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Acute and Overload Injuries of World Cup Ice Climbers

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Abstract

Introduction: Competition ice climbing has developed into a semi-professional sport. Nevertheless, scientific data on the injury profile and incidence are rare.

Objectives: To evaluate the causes, diagnoses and incidence of acute and overuse injuries in elite ice climbers during training and competition for better prevention.

Methods: Competitors in an Ice Climbing World Cup event volunteered to complete a questionnaire on their training, injuries and overuse symptoms. Injuries and accidents were analysed in each of the injury scoring systems of the UIAA, OSICS and NACA. Statistics were descriptive.

Results: A total of 73 climbers (M: 58; F:15) joined the study, including all World Cup winners. The average climbing experience was 5.9 years with most active in several climbing disciplines. Competition training averaged 11.8 hr/wk and was of a similar volume to previous months and years. Thirty-one climbers had mastered a UIAA climbing grade difficulty from 9 up to 11+. In 13 out of 16 climbers reporting an accident, the injury occurred in a discipline other than ice climbing - 6 happened in another climbing discipline, 4 during competitions, 3 while on tour, and one was unspecified. None reported securing errors or rockfall as causal, but 10 stated the accident was avoidable, and 4 felt it was 'fateful' and therefore unavoidable. Three accidents were caused by ice breakage, 5 by material damage, 4 by swaying, and 3 were 'other'. Using the NACA injury index for the 16 reported accidents: 25,0% were NACA 1, 68.7% NACA 2, 6.3% NACA 3, and none were NACA 4 or above.

The acute injuries sustained by 18 climbers using the UIAA Injury Score in brackets were: 4 frostbite (1/2), 6 open wound (1/2), 6 fractures (2/3), and one unclassified. In almost all cases the injury lasted between one day and less than a week, and one case lasted 5 weeks. The 16 reported injury locations using UIAA/OSICS Injury Indexes were: 4 lower leg, 2 head/face, 2 foot/toe/ankle/unspecified, 1 in each category for upper arm, wrist, knee, and chest, and 3 were unspecified. Overuse injury histories were reported by 40.6% of climbers, with women at a significantly higher risk.

Conclusion: Although the risk of overuse injuries is low in elite ice climbers, particular attention should be paid to the elbow joints and shoulders of women. Accidents were generally infrequent and involved minor injuries. Helmet use is mandatory during competitions. However protective goggles may help prevent eye injuries and wearing appropriately designed protective trousers may reduce lower leg injuries caused by crampons, thus reducing the risk and incidence of injuries.

Keywords: Ice climbing, Injuries, Risk, Training, Prevention, Competition

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Introduction

Extensive literature exists on the subject of accidents and injuries for the various alpine mountain sports, for sport climbing both on natural rocks and on artificial climbing facilities [1-20], and to a lesser extent to non-traumatological problems in climbing, and climbing with pre-existing health conditions [21-23]. In contrast, accident and injury data on ice climbing is rather sparse. Data on water ice climbing as a close relative to the sports of mountaineering and rock climbing, has traditionally been

considered subjectively as a high risk sport in the absence of objective data assessing this [24]. This is surprising considering the first ice climbing competition took place in June 1912 on the Brenva Glacier near Courmayeur (Mont Blanc region) [25]. The first World Cup was held in 1999. In 2002 ice climbing was established as an independent competition discipline by the UIAA (Union Internationale des Associations d'Alpinisme), after which the first World Championships were held in the same year [25]. Ice climbing has thus developed from a special form of alpinism into a distinct, trendy and competitive sport.

Schoffl et al. used a questionnaire to assess the activity frequency and injuries that occurred in 88 ice climbers (13 F; 75 M; mean age 34.6 y) and graded these injuries using the NACA score (**Table 1**) [26]. The UIAA Injury Score [27,28] was published later (**Table 2** and **Table 3**) and the risk was converted to incidences per 1000 hours of sport under plausible assumptions [29], to enable comparisons with other sports. A total of 17 study participants (19%) reported 35 overuse injuries within the last three years which they attributed to ice climbing. Acute injuries were significantly more common (67 x NACA 1, 24 x NACA 2, 4 x NACA 3), with most cases being open wounds (55.2%) or haematomas (21.9%). Most injuries (61.3%) occurred during lead climbing, 23.8% during second ascent, and the remainder during other ice climbing-related activities such as approach, return, belaying, etc. What is remarkable for a sport that seems rather sensational or subjectively risky in the eyes of laypersons is that the vast majority of all injuries could definitively be treated without medical assistance (NACA 1), and only a very small proportion had to be hospitalised (NACA 3), almost always only for a few days. No serious damage was reported in the group. Including minor injuries, the incidence of injury was 4.07/1000 hours of sport, with NACA 1 accounting for 2.87 of these. While overuse symptoms correlated with training frequency and intensity – which is hardly surprising – a high body mass index was significantly correlated with the risk of injury. However these ice climbers were of mixed grade ability, and not exclusively professional competition climbers.

Table 1: The NACA (National Advisory Committee of Aeronautics) Terrain and Injury Index [26], [38], [39].

Injury index		Terrain index	
1	Healthy	A	Hospital
2	No immediate therapy	B	Doctor's practice
3	Therapy without hospitalisation	C	Difficult access by vehicle
4	Possible vital hazard	D	Offside, easy terrain
5	Acute vital hazard	E	Offside, difficult terrain
6	Resuscitation	G	Extreme terrain
7	Dead		

Table 2: UIAA injury score Localization.

Main Grouping	Category	Equivalent OSICS Body Area Character [60]
Head and neck	Head / Face	H
	Neck / cervical spine	N
Upper limbs	Shoulder / clavicle	S
	Upper arm	U
	Elbow	E
	Forearm	R
	Wrist	W
	Hand / finger / thumb	P
Trunk	Sternum / ribs / upper back	C,D
	Abdomen	O
	Lower back / pelvis / sacrum	B,L
Lower limbs	Hip / groin	G
	Thigh	T
	Knee	K
	Lower leg / Achilles tendon	Q,A
	Ankle	A
	Foot / toe	F

Ganti et al. arrived at a similar conclusion, but found the frequency of injuries was apparently higher at a recreational ice climbing festival (17.6/1000 hours), but almost all were minor injuries [24]. This increased frequency of minor injuries was most likely due to the low level of experience in handling equipment and ice among ice climbing amateurs at a festival. This interpretation is also supported by the study by Mashkovskiy, who analysed the injury rate of mixed ability ice climbers at a climbing festival held during the Winter Olympics in Sochi 2014 [30]. The majority of ice climbing participants had no previous experience of ice climbing (n >2,000). Here the experienced lead climbers had an injury incidence of 0.82/1000 hours, in speed climbers it was 0.83/1000 hours, and in amateur climbers it was about 300 times higher at 248/1000 hours. Here also almost all sub-collectives had minor injuries (NACA 1). Unfortunately, no information was given on competition climbers who may have participated at this event as a subgroup.

According to the Canadian Alpine Club, which has been documenting ice climbing accidents separately for more than 30 years, a total of 92 climbers were injured and 30 have died in ice climbing accidents during this period. Similar numbers are reported from the USA (overview in [8]). Again, this data cannot be directly compared with the completely different collective of sport climbers, but they clearly show that the sport of ice climbing is not particularly dangerous compared to other sports. This is also illustrated by the comparison of the risk of injury with other sports (**Table 4**). Anecdotal reports and a small number of cases [31], reveal a special feature of ice climbing, apparently there are more eye injuries here than in any other climbing discipline. This is attributed to the specific use of hand tools, where superficial splintering of small pieces of ice is the rule. This indicates that the specific movement pattern and the equipment used determine a specific risk profile.

In summary, the injury risk profile for high level or world class competition ice climbers has not yet been investigated sufficiently. This was the aim of the current study.

Material and methods

The study group consisted of 73 out of 105 elite ice climbers competing in the 2011 World Cup in Saas Fee. These participants (response rate of 69.5%) voluntarily completed an established questionnaire [25,32], that had a minor modification based

Table 3: UIAA injury score Injury and Illness Classification IIC.

Score	Description
1	No injury or illness
2	Minor injury or illness, no medical treatment necessary, self-therapy (e.g. blisters, bruises, strains)
3	Moderately severe injury or illness, not life-threatening, medium-term outpatient conservative or surgical treatment, consultation with a doctor within a short time frame (days), incapacity to work due to injury or illness, healing without permanent damage (e.g. non-displaced fractures, torn ligaments, ruptured annular ligaments, dislocations)
4	More serious injury or illness, not life-threatening, but requiring inpatient treatment, immediate medical attention, incapacity to work due to injury or illness, healing with or without permanent damage (e.g. displaced fractures, vertebral fractures, I° craniocerebral trauma).
5	Acute danger to life, polytrauma, emergency medical care or care by paramedics required (if possible), acute medical intervention required; usually survives, but with permanent damage.
6	Acute danger to life, polytrauma, immediate emergency medical care or care by paramedics necessary (if possible), acute medical intervention, fatal outcome.
7	Primary death

Table 4: Injury risk of several sport disciplines per 1000 hours (from [8], [24], [30], [61]). Note: the severity of injury is not reported for most disciplines and differs significantly. In ice climbing most incidences cause minor injuries.

Discipline	Incidences / 1000 hours
Rugby, amateurs	283
Ice climbing event at Sochi, amateurs	**248**
Rugby, professionals	150
Ice hockey, professionals	83
Rugby, youth team	57
Handball, women	50
Soccer, Champions League	31.6
„Classic“ alpine climbing, 1980‘s	37.5
Motorbike sport	22.4
Recreational climbing festival	**17.6**
American Football	15.7
Sailing	8.8
Polo	7.8
Kite Surfing	7.0
Volleyball, school sports	6.7
Ice climbing	**4.07**
Soccer, German National League	3.1
Competition climbing	3.1
Triathlon	2.5
Boxing	2.0
Mountain Bike	1.0
Ski / Snowboard (downhill)	1.0
Nordic Walking	0.9
Ice climbing, competition (lead)	**0.82**
Ice climbing, competition (speed)	**0.83**
„Classic“ alpine mountaineering, today	0.56
Windsurfing	0.41
Sport climbing	0.027-0.079

on the analysis of the prior studies. The following data was recorded: basic demographic data (age, height, weight, sex), detailed questions about climbing disciplines, participation in competitions, type, severity and frequency of injuries during competition climbing and training, subjective avoidability of injuries, type and extent of training, subjective assessment of personal limits in climbing difficulty in various situations (lead, second ascent, artificial climbing walls, alpine, etc.) and a personal assessment of the risk of ice climbing. The study was conducted in accordance with the Declaration of Helsinki and was approved by the ethics committee at the RWTH Aachen (Ref.No. Ek 051/06) [33,34].

The climbing grade difficulty on ice was classified using the W scale, on mixed terrain the M rating was used (**Table 5** and **Table 6**), and on rock the UIAA Metric Scale was used (**Table 7**). The participants were asked to self-assess their lead climbing morale, i.e. their subjectively perceived mental stability or fear and insecurity as a rope starter in one of four classes: (1) very good; (2) good; (3) moderate; or (4) poor.

The injury localisations were differentiated according to the UIAA recommendations using the OSICS score [27,28,35-37], (**Table 2**). To enable comparison with other studies, a differentiation was also made using the NACA (National Advisory Committee of Aeronautics) injury index [26,38,39] (**Table 1**).

The data was transferred from the questionnaires to an Excel file and first checked for consistency. The analysis was initially descriptive. Data examination using the Kolmogorov-Smirnov test and Levine test confirmed, as expected, that the data was not normally distributed. Therefore subgroup comparisons were carried out using non-parametric tests using Chi-square and Mann-Whitney U-test. In addition to Excel, SPSS (version 15) and Origin (version 8) were used for evaluation and graphical realisation. For all comparisons p=0.05%. Due to the explorative nature of this study no adjustment was made to the significance level.

Results

Study group and activities

The participants (N=73) consisted of 58 male and 15 female elite ice climbers, including all the World Cup winners. The mean age was 25.1 years (Sx 5.6; median 25; range 14-39). There were no significant age differences between the sexes.

As expected, there were highly significant differences between the female and male ice climbers with respect to height, weight, and BMI. The mean height of the collective was 176 cm (Sx 8.2; median 176 cm; range 156-197 cm; N=73); respective average heights for females and males were 165 cm (156-179 cm) vs. 179 cm (167-197 cm) (p<0.001), The mean body weight of the

Table 5: Difficulties in ice climbing (W-Grading).

	Criteria			
Grade	Steepness	Ice conditions	Belaying options	Others
W1	40° - 70°	Compact ice	Easy to fix	Still feasible for experienced mountaineers
W2	60° - 70°	Compact ice	Very good	Start of more challenging ice climbing
W3	70° - 80°	Compact ice	Good	Alternating steeper and flatter passages
W4	80°	Short passages with vertical ice possible	Good, but sometimes difficult	Short sections of vertical ice possible
W5	85° - 90°	Short passages with tubular ice possible	Some are difficult	Longer vertical passages
W6	90°	Tube ice and free-standing ice columns	Some are questionnable	Persistently vertical passages are tactically and mentally demanding
W7	overhanging	Thin free-standing ice columns, free-hanging ice	Very bad possibilities	The limits of what is possible

Modified from: Deutscher Alpenverein (German Alpine Club) https://www.alpenverein.de/chameleon/public/bd3f4355-d634 d618-a699-00711a11be82/Schwierigkeitsgrade-Wasserfall-Eisklettern_19562.pdf (accessed 2.2.2024)

Table 6: Difficulties in mixed climbing (M-Grading).

Grade	Description
M1	Feels like 5.5 climbing.
M2	Feels like 5.6 climbing.
M3	Feels like 5.7 climbing.
M4	Feels like 5.8 climbing.
M5	Feels like 5.9 climbing; using the blades of ice axes in cracks to torque and dry-hook is useful.
M6	Feels like 5.9+ climbing; using the blades of ice axes in cracks to torque and dry-hook is mandatory.
M7	Feels like 5.10 climbing; using ice axes and crampons in such a way as to make the climb impossible without them. Usually somewhat overhanging.
M8	Feels like 5.11 climbing; using ice axes and crampons in such a way as to make the climb impossible without them. Involves overhanging and sustained climbing.
M9	Feels like 5.11+ climbing, using ice axes and crampons in such a way as to make the climb impossible without them. Involves severely sustained and extremely overhanging climbing.
M10	Feels like 5.12 climbing
M11	Feels like 5.12+ climbing
M12	Feels like 5.13 climbing
M13	Feels like 5.13+ climbing
M14	Feels like 5.14 climbing
M15	Feels like 5.14+ climbing
M16	Feels like 5.15 climbing

From: https://www.neice.com/ice-and-mixed-climbing-grades/ (accessed 2.2.2024)

collective was 67.5 kg (Sx 8.3; median 69 kg; range 48-92 kg; N=73); average weights for females vs. males were 56.6 kg (48-67 kg) vs. 70.3 kg (58-92 kg) ($p<0.001$). The mean BMI of the total collective was 21.6 kg/m^2 (Sx 1.6; median 21.6 kg/m^2; range 18.7-26.2 kg/m^2; N=73); the average male BMI was 21.9 kg/m^2 (18.7-26.2 kg/m^2) vs. female BMI 20.6 kg/m^2 (18.7-23.7 kg/m^2) $p<0.0063$.

The average for total climbing experience in years, regardless of the climbing discipline, was 5.9 y (Sx 4.1; median 5 y; range 1-26 y; N=72). There was no significant difference between the sexes or between a sub-collective and the overall collective (M vs. all p=0.691; F vs. all p=0.346; M vs. F p=0.245). On average, 8.7 tours/month were carried out in the past year (Sx= 7.7; range 1-25; N=60). Mainly due to the wide dispersion and the relatively small size of the sub-collective of women, no significant differences were found either between the sub-collectives or between a sub-collective and the overall collective (M vs. all p=0.815; W vs. all p=0.864; M vs. W p=0.755).

In the month before the World Championships, the participants trained an average of 11.8 hrs/wk (Sx=6.9; range 1-30 hrs/wk; N=70). Overall, no increase in training activity was observed before the competition, and it was more in line with the level of training in the previous months and years. Significant differences were not found between the sub-collectives.

For further analysis and interpretation, questions were asked about any other climbing related activities. Most participants stated that they had climbed on very different ice terrain. So in addition to training on the competition-relevant artificial ice walls, and on waterfall climbs using ice climbing equipment, they also trained and on mixed terrain where ice routes are interspersed with rocks and require "dry tooling" equipment. The

Table 7: The UIAA Metric Scale for assessing climbing difficulties on rock compared to other internationally used scales [62].

Metric Scale	UIAA-Scale	French Scale	Yosemite Decimal Scale (USA)
5,66	6-	5b/c	5.8
6	6	5c/6a	5.9
6,33	6+	6a/6a+	5.10a
6,66	7-	6a+/6b	5.10b/c
7	7	6b/6b+	5.10d
7,33	7+	6b+/6c	5.11a/b
7,66	8-	6c+	5.11c
8	8	7a	5.11c/d
8,33	8+	7a+/7b	5.12a/b
8,66	9-	7b/7b+	5.12b/c
9	9	7c/7c+	5.12d
9,33	9+	7c+/8a	5.13a
9,66	10-	8a/8a+	5.13b/c
10	10	8b	5.13d
10,33	10+	8b+/8c	5.14a/b
10,66	11-	8c/8c+	5.14b/c
11	11	9a	5.14d
11,33	11+	9a+	5.15a
11,66	12-	9b	5.15b
12	12	9c	5.15c
12,33	12+	9c+	5.15d

From: https://de.wikipedia.org/wiki/Schwierigkeitsskala_(Klettern) (accessed: 2.2.2024)

Table 8: Localisation of the 13 injuries according to the UIAA / OSICS system [27], [28], [35], [36], [37], numbers absolute and in %.

Localization	No.	%
Head / face (H)	2	15.40%
Upper arm (U)	1	7.70%
Foot / toe / ankle (A, F) Unspecified (X)	2	15.40%
Wrist (W)	1	7.70%
Knee (K)	1	7.70%
Lower leg (Q)	1	7.70%
Chest (C)	4	30.70%
	1	7.70%

sex-segregated analysis revealed no systematic differences, so that it can be summarized that the participants in the competition were active to varying degrees in practically every ice terrain, albeit with varying frequency, and also in rock climbing. A total of 31 people (44.3%) mastered the climbing grade of UIAA difficulty 9 and higher up to a maximum of 11+. This ability can be categorised as elite and higher elite rock climbers [40].

For 26/70 people (37.1%), the training volume was only up to 10 hours per week, for a further 21 (30%) 11-15 hours and for 23 (32.9%) more than 15 hours (maximum 31). On average, women spent around two hours more training each week compared to the men (n.s.).

Accidents and Injuries

A total of 16 people (23.5%) reported accidents, 52 (76.5%) answered this question in the negative, and 5 did not provide

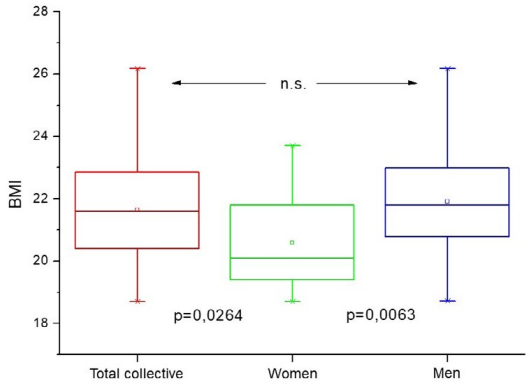

Figure 1 Body mass index of the total collective and of the female and male sub-coectives.

any information. The type and localisation of acute injuries was stated for 13. Their distribution according to the UIAA or OSICS injury index [27,28,35-37] is shown in (**Table 8**). No one suffered more than one accident with a significant injury (requiring treatment). With regard to the sex distribution, there was no significant difference: 3/15 women and 15/58 men stated that they had suffered an accident. In total, 13 of the 18 persons who had suffered an accident stated that they had suffered this in a discipline other than ice climbing. The injuries were as follows (UIAA Injury Score in brackets): 4 frostbite (1/2), 6 open wounds (1/2), 6 fractures (2/3) and one unclassified injury ("other"). After the accident 11/16 people consulted a doctor (68.8%), and 7 were temporarily unable to work (43.8%). In almost all cases, the latter lasted between one day and less than a week; in only one case did it last 5 weeks. The accident-related injuries were thus distributed as follows across the NACA injury score: 31.3% were NACA 1, 68.8% NACA 2, and 6.3% NACA 3. No case was classified as NACA 4 or higher. In this specific case, the UIAA MedCom Index for Injury Severity is considered more appropriate to use internationally when assessing injury severity (**Table 5**). According to this, of the injured 5/16 corresponded to category 2 (31.3%), 10/16 (62.4%) to category 3, and 1/16 (6.3%) to category 4. Regarding the consequences of the injury, 9/14 (64.3%) reported that a break from climbing was necessary (mostly 1-2 weeks), and 4/14 (28.6%) reported any form of permanent damage. Accidents that occurred during climbing training were reported by 6/14 (42.9%) participants, 4/14 (28.6%) occurred during competitions, 3/14 on tour (21.4%) and one (7.1%) was unspecified occurred elsewhere as 'other'. Accidents causes included ice breakage 3/15 (20.0%), 5/15 material damage (33.3%), 4/14 (26.7%) swaying and 3/15 (20.0%) 'other'. Securing errors or rockfall were not cited as the cause in any of the cases. According to the accident victims in 14 assessments, 10 (71.4%) stated 'yes' the accident could have been avoided, while only 4 (28.6%) saw the accident as 'fateful' and therefore unavoidable.

Chronic overstrain injuries

The question of whether overuse injuries had occurred during ice climbing was answered by 69/73 participants, 28 of whom (40.6%) answered 'yes'. No further details were given on the localisation of a number of overuse injuries, but women clearly

predominated among ice climbers with regard to overuse injuries. Of the total of 13 detailed reported cases (OSICS or UIAA MedCom injury code in brackets), all but one knee injury (K) and one finger injury (P) in men concerned women. Women reported these overuse injuries: 2 shoulder (S), 7 elbow (E), 1 finger (P), and a further tendon rupture (no details given concerning which one) (P) in a female who climbed both on rock and on ice. The overuse injuries in the elbow area were almost exclusively epicondylitis. It is noteworthy that the 11 people who reported overuse injuries reported them occurring in both ice and rock climbing activities (11/28 = 39.3% of ice climbers, 11/16 = 68.8% of participants in other disciplines). Ice climbing must therefore be ruled out as the sole causal activity in most cases. Permanent damage was reported in only one case in the form of chronic recurrent tendonitis of the bicep's tendon in the elbow region. Two people stated that they had suffered two overload injuries, but no one suffered more than two injuries. As the symptoms were at the same localisation, it must be assumed that the first injury left a predisposition, for example by returning to sport too early. This is also supported by the remarkably short treatment times for the overuse injuries.

Discussion

The aim of this study was to investigate whether elite competition ice climbers, particularly in the disciplines of 'lead' (difficulty climbing) and 'speed' (speed climbing), had any specific accident and injury patterns (acute or overuse), to inform preventative measures if necessary. Literature on ice climbing accidents and injuries is sparse.

In contrast, studies on specific injuries and overuse injuries in rock climbing are numerous. Schöffl's working group in particular has published very detailed studies on the mechanism, diagnosis and therapy [3,5-7,10], [41-51]. In these studies, including some with large collectives, were able to establish several previously unknown facts:

- The risk of injury during sport climbing was minimal compared with other sporting activities. Sport climbing resulted in 0.027-0.079 injury incidences per 1000 hours of sport participation, which is significantly lower than the risk of injury in school volleyball with 6.7 injuries per 1000 hours [8]. Other authors report somewhat higher incidences, for example 4.2/1000 hours [52]. Irrespective of this, it can be concluded from all available data that the risk is within the lower range of normal sports, including those regularly practised at school.

- With A2 and A4 pulley injuries, there is an injury that is almost pathognomonic for this type of sport.

- Epiphyseal detachment can occur in the fingers of performance-orientated young climbers.

Sport climbing as a popular competitive sport for years has recently become an Olympic discipline for the first time (Tokyo 2021). Sport climbing on rock or on artificial holds made of plastic holds has been extensively studied compared to ice climbing [8,30,53]. This may also be due to the fact that competition ice climbing has only become more popular in Western countries in recent years. However in countries from the former Soviet Union, in particular Russia, competitions have taken place for decades, especially in the very popular discipline of 'speed'. In Western countries, ice climbing was generally only associated with climbing high walls (e.g. central alpine). However, this ice climbing activity placed completely different demands on the participants compared to the competitive sport, which usually takes place in an objectively safe environment. The fact that it is also a fairly new sport, at least in Western Europe, is also shown by the fact that no systematic training was recognisable in our study. Some of the very successful participants had only been practising the sport for a few years (in some cases only one year), the weekly training times varied greatly and were generally short compared to other established sports. Even one of these factors would be enough in well-established competitive sports to be disqualified at an international competition, let alone at a world championship.

Until the study by Schöffl et al. in 2009, there was practically no data available on the prevalence of injuries in ice climbing [25,29]. Of the 88 participants analysed in this study, 17 (19%) reported a total of 35 overuse injuries and 95 acute injuries (both within the last 3 years). The latter were mostly open wounds (55.2%) and haematomas (21.2%). Localised frostbite reported at 11.5% was similar to the current study. Most of the injuries were minor: 67 x NACA 1, 24 x NACA 2, 4 x NACA 3; with 61.3% of the accidents occurring during lead climbing, and 23.8% during second climbing. The incidence rate for acute injuries was calculated at 4.07/1000 hours of climbing participation, and at 0.77/1000 hours for overuse injuries. In the current study, the incidence could not be calculated with sufficient accuracy as the information provided by the participants about the duration of their activities was too imprecise. However, the other results essentially correspond to those of Schöffl et al. and Schwarz et al. [25,29] although in their study the high-performance climbing played a subordinate role.

Interestingly, BMI was positively correlated with accident risk, with ice climbers having a higher BMI than performance-orientated sport climbers. Due to the small number of accident victims with a higher BMI in the current study, no statement can be made. However in both our study and in Vujic et al., a higher average BMI was reported, which Vujic interprets as a possible adaptation to the cold environment [53]. In contrast, water ice climbing overuse injuries were correlated significantly with the training, the technical difficulty of the routes, and the willingness to lead climb [29]. This can neither be supported nor refuted in the current study as the collective's training involved different climbing disciplines, so that an injury could not be attributed exclusively to any one of these disciplines, or to an action within the discipline (e.g. lead climbing).

The Alpine Clubs of Germany, America, Canada and other countries publish annual injury reports on the various alpine disciplines. Unfortunately the bias here reflects only major injuries that are reported to their insurances, and thus cannot be directly compared to our data here [1-3,54]. However, it should be emphasised that an astonishingly low accident risk was also calculated in the Alpine injury reports.

At the 2014 Winter Olympics in Sochi, ice climbing was publicised

to a wider global audience as part of a local climbing festival that was medically supported, and injuries were recorded [30]. Over 2500 beginners, and around 50 experienced climbers, took part in the 'speed' and 'lead' disciplines over a fortnight. To summarise the authors concluded that competitive ice climbing on artificial ice walls had a significantly lower fatality rate, but a higher rate of minor injuries compared to traditional ice climbing on waterfalls or high mountains. Penetrating and superficial injuries (e.g. abrasions) accounted for the majority of injuries (NACA 1). The incidence rate, based on the quotient of injuries detected and the total number of participants was given as 0.82/100 participants for 'lead' and 0.83/100 participants for 'speed'. The injury risk incidence for amateurs was given as 248 / 1000 hours of sport. There were no serious accidents. The authors cited several limitations to their study, but primarily the majority of participants were beginners with no ice climbing experience. The results are therefore not comparable with the current study.

Since the focus of the study by Vujic at al. [53] was on the anthropology and training characteristics of high-performance level ice climbers, it must be stated to the best of our knowledge, the present study is the first that systematically deals with questions of injury patterns, consequences of accidents and overuse injuries in elite ice climbers.

Unlike the collective of rock climbers, ice climbers are older and have conspicuously short sporting careers on ice and involve short training periods. With an average experience in the discipline of only 5.9 years, an average age of 25.1 years and a very manageable amount of training (37.1% 10 h/week; 30% 11-15 h/week; 32.9% >15 h/week) it would be impossible to exceed the performance level of the middle amateur level in most sports. With regard to the results of Niestroj et al. [55], the question naturally arises as to whether specific health problems, in particular chronic overuse injuries, could arise due to less access to sports medicine and physiotherapy care in the amateur sector. The study found no evidence for this, which may have several reasons. Firstly, the training volume was manageable and this limited the probability of overuse injuries. Perhaps more importantly is was more likely the athletes were more or less regularly active in many disciplines, thereby consciously or unconsciously avoiding one-sidedness in their training. This versatility was so great that even in the collective of high-performance sport it was not possible to assign overuse injuries that occurred to a specific discipline, for example the sporting or competitive ice climbing and its training. On the contrary, most of those affected stated that the complaints occurred during activities other than in ice climbing. However, our data indicate that the coaches should pay particular attention to the women with their high rate of elbow problems and relatively numerous shoulder complaints.

An overuse injury of the wrist - "ice axe wrist" - was recently described in climbers [50,56]. This rare inflammatory condition is an intersection syndrome located at the crossing point between the first and second dorsal compartments in the wrist [56,57]. Tobin's report gives details about two cases of intersection syndrome associated with the use of an ice axe. The first was in a female climber who was using an ice axe for climbing in the Nepal Himalayas and the second was in a male climber using an ice axe for alpine winter climbing. Both cases differ technically from competition ice climbing. However, all include a striking phase of movement. Biomechanically this includes significant torque and impulse forces on the wrists which may be an important risk factor after a multitude of repetitions during intense climbing [58].

We tried to get more detailed information about this condition and the relevance for elite ice climbers but obviously this is not yet a topic here. There was no one who reported such symptoms, even though leashes to reduce the loading on the wrist were rarely used. The relatively low amount of training hours in these elite ice climbers compared to other sports may be the main reason of the very low incidence of intersection syndrome in elite ice climbing.

With respect to the accidents and acute injuries that 16/73 participants reported in our study, there was a striking difference when compared to well-studied rock climbers where accidents occurred almost exclusively during training and almost never during competitions. In elite competitive ice climbing our study found that only 42.9% of accidents occur during training, but 28.6% during competitions and 21.4% on tour. The latter can easily be explained by the fact that competition-orientated sport climbers are almost exclusively indoors and only rarely out in the mountains. The very high injury rate in competitions compared to sport climbing is a cause for concern and should be the starting point for preventive considerations.

Prevention

A helmet is now mandatory for competitive ice climbing. However, this does not protect the face. Mandating the use of eye goggles could further reduce the injury rate in ice climbing, as the hand tools are typically used at or above eye level, meaning that the eyes are always within reach of any ice splinters. Lower legs and feet were another focus of injury. These were often penetrating injuries caused by the sharp points of the crampons. Various designs of trousers that are intended for high mountains or ice climbing have a medial reinforcement around the distal lower leg and ankle with a mostly smooth but always very robust fabric. This construction design was originally developed to prevent the crampon points from getting caught in the fabric of the opposite leg, and thus preventing tripping accidents during mountaineering. However, practice has shown that this also regularly prevents injuries to the calf caused by crampon points. Using the analogy of wearing protective cut-resistant trousers when working with chainsaws [59], perhaps it should be made a requirement in competition ice climbing that trousers incorporate cut resistant fabric, at least from foot to knee, to protect from crampon injuries. The question of the advantages and disadvantages of using leashes on ice axes could not be answered with this study. However, as almost none of the athletes used slings, the fundamental question remains as to whether such a study would make sense and, if so, which target group should be investigated. In the dedicated amateur field, they could help to relieve the hand and forearm muscles, and thus prevent overuse injuries. Such overuse injuries were not found in the current study.

Limitations

This study had some limitations. Firstly, the rather long questionnaire may have reduced the responder rate. However, there were no previous studies that would have made it possible to shorten the questionnaire to narrow the issues to relevant focal points. The questionnaire was nevertheless not shortened in order to avoid missing potentially relevant information in the later evaluation. The rather large collective for this study (n=73) suggests the questionnaire's length was not an issue. It can be assumed that some factors influenced each other with regard to a possible risk of injury. As very few injuries had occurred overall, the group of people affected was too small to carry out intercorrelations or a multivariate analysis in a meaningful manner. Therefore the presentation of the study results was deliberately limited to descriptive statistics and significant differences between sub-collectives. In retrospect, the high number of participants from countries of the former Soviet Union may have posed a bias. The questionnaire had been translated by a native speaker, but during data collection there was no Russian-speaking test leader to answer any queries, and it was also not always clear whether the participants who came from former USSR states, but not from Russia itself, had sufficient knowledge of Russian to comprehend all the questions fully. In particular, some of injury detail may have been lost.

Conclusions

In the still young sport of competitive ice climbing, there is currently a low risk of overuse injuries. However, particular attention should be paid to the elbow joints and shoulders of women. It is not yet possible to say whether overuse injuries will occur more frequently in the future with increasing professionalization, and the associated intensification and specialisation of training it would bring. With respect to acute injuries caused by accidents, which are generally rare incidents and in most cases involve minor injuries, there are prospects for further risk reduction. For example, wearing protective goggles to prevent eye injuries and cut-resistant protective trousers to provide better protection against lower leg injuries caused by the crampons.

Declarations

All authors declare that there is no conflict of interest.

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