al. (15), which investigated the influence of a training program involving viewing videotaped knee-injury scenes of on-slope staff (patrollers) on the knee injury risk. Serious knee injuries declined by 62% among trained patrollers, but no decline occurred in the control group (15). Therefore, a potential preventive

measure to reduce the knee injury risk could be to show video-taped scenes during waiting on ski lifts, cable cars, and restaurants. Moreover, the fitness level of female skiers with a knee injury seems to be lower when compared to females suffering from other injuries highlighting the importance of preparatory training before the winter season (8). A study by Menz et al. (32) showed that more than 63% of interviewed skiers consumed alcohol. As only a small amount of alcohol can already affect motor and cognitive skills, it may be strongly assumed that the risk for skiing injuries is increased with alcohol consumption (32). Knowing that a lower skill level increases the injury risk in recreational alpine skiing, skiing instruction could potentially decrease the risk of severe injuries, as it was shown in a study by Sulheim et al. (54). Therefore, an adaption of the individual skiing behavior and adequate skiing speed depending on skill level can represent potential preventive measures to reduce traumatic deaths (37, 41). In addition, it might be possible that especially the incidence of traumatic fatalities has benefitted from equipment-related improvements to a certain extent (37). An overview of practically relevant preventive measures is shown in table 1. ■

Conflict of Interest

The authors have no conflict of interest.

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