Incidence and Risk Factors for Upper Extremity Climbing Injuries in Indoor Climbers

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Key words
- climbing
- prospective
- injury
- risk factor

Abstract

The purpose of this study was to describe the prevalence, incidence and risk factors for climbing-related injuries of the upper extremities in recreational climbers. A total of 426 recreational climbers were recruited from indoor climbing halls. The baseline questionnaire included questions on potential risk factors for climbing injuries: personal factors, climbing-related factors and upper extremity injuries that had occurred in the previous 12 months. Follow-up questionnaires collected information on new injuries that occurred during the follow-up period.

The incidence of climbing-related injuries during one-year follow-up was 42.4% with 13 injuries per 1000 h of climbing. The finger was the most frequently affected injury location (36.0%). The following risk factors were associated with the occurrence of upper extremity injuries: higher age (OR 1.03, 95%CI 1.01;1.05), performing a cooling-down (OR 2.02, 95%CI 1.28;3.18), climbing with campus board (OR 2.48, 95%CI 1.23;5.02), finger strength middle finger (OR 1.12, 95%CI 1.05;1.18) and previous injuries (OR 3.05, 95%CI 2.01;4.83).

Climbing injuries of the upper body extremities are very common among recreational climbers in indoor halls and several risk factors can be identified that are related to a higher injury risk.

Introduction

Sport climbing is an increasingly popular sports activity, especially in indoor climbing halls [2]. Climbing has, as any recreational or competitive sport, a spectrum of associated injuries [1,12]. In a cross-sectional study among experienced climbers based on questionnaires, Logan et al. reported a high frequency of injuries sustained during climbing (25%) and found that the most common injuries associated with rock climbing involve the wrist and hand [12]. Wright et al. reported in a cross-sectional study using questionnaires that about 44% of the respondents had at some time sustained an overuse injury during indoor climbing, 19% at more than one site. However, this population included both competitive climbers and recreational climbers. The most common site of injury was at level of the fingers [22]. A more recent study among recreational climbers found a prevalence of climbing injuries of 50% [9]. Nevertheless, the Consumer Safety Institute in the Netherlands concluded that climbing is a relatively safe sport, looking at the accidents occurring in climbing halls and reported by emergency rooms [19]. However, it is also suggested that a subset of chronically injured climbers exists whose injuries may cause significant impact on activities of daily living and sports-related function [3].

Sport climbing is generally subdivided into different disciplines, including bouldering, top roping and leading. In bouldering, boulders (small rocks up to 4 m) are climbed without a securing rope and recent years it has developed into a new climbing discipline. In the other disciplines, there is always a securing rope, either from the top (top roping) or from fixed bolts placed on the climbing wall at intervals of about 2 m (leading). Due to improved climbing gear and the top rope system in indoor climbing walls to protect climbers, the chance for traumatic injury is small. However, due to this increased safety, climbers can push themselves harder to climb more difficult routes, which might increase the risk for overuse injuries. Considering the specific spectrum of climbing-related injuries, it is important to trace the specific risk factors for these injuries. These risk factors have mainly been determined in retrospective studies and have not been studied in representative cohorts [10,22].

accepted after revision
January 28, 2015

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DOI http://dx.doi.org/10.1055/s-0035-1547224
Published online: May 6, 2015
Int J Sports Med 2015; 36: 837–842 © Georg Thieme Verlag KG Stuttgart · New York
ISSN 0172-4622

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Therefore, the aim of this study was to describe the prevalence, incidence and risk factors for climbing-related injuries of the upper extremities in recreational climbers in the Netherlands in a prospective fashion.

Materials and Methods

Participants

A prospective cohort study with a one-year follow-up was set up among recreational indoor climbers in the Netherlands from June 2007 to April 2008. The recreational climbers were recruited in 4 different indoor climbing halls in Rotterdam and The Hague, the Netherlands. All recreational indoor climbers that visited the climbing hall during visiting hours of the research team (mostly evenings) were approached by the research staff for participation. Inclusion criteria for participation were: above 12 years of age, a good understanding of the Dutch language, and not a one-time climber.

Sample size

The incidence of sport climbing-related injuries to upper extremities is still unknown. To determine an odds ratio of 2.31 with a power of 80% and an alpha of 0.05 and, if in 33% of the climbers, the risk factor is present and, if the baseline risk for sustaining a new injury is 15%, 370 climbers needed to be included. Accounting for a 10% loss of participants in the follow-up phase, a baseline inclusion was aimed at 410 climbers.

Procedure

Climbers who were willing to participate in the study were asked to fill out a baseline questionnaire. After completing the questionnaire, participants underwent a standardized physical examination, carried out by a medical doctor and performed finger strength measurements. All measurements were conducted after their climbing activities. After 3, 6, 9 and 12 months, all participating climbers were sent follow-up questionnaires.

This study was conducted in accordance with the Medical Research Involving Human Subjects Act (WMO) and other guidelines, regulations and Acts and was approved by the Medical Ethics Committee of the Erasmus MC Medical University (2007-270) [5]. All participants signed informed consent forms.

Measurements

The baseline questionnaire included questions on personal factors (age, sex, weight and height, education, work, other sport activities), climbing-related factors (frequency, experience, climbing level, type of climbing, performing a warming-up and/or cooling down, usage of a campus board) and questions on upper extremity climbing injuries that had occurred in the previous 12 months and were prevalent at the moment of filling out the questionnaire. A climbing injury was defined as any damage on the body by climbing causing pain and/or disability (i.e., pulley ruptures, wounds or muscle and tendinopathy) other than the normal post-training aching muscles. Injuries were further specified for location: fingers, wrist, elbow and shoulders.

Physical functioning of the climbers was measured with the Quick DASH (Disabilities of Arm, Shoulder, and Hand) [8]. The Quick DASH questionnaire includes 3 modules: disability, work and sport, including a total of 19 questions, and resulting in 3 scores between 0 and 100.

The physical examination of the hands and fingers included inspection of scars, swelling, contractures, bowstringing and nodes in the tendons. For the wrist Tinel's and Phalen test were done as an indication for carpal tunnel syndrome and the wrist was further inspected for ganglia. The Hawkins test was performed to test impingement of the shoulder [6]. (data not reported)

Finger strength of the index, middle and ring fingers were measured using the NK DIGITS grip (NK Biotechnical Corporation, Minneapolis, USA). The tests were performed on both hands and 3 measurements using each hand were made. The final finger strength included the mean of the 6 measurements of both hands on each finger and was expressed in Newton.

The follow-up questionnaires included questions on new injuries of the fingers, wrist, elbow and shoulder in the previous 3 months.

Statistical analysis

Descriptive statistics were used to describe the baseline characteristics and to calculate the one-year period prevalence (climbers with a self-reported injury in previous 12 months in the baseline questionnaire), point-prevalence (climbers reporting an injury at baseline), incidence of injuries (climbers who reported a new injury during the one-year follow-up period in the questionnaires) and time-related injury risk in terms of new injuries (during the follow-up period) per 1000 h of climbing (reported in every 3-month follow-up questionnaire). Additionally, the locations of injuries that occurred are presented (in percentage of total injuries). The following potential risk factors were measured at baseline and will be analyzed: age (years), sex, BMI (kg/m^2), education level (low/medium vs. high), work (less than 32 h vs. more than 32 h), other sports activity (yes or no), finger strength (index, middle, ring), type of climbing (bouldering or sport climbing), climbing experience (years), climbing time (hours per week), climbing level, climbing with campus board (yes or no), performing warming-up (yes or no), performing cooling-down (yes or no), Quick DASH Disability score and injury in previous 12 months (yes or no).

Using incident climbing injuries as the dependent variable, univariable logistic regression analyses were performed on the independent variables to explore the association between any of the potential risk factors and new climbing injuries. Independent of the univariable analyses, all variables were entered in a multivariable logistic regression model. Backward stepwise elimination was used for the multivariable logistic analyses of prediction of climbers at risk for injuries, and $p \leq 0.10$ was used as a cut-off level for elimination of non-significant predictors from the model. Variables with a p-value < 0.05 were regarded as statistically significant.

Calibration of the logistic model was assessed using the Hosmer-Lemeshow goodness-of-fit test [7], and discrimination was assessed using the area under the receiver operating characteristic (ROC) curve to evaluate how well the model distinguished patients who were injured from those who were not injured [11, 24].

Odds ratios (ORs) are presented with 95% confidence intervals (CI). All available data was analyzed using SPSS for Windows, version 17.0, 2010.

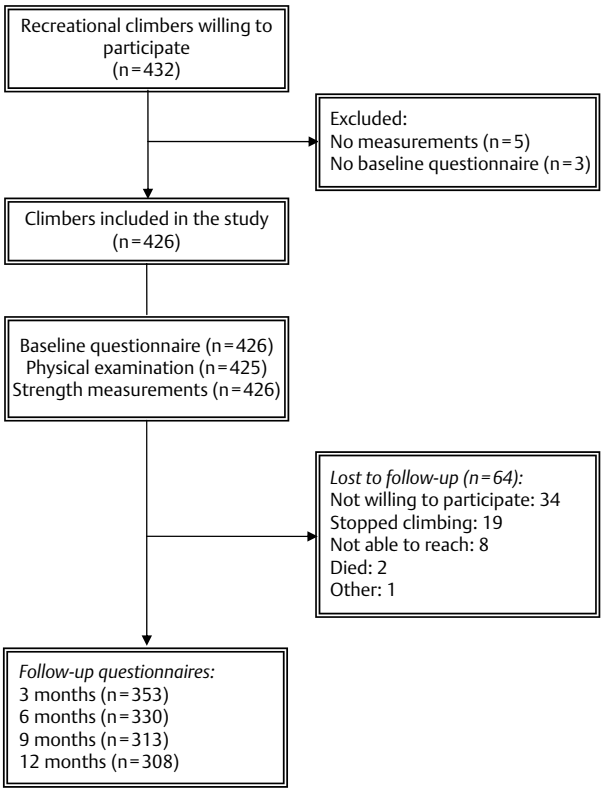

Fig. 1 Flowchart of the study.

Results

In total, 434 climbers agreed to participate in the study. Of these, 5 climbers did not participate in any of the measurements and 3 climbers did not complete the baseline questionnaire and were therefore excluded from this study. Therefore, 426 participants were finally included in this study. After one year, 72.3% (n=308) completed the 12-month follow-up questionnaire. (**Fig. 1**) No differences were found for age, sex and BMI between the responders and the non-responders after 12-months. Baseline characteristics of the study participants are presented in **Table 1**.

The mean age of the included recreation climbers was 32 years, including 117 female participants (27.5%). The mean climbing experience was 6.7 (6.4) years and they climbed a mean of 16 h per month. About 62% of the climbers had a climbing level of 6a or higher.

At the baseline, 157 climbers (36.9%, 95%CI 31.3–43.1) had sustained at least one injury in the past 12 months, causing a total of 220 injuries of the upper body extremities (**Table 2**).

Fingers were the most common reported injury site (35.0%), followed by elbow and wrist injuries (both 23.6%) (**Table 3**). At the time of completing the baseline questionnaire, 22.8% (n=97) reported a present injury. The location of the injuries, counting from most to least frequently affected were finger (31.9%), elbow (29.3%), shoulder (20.7%) and wrist (18.1%).

The incidence of climbing-related injuries during the one-year follow-up was 42.2% (n=180), with a total of 267 new injuries. The total number of injuries per 1000 h reported climbing during the one-year follow-up period was 13.04 (95%CI 11.86–14.30) injuries per 1000 h. Again, the finger (36.0%) was the most affected injury location followed by elbow (25.8%), wrist (19.5%) and the shoulder (18.7%).

Table 1 Baseline characteristics of recreational climbers (n=426).

Characteristic	N (%)	Mean (SD)
age (years)		32.28 (10.8)
sex (female)	117 (27.5%)	
BMI (kg/m^2)		21.84 (2.5)
education level		
low (elementary school/high school)	122 (28.6%)	
high (college/university)	237 (55.6%)	
work		
0–32 h/week	180 (42.3%)	
more than 32 h/week	241 (56.6%)	
other sports activity	313 (73.5%)	
climbing experience (years)		6.73 (6.4)
climbing time (h/month), previous 3 months		16.03 (32.8)
primary type of climbing (bouldering)	36 (8.5%)	
level of climbing		
Level 4–5c	156 (36.6%)	
Level 6a–7c	263 (61.7%)	
Level 8a–9a	4 (0.9%)	
performing warm-up	336 (78.9%)	
performing cooling-down	141 (33.1%)	
climbing with campus board	45 (10.6%)	
finger strength (N)		
index		7.81 (2.5)
middle		11.47 (3.7)
ring		8.03 (2.5)
dash disability score (0–100)		3.56 (6.6)
dash work score (0–100)		2.57 (9.2)
dash work score (0–100)		5.59 (15.2)
physical examination	**N=425**	
finger wounds	42 (9.9%)	
flexion contracture (fingers or thumb)	13 (3.1%)	
trigger finger or thumb	17 (4.0%)	
ganglia wrist	1 (0.24%)	
impingement shoulder (Hawkins test positive)	8 (1.9%)	

7 of the possible 15 potential risk factors measured at baseline were univariate positively associated ($p<0.05$) with climbing injuries, including a higher climbing level, bouldering, performing a cooling down, training with campus board, a higher DASH score, a higher strength in the finger, and previous injuries in the past 12 months (**Table 4**).

The multivariate analysis showed an association with the occurrence of new climbing injuries with higher age (OR 1.03, 95% 1.01; 1.05), performing a cooling-down (OR 2.02, 95%CI 1.28; 3.18), training with campus board (OR 2.48, 95%CI 1.23; 5.02), middle finger strength (OR 1.12, 95%CI 1.05;1.18) and previous injuries (OR 3.12, 95%CI 2.01; 4.83). The explained variance of the multivariable model was 19% and the Hosmer-Lemeshow goodness-of-fit ($p=0.92$) showed no lack of fit of the final multivariable model to the data (a large p-value indicates that there is no large discrepancy between the observed and expected injuries). The area under the ROC curve, as index of predictive discrimination, is 0.72, reflecting a moderate ability of the model to discriminate between injured climbers and non-injured climbers.

Discussion

The aim of this study was to describe the prevalence, incidence and risk factors for climbing-related injuries of the upper extremities in a representative sample of recreational climbers in the Netherlands. We found a one-year prevalence of 36.9%

	One-year prevalence * n (%)	Point-prevalence § n (%)	Incidence || n (%)
number of injured climbers	157 (36.9 %) 95 %CI 31.3–43.1	97 (22.8 %) 95 %CI 18.5–27.8	180 (42.2 %) 95 %CI 36.3–48.9
number of injuries	220	116	267
injuries per 1 000 h			13.04 95 %CI 11.86–14.30

95 %CI, 95 % confidence interval

* Injuries reported at baseline in previous 12 months

§ Injuries reported at baseline

|| New injuries reported during 12 month follow-up period

Table 2 Point-prevalence, one-year prevalence and incidence of climbing-related injuries in Dutch recreational climbers (N = 426).

Table 3 Location of injury.

	One-year prevalence * n = 220	Point- prevalence § n = 116	Incidence || n = 267
finger	77 (35.0 %)	37 (31.9 %)	96 (36.0 %)
wrist	52 (23.6 %)	21 (18.1 %)	52 (19.5 %)
elbow	52 (23.6 %)	34 (29.3 %)	69 (25.8 %)
shoulder	39 (17.7 %)	24 (20.7 %)	50 (18.7 %)

* Injuries reported at baseline in previous 12 months

§ Injuries reported at baseline

|| New injuries reported during 12 month follow-up period

and an incidence of 42.2 %. The incidence was defined as new injuries that occurred during the 12-month follow-up period. Prevalence was defined as reported injuries at baseline in the previous 12 months. Both were calculated as a percentage of the total included climbers. Injuries of the fingers accounted for the majority of the injuries. Furthermore, climbers who perform cooling-downs, climb with campus board, have higher finger strength of the middle finger and had a previous injury in the past 12 months were at higher risk for new climbing injuries.

The prevalence of injuries found in this study is comparable to the ratios reported in previous studies (28–50 %) [9, 12]. The high prevalence found in the study of Jones et al. is probably caused by the difference in injury definition: in their study, climbing-related injuries of any body part were included whereas in our study only injuries of the upper body extremities were reported [9].

The present study is one of the first to describe the incidence of climbing injuries among recreational climbers in a prospective study. In the current literature, only 3 prospective studies have studied climbing injuries [10, 18, 23]. Results of these studies are difficult to compare with ours because one study focused on the presentation to emergency rooms while another only focused on bouldering. Of the 22 boulder climbers included in the study by Josepsen et al., 18 (81.8 %) new injuries were reported during the one year follow-up [10]. Of the 426 climbers included in our cohort study, 36 were bouldering and of these, 21 (58 %) reported a new injury. The percentage of climbers lost to follow-up (72 %) in the study of Josepsen et al. might partly explain the high incidence found in their study. A more recent study of Schöffl et al. (2013) prospectively investigated acute injuries in indoor climbing [18]. The reported incidence in 1 000 h of climbing was significantly lower compared to our study. This is, however, not surprising, since only acute injuries that required immediate medical attention were included.

The fingers were the most commonly reported location of injury; more than one third of the new reported injuries during follow-up period were finger injuries. This is in line with several other studies that have also shown the high prevalence of finger injuries in climbers [4, 15, 23]. Unfortunately, the injuries were not clinically diagnosed in our study. The precise type of injury is therefore unclear. In addition, it is difficult to determine to what extent these finger injuries have an impact on or impair daily life. A recent review from Schöffl et al. (2012), however, concluded that most climbing injuries include fractures, strains and sprains, with chronic injuries mostly occurring in the upper extremities [17].

This is the first prospective cohort study examining risk factors for climbing injuries. In contrast to our findings, Backe et al. found a lower injury risk for the climbers between the ages of 20 and 46 compared with those younger than 20 [1]. A cross-sectional study among indoor climbers did not find an association between injury risk and age [22]. However, this might be due to the power of the study and the categorization of age, since a positive trend was seen for an increased injury risk in older climbers. Therefore, the relationship between age and injury risk remains unclear.

The higher injury risk found in climbers who always or often perform a cooling down and climbers, who climb with a campus-board might be explained by proxy variables. However, these were not measured in this study. Climbers who perform their sport in a more serious manner, train more often and are more fanatical in their sport, are probably more likely to perform a cooling-down. However, the multivariable analyses showed that volume of climbing (hours per week) and climbing level were not associated with an increased injury risk. Additional analyses showed that there was no correlation between the 2 variables. The exact nature of the cooling down is unknown since we only asked whether the climbers usually perform any type of cooling down after their climbing activity. Therefore, the relationship between a higher injury risk in climbers performing a cooling down and climbing with a campus board is hard to explain but it is likely that the variable 'performing a cooling-down' is a proxy variable for another measure that is not measured in this study.

As also seen in many other studies on sports injuries, climbers with a previous injury are at higher risk to experience a new injury [13, 20, 21]. This could suggest a possible role of unfavorable individual characteristics of often injured climbers, but might also be related to inadequate training or climbing techniques, to insufficient healing of previous injuries, an inadequate treatment or return to sports too soon.

Strengths and Limitations

The strength of this study is its prospective study design and the amount of climbers included in this study. We included a representative group and therefore the results of this study may be generalized to regular recreational indoor climbers. Due to the sample size, it was possible to adhere to the 'rule of 10' by testing 15 potential risk factors for incident injuries [14].

Variable	Univariate analysis		Multivariable analysis	
	Odds Ratio, 95 %CI	p-value	Odds Ratio, 95 %CI	p-value
age (years)	1.01 (0.99;1.03)	0.22	1.03 (1.01;1.05)	**0.005**
sex (male)	1.44 (0.93;2.24)	0.10		
BMI (kg/m^2)	0.96 (0.89;1.04)	0.31		
education level (high)	1.09 (0.70;1.69)	0.70		
work (more than 32 h/week)	0.93 (0.63;1.37)	0.70		
other sports activity	1.23 (0.79;1.94)	0.36		
climbing experience (years)	1.01 (0.98;1.04)	0.44		
climbing time (h/month), previous 3 months	0.99 (0.99;1.00)	0.55		
level of climbing (Level >6a)	2.03 (1.34;3.07)	**0.001**		
primary type of climbing (bouldering)	2.02 (1.01;4.05)	**0.046**		
performing warm-up	1.47 (0.91;2.40)	0.12		
performing cooling-down	1.86 (1.23;2.79)	**0.003**	2.02 (1.28;3.18)	**0.002**
climbing with campus board	2.77 (1.46;5.29)	**0.002**	2.48 (1.23;5.02)	**0.011**
function, DASH	1.04 (1.00;1.07)	**0.024**		
finger strength (N)				
index	1.06 (0.98;1.15)	0.14		
middle	1.09 (1.03;1.15)	**0.002**	1.12 (1.05;1.18)	**<0.001**
ring	1.08 (0.99;1.16)	0.053		
previous injury (12 months)	3.05 (2.02;4.60)	**<0.001**	3.12 (2.01;4.83)	**<0.001**

* n = 410 in final multivariable model; statistically significant p-values in bold

Table 4 Risk factors for new climbing injuries (multivariable model *).

Unfortunately, all climbing-related injuries were self-reported and the diagnosis and severity of injuries therefore remains unclear. We have chosen not to include the duration of the injury in our definition of an injury. This could have been useful to make a distinction between less and more severe injuries and their potential risk factors. Additionally, all potential risk factors were self-reported, except for the strength measures and the clustering of injury location (i. e., fingers, wrist, elbow and shoulders) might have biased the results since climbers could not precisely indicate their injury location.

For the measurements in the climbing hall, we followed the same procedure in all climbers. However, strength measurements were taken before training in some participants and in others after a training session. Although all climbers were advised to take some rest and first fill in the questionnaire before the strength measurements were performed, this might have introduced some bias due to fatigue.

The one-year prevalence is slightly lower compare to the one-year incidence. This might have been caused by recall bias, since prevalence was reported retrospectively and some injuries might have been missed.

After this study was set up, the UIAA has recommended the use of predefined scales and scores to report on climbing injuries [16]. Unfortunately, we were not able to report these in our manuscript, since these measures were not incorporated in the questionnaires. Nevertheless, by reporting the time-related injury risk, as suggested by the UIAA Medical Commission, future studies will be able to compare injury risks.

Some selection bias might have occurred since all climbers were recruited in climbing halls and as a consequence we might have missed injured climbers not visiting the climbing halls. However, since we have recruited climbers in a 9-month period the selection that might have occurred is likely to be small.

A total of 118 climbers (27.7 %) were lost to follow-up after 12 months. This may have introduced some bias, whereas climbers with injuries might have been more likely to fill out the follow-up questionnaires. This might have caused some overestimation of the incidence ratio in our study.

Conclusion

Injuries of the upper extremities are common among recreational indoor climbers: the fingers are the most frequently affected. Climbers at higher risk for new injuries are those who have a higher age, often or always perform a cooling-down, train with a campus-board, have a higher strength of the middle finger or had previous injuries.

Acknowledgements

The described study was supported by ZON-MW (project number 75020011) (The Netherlands organisation for health research and development).

Conflict of interest: The authors have no conflict of interest to declare.

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