Medicina Sportiva
Med Sport 13 (4): 210–218, 2009
DOI: 10.2478/v10036-009-0032-3

INJURY-RISK EVALUATION IN WATER ICE CLIMBING

Volker Schöffl[1,2,3] (A,B,C,D,E,F), Isabelle Schöffl[4] (A,B,C,D,E), Ulrich Schwarz[5] (A,B,C,D,E,F), Friedrich Hennig[2] (A,D,E), Thomas Küpper[3,6] (A,B,C,D,E,F)

[1] Department of Sportorthopedics, Klinikum, Bamberg, Germany
[2] Department of Trauma Surgery, Friedrich Alexander University, Erlangen-Nuremberg, Germany
[3] Medical Comission UIAA, Bern, Switzerland
[4] Institute of Anatomy I, Friedrich Alexander University Erlangen-Nuremberg, Germany
[5] Private Practise, Oberstdorf, Germany
[6] Institute of Occupational and Social Medicine, RWTH Aachen University, Aachen, Germany

Abstract

Introduction: Ice-climbing is widely considered to be a hazardous sport with a high risk of injury. To date, there has been no scientific analysis to characterize and reveal the prevalence of injury in this sport. The purpose of this study was to quantify and rate ice-climbing injuries.

Methods: Eighty-eight ice-climbers (water ice) (13 female, 75 male, mean age 34.6 years) from nine countries completed a comprehensive questionnaire on ice-climbing accidents and injuries, climbing frequency and risk taking behaviour. Ice-climbing hours were quantified and injuries rated according to the NACA (National Advisory Committee for Aeronautics) score. To enable comparison to other sports, the injury risk was calculated per 1000 hours of participation in a given sport.

Results: Seventeen athletes (19%) reported a total of 35 overuse syndromes resulting from ice-climbing. Ninety-five injuries were retrospectively reported for a consecutive 3-year period. The incidence and respective grading of the acute injuries were: 67 for NACA 1, 24 for NACA 2, and 4 for NACA 3. Most acute injuries were open wounds (55.2%) and haematomas (21.9%). These injuries occurred 61.3% of the time while lead climbing, 23.8% while following and the rest during belaying, approach or return. The incidence of overuse injury syndromes was 0.77/1000 hours of sports participation. The injury incidence was 4.07/1000hr for NACA 1-3 with 2.87/1000hr in NACA 1, and none in NACA 4-7. Body mass index (BMI) correlated significantly ($P<0.05$) with an increased risk of injury. Overuse syndromes correlated significantly with training hours ($P<0.01$), ice-climbing level ($P<0.01$) and the risk willingness while lead climbing on ice ($P<0.01$).

Conclusion: Contrary to the popular perception, our study demonstrated that ice-climbing is not a sport with a high risk of injury. All NACA I injuries are of minor medical relevance and would normally not need special treatment or a doctor's attendance. The results of injury risk per 1000 hours of participation in ice-climbing was comparable to that of indoor competition climbing and to other outdoor sports (hiking, mountain biking, kayaking). The injury risk was also much less than a standard sport such as soccer.

***Key words**: ice climbing, injury risk, rock climbing, winter sports, sports injury*

Introduction

Ice climbing

Water ice-climbing has become an increasingly popular sport over the past 15 years. Ice-climbing normally refers to climbing of features of frozen ice such as icefalls, frozen waterfalls, and cliffs and rock slabs covered with ice refrozen from flows of water. However, the term ice-climbing can be broadly divided into two sub-disciplines known as alpine ice and water ice climbing. These two sub-classes require slightly different climbing styles and equipment. Alpine ice is found in a mountain environment, usually requires an approach to reach the climbing site, and is often climbed in an attempt to summit a mountain. Water ice is usually found on a cliff or other outcropping beneath water flows. Alpine ice is frozen precipitation whereas water ice is a frozen liquid flow of water (1).

In contrast to the steep snow and ice slopes that are mastered in alpine ice climbing, waterfall ice climbing is about vertical or even overhanging ice formations that require specialized equipment and climbing techniques. Recent technological developments in ice climbing equipment, such as special curved ice axes, crampons with one single frontal spike and new fast twisting ice-screws, reflect the differences in these sub-disciplines and have helped advance the graded level of difficulty in water ice.

The grading system developed by the UIAA (Union International des Associations d`Alpinisme) (2) is internationally recognized and reflects the technical difficulty required to climb different types of ice formations as well as the level of risk or danger involved. For example, water ice-climbing uses the WI-scale (Water Ice 1-7), which reflects the angle of the ice wall, the ice quality and the ability to place 'protection', mostly in form of ice screws. Water ice-climbing in terrain which combines mixed rock climbing and ice-climbing is called Mixed-Climbing and is graded accordingly using the M-scale (Mixed 1-13) (3). An additional grade numbered I to VII is added to these technical grades to independently signify the level of risk or danger involved - grade I indicates a relatively safe climb, and grade VII indicates a disastrous and potentially lethal climb (3).

Specialized equipment

The first records of specialized ice climbing equipment feature footwear. Descriptions of crampons - or 'nailed shoes' which were the predecessors of crampons - were given by the Jewish General and historian Flavius Josephus (37 – 100 A.D.) (4). Josephus describes the shoes of the Roman soldiers - the 'caligae' - that were tough hobnailed sandals with 80 to 90 iron nails in an 8mm thick leather sole. Hobnailed footwear greatly aided traction. Modern crampons with the prominent frontal spikes have become popular with Anderl Heckmaier and Wiggerl Vörg doing the first ascent of the Eiger North Face (5) wearing them. Nowadays a single frontal spike and even heel spurs are state of the art (3).

Ice axes were already in use at the time of the first ascent of the Mont Blanc on the 8th of August 1786 through Pascard and Balmat. They represented a major technological development that originated from the 'glacier stick' described by Josias Simmler almost 200 years earlier (6). More recent technological advances have witnessed the transformation of these long-shafted ice axes into a short-shafted curved crossbar that looks like an assault weapon (Figure 1). It is widely discussed and hotly debated in the ice-climbing community whether ice axes should be used with or without leashes (3). Leashes, which do reduce the stress onto the forearms, can increase the risk of injuring oneself during a fall, as they attach the ice axes to the body.

Fig.1. *Modern ice axes with a curved crossbar (with permission of Sportorthopädie-Sporttraumatologie – Elsevier, FRG)*

In parallel with the technological advancements in crampons and ice axes, Erich Friedli from Switzerland developed the first real ice-screws. These ice-screws have played a pivotal role in increasing the safety of the sport. These screws guarantee a comparable pull-out strength to bolts if placed in good ice and at the correct angle (7).

History of ice climbing

Although the first ice-climbing competition was held on June 30th 1912 at the Brenva-glacier in Courmayeur in Italy, it took almost a century for such competitions to have a global appeal with the first World-Cup competition taking place in 1999 and the first World Championships in 2002. For ice-climbing competitions, the ice axes and the crampons are regulated in both size and shape through UIAA standards (2). In contrast to climbing on natural ice, ice-climbing competition walls are mostly artificial with pre-prepared holds, unnatural steep angles and dry-tolling sections requiring a different technique. Spectacular photographs disseminated by the media of the ice-climbing competitions on artificial and bizarre structured ice formations have served to increase public awareness and participation in the sport. Nowadays almost every European Mountaineering School offers special ice-climbing courses.

Unfortunately these spectacular competition pictures of elite ice climbers pushing the limits have contributed to a public perception that all ice-climbing is hazardous and therefore a high-risk sport. In Europe many insurance companies limit their coverage to exclude ice climbing. Nevertheless to date, there has been no scientific analysis to characterize and reveal the prevalence of injury in this climbing sub-discipline. Injuries sustained during general rock climbing (8-17), indoor climbing (18-20), and competition climbing (21) have already been examined by numerous studies so that the injury risk per 1000 hours could be analyzed. For ice climbing, data on injuries are biased towards serious injuries or deaths because they are based on reports by mountain rescue teams (22-26) and death analysis by Alpine clubs (22-26). In rock climbing the studies of Schussmann *et al.* (10) and Bowie *et al.* (9) were the first ones to not only collect injuries but to grade the registered injuries with a scoring system (ISS-score) and to calculate the correlation between the injury risk to climbing days (9) or to climbing time (10). Nevertheless the ISS-score showed a weak validity for injury self recall (27). For comparison to other sports (28-41) the injury risk of ice climbing per 1000 hours of sport exposure is important and has not yet been analyzed.

Therefore the purposes of this study were to attempt to quantify and rate ice-climbing injuries, analyse the mechanisms of injuries and overuse syndromes, and to identify areas for injury prevention. The question as to whether ice climbing should be considered a high-risk sport is also evaluated.

Methods

A 21-page questionnaire (in German and English) on ice-climbing accidents and injuries, climbing frequency and risk behavior was developed. This pilot questionnaire was adapted following a pre-test on 10 ice climbers before 200 printed questionnaires were distributed throughout Germany in climbing gyms, ice-climbing areas, climbing shops, mountain-ranger and mountain-guide offices. Twenty questionnaires were emailed to well-known ice climbers in Europe, Canada and the USA. The questionnaire was simultaneously posted onto two German-speaking web pages (www.climbing.de and www.bergsteigen.at) and the German Climbing magazine "Klettern" posted a note on the study.

The data acquisition took 4 months. Ninety questionnaires were returned; from which two were excluded as the data were incomplete. The remaining 88 questionnaires (13 female, 75 male, mean age 34.6 years) from nine countries were used for the study. Fifty climbers were further contacted by telephone to clarify unclear answers in the questionnaire.

To evaluate the total ice-climbing time over the period, a single ice climbing day as well as a multi-pitch ice-climb were calculated as 6 hours of ice climbing. The rock climbing ability was transferred from the US and French grading into the international UIAA scale and then into the metric scale (42). The study population was then sub-divided by ice-climbing level: <=WI 5 and >WI 5.

The injuries were rated according to the NACA (National Advisory Committee for Aeronautics) (43) (Table 1). The NACA-Score is the most common emergency score in Germany and also part of the nationwide standard pre-hospital emergency physicians report form (44) and is recommended internationally for alpine trauma evaluation (45). To enable comparison to other sports, the injury risk was calculated per 1000 hours of participation in a given sport. For the calculation of the injury risk per 1000 hours the ice-climbing injuries and hours of sports participation of the last 3 years were used.

Table 1. *The National Advisory Committee for Aeronautics (NACA) Score (43)*

Patient Status	Score Level
Not an acute life-threatening disease or injury	1
Acute intervention not necessary; further diagnostic examination needed	2
Severe but not life threatening disease or injury; acute intervention necessary	3
Development of vital (life threatening) danger possible	4
Acute vital (life threatening) danger	5
Acute cardiac or respiratory arrest	6
Dead	7

Statistical analysis

Statistical analysis was performed using Microsoft Excel XP® for data collection, Microsoft Access® for data handling and EPI INFO™ (Version 3.3.2) for statistical analysis. All measured values are reported as means and standard deviations. The Kologomorov-Smirnov test was used to check for normal distribution. Homogeneity of variance was investigated using Levine's F-test. For normally distributed ordinal or nominal variables the Chi-Quadrat test was used to compare groups in cross over tables. For normally distributed metrical variables differences within and between groups were assessed with paired and unpaired t-tests. A 5% probability level was considered significant (*), and a 1% probability level considered highly significant (**).

Results

Participants

Thirteen female and 75 male ice climbers (mean age 34.6 ± 8.8 y) from 9 countries (Germany, Austria, Switzerland, UK, USA, Hungary, Netherlands, Italy and Czech Republic) completed the questionnaire. The mean body-mass index (BMI) was 22.81 ± 2.12. Most of the climbers (34%) worked in a job that demanded a university degree, for the other professions amongst the climbers see figure 2.

The mean ice-climbing experience was 10.98 ± 8.47 years. Climbing preferences showed 55% climbed mainly on water ice, 17% mainly in mixed climbing terrain, 9% mainly in alpine terrain and 6% mainly on artificial ice structures. First ascents on ice climbs were reported by 33% of the climbers. The ice climbers reported climbing in 12 different countries in Europe and North America at 116 different ice-climbing areas. Virtually all ice climbers (99%) participated regularly in other mountain sports - 99% alpine climbing, 98% sport climbing, 82% combined alpine ice and rock climbing. Almost a fifth of the climbers (21%) participated in ice climbing competitions. The mean training time for climbing (all sub-disciplines) per week was 7.43 ± 5.66 hours. The average (lead climbing) ice-climbing level was WI 5+ for ice falls, M 9- for mixed climbing, 6.7 metric (7- UIAA) for alpine climbing, 7.7 metric (8- UIAA) for sport climbing and 7.7 metric (8- UIAA) for indoor climbing.

Epidemiology

Female climbers were injured more often (76.9%) when compared to male climbers (58.7%). Climbers having children, thus having more responsibility and probably being more careful, reported injuries in 58.3%, those who had no children in 62.5%. The younger (under 30 y) ice climbers had a higher injury incidence than did older climbers (over 50 y). More than 10 years of ice-climbing experience resulted in a lower injury risk (see table 2). Most ice-climbers had a university degree. Figure 2 displays other professions noted amongst the climbers.

The injury rate (number of injuries divided through number of ice climbers within the respective population group) was the highest amongst professions demanding a university degree (1.54), followed by students (1.38), policemen/soldiers/fire-fighters (1.25), professional climbers and/or mountain guides (1.18), technical assistants (1.05) to skilled labourers (0.29). The overall average injury rate was 1.23. This injury rate was not correlated to years of ice-climbing. It was the highest for climbers with 6-10 years of ice climbing experience (1.44), then for climbers with over 20 years experience (1.36), than for climbers with less than 5 years of experience (1.06) and least for the group of climbers with 11-20 years of ice climbing experience (0.67).

In the climbing level ≤ WI-5 more people (63.4%) were injured than in > WI-5 (52.9%). Age, gender, ice climbing years, climbing level in water ice and rock, performance of first ascents, training hours, job profile, family responsibility and self perception of risk willingness while lead climbing in ice was not significant for the development of ice-climbing injuries. However, a high BMI was significant for getting less ice-climbing injuries ($P = 0.017$).

Subjective risk perception

From the subjective questions asked in the questionnaire, 82% of the ice climbers felt that ice climbing was of no higher risk for the development of overuse injuries than rock climbing. More than half of the climbers (65%) felt a subjectively higher injury risk

Table 2. *Injury distribution in correlation to age groups and ice-climbing experience*

Injury distribution in different age groups			Injury distribution related to years of ice-climbing experience		
Injuries			Injuries		
Age in years	n	%	Ice-climbing years	n	%
<30	17	68.0%	Ł 5	22	68.8%
30 - 40	24	61.5%	6 - 10	13	72.2%
40 - 50	11	61.1%	11 - 20	12	50%
> 50	2	40.0%	>20	7	50%
All age groups	54	61.4%		54	61.4%

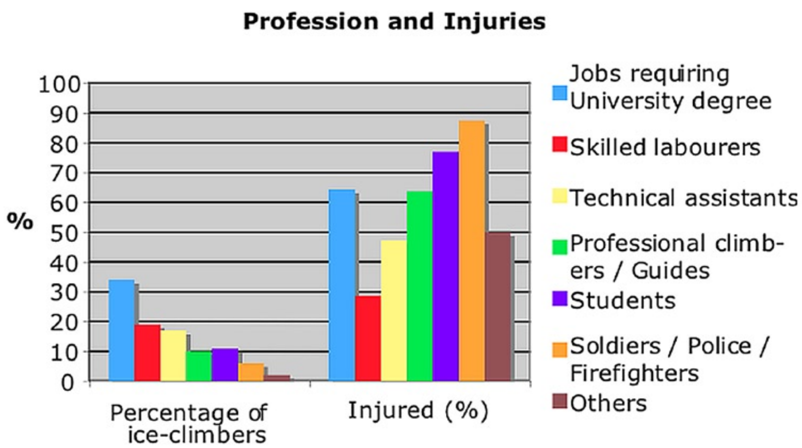

Fig. 2. *Distribution of professions and injury percentage within the respective group*

while ice climbing in comparison to rock climbing. The most common reported causes of acute injury, in descending order, were: ice and rock falls, avalanches, weak belay points and potentially more dangerous falls of climbers with injuries related to their own equipment (crampons, ice axes etc.)

Sixty-five percent of climbers reported using ice axes with leashes (42% always and the others only sometimes).

Overuse syndromes

Seventeen (19.3%) athletes reported a total of 35 overuse syndromes from ice climbing. 18 (51%) of these occurred within the study protocol time frame between 2003 and 2006. 94.4% occurred on the upper extremity, 15 (83.3%) were NACA 1 and three (16.7%) were NACA 2. Lost work time due to an overuse syndrome was reported by only one climber. Persisting medical problems were not reported by any climbers. One climber with an overuse syndrome required inpatient care, 3 needed a physician's attendance, and five received physiotherapy. In 72.2% poor ice-climbing technique was perceived to be the cause of the overuse syndrome.

The overuse syndromes were: muscle strains in the arm (5), in the shoulder (1), in the calf (1), tendonitis in the arm (3), the fingers (4), and the shoulder (4).

The correlation of training time with the risk for development of overuse syndromes was highly significant ($P < 0.01$). The BMI did not significantly correlated with overuse syndromes. How much risk the climber was willing to take lead ice-climbing (self perception, scale from 1-4) correlated highly significantly with overuse syndromes ($P < 0.01$). Also the climbing level in water ice correlated highly significantly with overuse syndromes ($P < 0.01$).

Acute ice climbing injuries

Fifty four (61.4%) athletes reported one or several acute injuries during ice-climbing, while 34 (38.6%) did not. Ninety five acute injuries were reported for the interval from 2003 - 2006, 67 NACA 1, 24 NACA 2 and 4 NACA 3. Most acute injuries were open wounds (55.2%) and haematomas (21.9%) (see table 3)

The 'other injuries' were eye injuries (3), contusions (1), meniscal injury of the knee joint (1), finger contusions (3), multiple contusions (2), intercostal muscular sprain (1), skin injury caused through the crampon spokes (1), torn muscle (1), ankle sprain (1) or dental fractures (3). For the location of these injuries and their distribution see table 4.

Most of the acute injuries (61.3%) occurred while lead climbing, 23.8% while climbing second, the rest was rare (6.3% belaying, 3.8% on return and 2.5% on approach, other 2.5%). Most of the acute injuries (73.4%) happened in a waterfall, few in glacier ice walls (11.4%) and on artificial ice walls (2.5%) (12.7% other places). Climber fall related acute injuries amounted 10.5%. During injury events, 75.8% of the climbers were wearing a helmet. Although over a quarter (27.3%) of the injuries needed to be seen by a doctor; only few (5.7%) needed hospitalisation. Moreover, permanent damage occurred in 22.7% of the injury cases. The permanent damage consisted of: dysaesthesia (2), cartilage damage (1), skin scars (6) and dental damage (2). The climbing purpose was in most cases (73%) climbing a waterfall, very few (16.4%) during training in the ice and one case (1.4%) during a competition (other: 1.4%). For injury cause see table 5.

Table 3. *Ice-climbing injuries*

Injury	n	%
Frostbite	9	8.8
Open wounds	53	52
Fractures	2	1.9
Haematoma	21	20.6
Other injuries	17	16.7
total	102 (in 95 incidences)	100

Table 4. *Location of Injury and distribution*

Body part	n	%
Head	49	40.8
Finger	16	13.3
Leg	15	12.5
Foot	6	5
Arm	6	5
Shoulder	3	2.5
Chest	3	2.5
Back	2	1.7
Neck	1	0.8
Perianal	1	0.8
Others	18	15
Total	120	99.9

Table 5. *Cause of injury*

Cause	n	%
Ice fall	48	52.7
Technical deficit	24	26.4
Cold	5	5.5
Rock fall	3	3.3
False belay	2	2.2
Equipment failure	1	1.1
Others	8	8.8
Total	91	100

The climbers thought that the injury would have been avoidable in 65.9%. To avoid the acute injury a better climbing technique was recommended in 44.4%, a better tactic in 31.5% and improvements in the used equipment in 24.1%.

Overuse syndrome and acute injury rate per 1000 hours sport participation

The incidence of overuse syndromes per 1000 hours of sport participation was smaller than the acute injury incidence. In both groups (OS and I) NACA 1 conditions were the most frequent (see table 6):

Table 6. *Incidence of overuse syndromes and acute injuries per 1000 hours of ice climbing*

Type	Overuse syndromes	Injuries	Overuse syndromes and injuries
Total	0.77	4.07	4.84
NACA 1	0.64	2.87	3.51
NACA 2	0.13	1.03	1.16
NACA 3	0	0.17	0.17

NACA = The National Advisory Committee for Aeronautics Score [43]

Discussion

This cross-sectional study is the first to evaluate ice-climbing injuries. More males (85%) actively climbed ice than females which is almost identical to the figures of Gerdes et al. (13) and Bowie et al. (9). In contrast to Bowie et al. (9) we found that most of the injuries were reported by women (76% of all injuries). We found no difference for ice climbers having or not having children (different level of responsibility) and with or without performing first ascents. Considering the various professions within our ice-climbers the injury rate was the highest in professions demanding a university degree and the lowest in skilled labourers. Climbers in professions demanding a university degree may be less well trained in manual techniques that may translate to ice climbing skills. The quite high acute injury rate found in professional climbers and mountain guides was remarkable and unexpected.

Analysing the acute injury patterns, it is remarkable that no injury was sustained by using leashes on the ice axes. Thus, the argument by many climbers against the use of leashes, citing the increased risk of self-injury caused through dangling ice axes while falling, would appear to be unfounded based on the results of the present study. This argument concerns natural ice-climbing only as in competition ice-climbing no leashes are allowed. As climbing technique deficits were the cause of the injury in about one quarter, this is a risk factor that the ice climbers can influence through training and practice. While rock climbing can be performed throughout the year, ice climbing is seasonable, thus some ice climbers only perform the sport for one week per year and lack in experience and technique. Furthermore, some of them are quite skilled rock climbers and possess a very good physical trained status and are eager to climb higher ice grades than their level of ice climbing experience and technique allows.

Injury risk

The overall injury rate is comparable to other outdoor sports (10, 19-21, 28, 32). What was perhaps most remarkable and unexpected was the finding that most of the acute injuries were of minor severity (i.e. NACA 1 rating). The acute injury rate was also not correlated to the number of ice climbing years, suggesting a more experienced ice climber was just as likely to get injured as a less experienced climber. However, the sample size was rather small for showing clear distinctions. It was difficult to get a higher number of corresponding ice climbers for the study as the overall number of athletes who perform ice climbing on a regular basis is small.

Ice climbing is a popular sport, nevertheless very few data on injuries are existing. Pub med (assessed 11.09.2007) gives only one article in prose style (46) but no scientific study. We found one report on ice-climbing injuries in a non-review journal „Bergundsteigen", a risk-management magazine of the German-, Swiss and Austrian Alpine Club. Mosimann (22) evaluated 46 injured ice climbers who were rescued by the Swiss mountain rescue service in a 6 year period. The injuries were rated according to the NACA-Score. 31% had no injury (NACA 0) and 13% (6 climbers) had a fatal injury (NACA 7). 42% had injuries of NACA 2-3, 8% of NACA 4 and 6% of NACA 5. The most frequent injury causes were falls with 55%. However, no fatal injury was caused by a fall. The percentile death risk, which the author defined as the percent of deaths related to the sum of all known emergencies, was 13%. The author suggested this risk is higher in ice climbing than in mountaineering (8%), ski mountaineering (7.5%) and rock climbing (4%), but no reference was given for these data.

Fatalities

Our study cannot give a percentile death risk, as it was conducted through a retrospective questionnaire. However, the general death numbers in ice-climbing can be analysed as all mountaineering accidents are very well recorded in North America. The Canadian (26) and the American Alpine Club (25) have statistically recorded and analysed all mountain accidents since 1951. In the USA, up to the year 2005, there were 6111 incidents involving 11 089 mountaineers recorded by the American Alpine Club (25). Of these, 5931 (53%) were unharmed (NACA 0) and there were 1373 (12%) fatalities (NACA 7) (25). 254 (4%) of the accidents happened in ice, though no further evaluation of the ice-climbing injuries was given. Nevertheless if 4% of all injuries are to be accounted to ice-climbing, also 4% of the deaths can be assumed to be related to ice-climbing. This would calculate to 55 fatally ice-climbing injuries in 54 years; in average one ice-climbing fatality per year within the USA. In the same time frame 958 accidents in 2003 mountaineers were recorded in Canada (26). 715 (36%) mountaineers were injured, 292 (15%) fatal. 163 (17%) of the Canadian accidents occurred on „ice"-terrain. In 30 years, 92 mountaineers were injured while ice-climbing, 30 fatally. The German Alpine Club (DAV) records ice-climbing accidents that are reported to their insurance carrier. In the years 2004-2005, 150 climbing accidents were recorded, which was 12% of all accidents in mountain sports (1270) (23). Alpine mixed climbing accounted for 8% of all accidents and water ice-climbing for 6%. It is not possible to precisely determine the death risk from these numbers, as the absolute number of ice climbers in these areas is unknown. The major ice climbing countries, Switzerland and Canada, report about one death per year (22) (26). Further prospective study will be necessary to determine the true incidence of mortality related to water ice-climbing.

Overuse syndromes

In the ice-climbers 94% of the overuse syndromes occurred in the upper extremity, which is similar to the findings for rock climbing (14, 47-51). Most overuse syndromes were minor severity and consisted of strains and tendonitis. Four ice-climbers reported tendonitis of the fingers which is surprising given that the predominant hand position in ice-climbing is on the large grip of the ice tool, and does not require the crimping position responsible for tenosynovitis of the finger flexor tendons in sport climbers (49, 52-56). It is possible that ice-climbers initially develop finger tendonitis during indoor rock climbing training and this is subsequently exacerbated by use of the ice tool, applying local pressure onto already inflammed tendon sheaths. Most ice-climbers also train in rock climbing, making a differentiation of the origin of overuse syndromes difficult.

Injury risk in comparison to rock climbing

When comparing ice to rock climbing, one has to take into account that outdoor rock climbing is very diverse, and it is difficult to run exact scientific studies on the injury risk of outdoor climbing because the risks and the precautions taken are different, depending on the type of rock climbing chosen by each individual (57). Bowie at al. (9) reported an injury risk of 0.2-0.4% per rock climbing day in the Yosemite National Park, equaling 37.5 injuries / 1000 hours of exposure (assuming one day of climbing in Yosemite is 8 hours). Schussmann et al. (58) reported an accident incidence of 0.56 injuries per 1000 hours of mountaineering (Teton National Park, USA). No other study on outdoor rock climbing gives a number on an injury rate. A lower risk potential was observed for indoor climbing. Limb (20), assuming an average of two hours per visit, found 0.027 injuries / 1000 hours and Schöffl et al. (19) 0.079 injuries / 1000 hours of performance. For indoor competition climbing the injury risk was 3.1/1000 hours (21).

Injury risk in comparison to other sports

To compare the injury risk in ice climbing to other sports the injury risk per 1000 hours of sport performance is important. Gabbet et al. (30) found a high injury risk in rugby players (283 injuries/1000h participation). Gissane et al. (33), also studying rugby players, reported approximately 150 injuries per 1000 hours of participation in summer and 52 per 1000h in winter. A high injury rate is also reported for ice-hockey (83/1000h (59)), handball (50/1000h (40)) and soccer (competition / training: 31.6/ 3-5 (60)). All these more mainstream sports demonstrated a much higher injury risk compared to our ice climbing study (4.07/1000h) (figure 3). Other general sports such as kite surfing have a general minor injury rate (7/1000 h) (37) but the injury severity rate is also high with even fatal injuries in 235 kite surfers prospectively evaluated over 6 months (235 kite surfers, 6 month prospectively, 124 injuries, 11 severe injuries and 1 fatal). Other

Fig. 3. *Ice climbing in Val di Cogne (Tuborg WI 4+/5), Italy (with permission of Sportorthopädie-Sporttraumatologie – Elsevier, FRG)*

general sports as horse riding, skiing or bicycling (especially racing) also obtain the risk of severe or fatal injuries according to the definition of Kajtna and Tusak (61), nevertheless according to public opinion they are considered as a normal sport activity. Nevertheless no general scoring system exists to compare these relative injury risks of various sports, as the injury definition and grading varies between the studies. A general score, as the NACA score is important and we propose to use the NACA score for further studies.

Conclusion: Is ice-climbing a high-risk sport?

Many sports enjoyed by large portions of the population are widely considered to be safe (62). Ice climbing, which is presented through the media with spectacular pictures, is widely considered as a high-risk sport. Analysing ice-climbing, it is obvious that the ice climbers are confronted with many objective dangers: weapon-like equipment, variable ice formations, weak protection, extreme weather conditions, avalanche risk, ice and rock fall, difficult approaches and high mental and physical stress. Nevertheless all these factors are considered before attempting such climbs. Ice climbers are no different to the majority of participants in other sports – they do not want to get injured or even die pursuing their passion.

Meyers Encyclopaedia (63) defines extreme sports as the performance of exceptional sport disciplines in which the athlete deals with high mental and physical stress. If the sport contains an objective or subjective risk of damage to health or life it is considered a high risk sport. Meyers´s definition is accurate though it does not define any real risk for the athlete. Kajtna and Tusak (61) define high risk sports as any sport in which one has to accept the possibility of severe injury or death as an inherent part of the activity. This would make many sports "high risk", including bicycling, skiing, horse riding, etc.. There is clearly a distinct divide between what different bodies (including insurance companies) consider as high-risk sports.

It is the task of science to evaluate the injury risk, injury severity and the fatality rate of various sports. Therefore standards and scores should be defined to allow appropriate comparisons. The injury risk per 1000 hours of sport participation is an established parameter to assess relative injury risk. Most important for future studies is a standardized injury score such as the NACA- Score (43) used in this study which provides the necessary accuracy.

In our study ice-climbing had, in comparison to many other sports, a low injury risk. Considering the above definition of high risk, ice climbing must be considered a high-risk sport. Severe and fatal injuries are possible. Nevertheless the overall injury risk is small and the average injury severity is minor.

The sample size of our study was small and it contains all disadvantages of a retrospective study. Also, the questionnaire was not anonymous which is another limitation. Future studies with larger subject numbers that are conducted in a prospective way are necessary. This way the death risk can be obtained.

To evaluate the overall seriousness of a sport and the injury risk as well as injury severity, a combination of NACA score, lethality and injury risk evaluation is necessary, and a robust and comprehensive sport-specific scoring model must be developed. Ultimately such continued analysis can then target interventions to reduce the incidence of sport-specific injuries and improve the safety records of sports such as ice climbing.

References

1. Lowe J. Ice World: Techniques and Experiences of Modern Ice Climbing. Seattle: The Mountaineers, 1996.
2. UIAA. Union International des Associations d`Alpinisme. 2008 (cited 05.01.2009); www.uiaa.ch.
3. Gadd W. Eisklettern - Eis - Mixed - Drytooling. Köngen: Panico Alpinverlag, 2006.
4. Junkelmann M. Die Legionen des Augustus, Mainz: Phillip von Zabern, 2003.
5. Auffermann U. Was zählt das Erlebnis: Anderl Heckmair, Alpinist und Lebenskünstler. 2 ed. Bochum: Semann, 2002.
6. Simler J. De Alpibus commentarius - Die Alpen. München: Gesellschaft Alpiner Bücherfreunde, 1931.
7. Semmel C, Stopper D. Eiskalt und doch brandheiß - Was halten Sicherungen in Eisfällen. *DAV Panorama* 2005(2): 91-5.
8. Addiss DG, Baker SP. Mountaineering and rock-climbing injuries in US national parks. *Ann Emerg Med* 1989; 18(9): 975-9.
9. Bowie WS, Hunt TK, Allen HA, Jr. Rock-climbing injuries in Yosemite National Park. *West J Med* 1988; 149(2): 172-7.
10. Schussmann LC, Lutz LJ, Shaw RR, et al. The epidemiology of mountaineering and rock climbing accidents. *Wilderness Environ Med* 1990; 1: 235-48.
11. Paige TE, Fiore DC,Houston JD. Injury in traditional and sport rock climbing. *Wilderness Environ Med* 1998; 9(1): 2-7.
12. Rooks MD, Johnston RB, 3rd, Ensor CD, et al. Injury patterns in recreational rock climbers. *Am J Sports Med* 1995; 23(6): 683-5.
13. Gerdes EM, Hafner JW, Aldag JC. Injury patterns and safety practices of rock climbers. *J Trauma* 2006; 61(6): 1517-25.
14. Hochholzer T,Schöffl V. One move too many. Ebenhausen: Lochner Verlag, 2003.
15. Schöffl V, Hochholzer T, Winkelmann HP, et al. Pulley injuries in rock climbers. *Wilderness Environ Med* 2003; 14(2): 94-100.
16. Schöffl V, Hochholzer T, Imhoff A. Radiographic changes in the hands and fingers of young, high-level climbers. *Am J Sports Med* 2004; 32(7): 1688-94.
17. Smith LO. Alpine climbing: injuries and illness. *Phys Med Rehabil Clin N Am* 2006; 17(3): 633-44.
18. Wright DM, Royle TJ, Marshall T. Indoor rock climbing: who gets injured? *Br J Sports Med* 2001; 35(3): 181-5.
19. Schöffl V, Winkelmann HP. (Accident statistics at „indoor climbing walls") Unfallstatistik an „Indoor-Kletteranlagen". *Sportverletz Sportschaden* 1999; 13(1): 14-6.
20. Limb D. Injuries on British climbing walls. *Br J Sports Med* 1995; 29(3): 168-70.
21. Schöffl V, Küpper T. Injuries at the 2005 World Championships in Rock Climbing. *Wilderness Environ Med* 2006; 17: 187-90.
22. Mosimann U. Notfälle beim Eisklettern. *Bergundsteigen* 2006(4): 70-73.

23. DAV. Bergunfallstatistik 2004-2005, Deustcher Alpenverein e.V., München, 2006.
24. DAV. Bergunfallstatistik 2002-2003. München: Deutscher Alpenverein e.V., 2004.
25. American-Alpine-Club. Accidents in North American Mountaineering. *The American Alpine Club* 2006; 9(1): 59.
26. Canadian-Alpine-Club. 2007 (cited 30.12.2007).
27. Valuri G, Stevenson M, Finch C, et al. The validity of a four week self-recall of sports injuries. *Injury Prevention* 2005; 11: 135-7.
28. Aschauer E, Ritter E, Resch H, et al. Injuries and injury risk in skiing and snowboarding. *Unfallchirurg* 2007; 110(4): 301-6.
29. Cumps ED, Verhagen E, Annemans L, et al. Injury risk and socio-economic costs resulting from sports injuries in Flanders. Data derived from Sports Insurance Statistics 2003. *Br J Sports Med* 2008; 42(9): 767-72.
30. Gabbett TJ. Incidence of injury in amateur rugby league sevens. *Br J Sports Med* 2002; 36(1): 23-6.
31. Gabbett TJ. Incidence of injury in junior rugby league players over four competitive seasons. *J Sci Med Sport* 2007; 11(3): 323-8.
32. Gaulrapp H, Weber A,Rosemeyer B. Injuries in mountain biking. *Knee Surg Sports Traumatol Arthrosc* 2001; 9(1): 48-53.
33. Gissane C, Jennings D, Kerr K, et al. Injury rates in rugby league football: impact of change in playing season. *Am J Sports Med* 2003; 31(6): 954-8.
34. Knobloch K, Vogt PM. Nordic pole walking injuries-nordic walking thumb as novel injury entity. *Sportverletz Sportschaden* 2006; 20(3): 137-42.
35. Monasterio ME. Accident and fatality characteristics in a population of mountain climbers in New Zealand. *N Z Med J* 2005; 118(1208): U1249.
36. Neville VJ, Molloy J, Brooks JH, et al. Epidemiology of injuries and illnesses in America's Cup yacht racing. *Br J Sports Med* 2006; 40(4): 304-11; discussion 311-2.
37. Nickel C, Zernial O, Musahl V, et al. A prospective study of kitesurfing injuries. *Am J Sports Med* 2004; 32(4): 921-7.
38. Seil R, Rupp S, Tempelhof S, et al. Sports injuries in team handball. A one-year prospective study of sixteen men's senior teams of a superior nonprofessional level. *Am J Sports Med* 1998; 26(5): 681-7.
39. Tomida Y, Hirata H, Fukuda A, et al. Injuries in elite motorcycle racing in Japan. *Br J Sports Med* 2005; 39(8): 508-11.
40. Wedderkopp N, Kaltoft M, Lundgaard B, et al. Prevention of injuries in young female players in European team handball. A prospective intervention study. *Scand J Med Sci Sports* 1999; 9(1): 41-7.
41. Wedderkopp N, Kaltoft M, Lundgaard B, et al. Injuries in young female players in European team handball. *Scand J Med Sci Sports* 1997; 7(6): 342-7.
42. Schöffl V, Klee S, Strecker W. Evaluation of physiological standard pressures of the forearm flexor muscles during sport specific ergometry in sport climbers. *Br J Sports Med* 2004; 38(4): 422-5.
43. Veldman A, Fischer D, Brand J, et al. Proposal for a new scoring system in international interhospital air transport. *J Travel Med* 2001; 8: 154-7.
44. Bein T, Scores - Hilfsmittel zur Risikoeinschätzung, in Das NAW - Buch: Akutmedizin der ersten 24 Stunden, Madler C, Jauch K, Werdan K, et al., ed. Elvesier, Urban & Fischer: München, Jena, 2005: 193-99.
45. ÖGAN. Scoring Systeme im Rettungsdienst. 2008 (cited 2008 08.01.2008); www.oegan.at.
46. Patterson R. On thin ice: a rather personal look at the hazards of winter climbing. *Can Med Ass J* 1992; 146(6): 1041-7.
47. Schöffl V, Schöffl I. Finger pain in rock climbers-reaching the right differential diagnosis (in press). *J Sports Med Phys Fitness* 2007; 47(1): 70-8.
48. Schöffl V. (Hand Injuries in Rock Climbing) Handverletzungen beim Klettern. *D Z Sportmed* 2008; 59(4): 85-90.
49. Schöffl VR, Schoffl I. Finger pain in rock climbers: reaching the right differential diagnosis and therapy. *J Sports Med Phys Fitness* 2007; 47(1): 70-8.
50. Haas JC, Meyers MC. Rock climbing injuries. *Sports Med* 1995; 20(3): 199-205.
51. Binney DM. Getting a grip of rock climbers injuries. *Sport Med* 2001(3): 44-6.
52. Schöffl I, Einwag F, Strecker W, et al. Impact of Taping after Finger Flexor Tendon Pulley Ruptures in Rock Climbers. *J Apl Biomech* 2007; 23: 52-62.
53. Schöffl V, Einwag F, Strecker W, et al. Strength Measurement after conservatively treated Pulley Ruptures in Climbers. *Med Sci Sports Exerc* 2006; 38(4): 637-43.
54. Roloff I, Schöffl VR, Vigouroux L, et al. Biomechanical Model for the determination of the forces acting on the finger pulley system *J Biomech* 2006; 39(5): 915-23.
55. Schweizer A. Biomechanical properties of the crimp grip position in rock climbers. *J Biomech* 2001; 34(2): 217-23.
56. Schweizer A, Frank O, Ochsner PE, et al. Friction between human finger flexor tendons and pulleys at high loads. *J Biomech* 2003; 36(1): 63-71.
57. Jakus PM,Shaw WD. An empirical analysis of rock climbers' response to hazard warnings. *Risk Anal* 1996; 16(4): 581-6.
58. Schussman LC, Lutz LJ, Shaw RR, et al. The epidemiology of mountaineering and rock climbing accidents. *Wilderness Environ Med* 1990; 1: 235-48.
59. Molsa J, Kujala U, Nasman O, et al. Injury profile in ice hockey from the 1970s through the 1990s in Finland. *Am J Sports Med* 2000; 28(3): 322-7.
60. Ekstrand J, Walden M,Hagglund M. Risk for injury when playing in a national football team. *Scand J Med Sci Sports* 2004; 14(1): 34-8.
61. Kajtna T,Tusak M. Some psychological studies of high risk sports. *Kinesiologia Slovenica* 2004; 10(1): 96-105.
62. Henke TH. G, Die Risikobewertung der verschiedenen Sportarten - Epidemiologie von Sportverletzungen. In: Bergler R., ed. Irrationalität und Risiko. Gesundheitliche Risikofaktoren und deren naturwissenschaftliche und psychologische Bewertung. Köln: Kölner Universitätsverlag, 2000: 300-18.
63. Meyers. Meyers Lexikon-Online 2.0. 2008 (cited 16.01.2008); www.lexikon.meyers.de/meyers/extremsport.

Received: June 06, 2009
Accepted: October 15, 2009
Published: October 27, 2009

Address for correspodence:
Priv. –Doz. Dr. Volker Schöffl
Sektion Sportorthopädie, Klinikum Bamberg
Bugerstr. 80
96049 Bamberg
Germany
volker.schoeffl@me.com
volker.schoeffl@sozialstiftung-bamberg.de

Isabelle Schöffl: isabelle.schoeffl@me.com
Ulrich Schwarz: 320046969491-0001@T-Online.de
Friedrich Hennig: friedrichhennig@yahoo.de
Thomas Küpper: tkuepper@ukaachen.de