

Previous injury as a risk factor for reinjury in rock climbing: a secondary analysis of data from a retrospective cross-sectional cohort survey of active rock climbers

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To cite: Jones G, Llewellyn D, Johnson MI. Previous injury as a risk factor for reinjury in rock climbing: a secondary analysis of data from a retrospective cross-sectional cohort survey of active rock climbers. *BMJ Open Sport Exerc Med* 2015;**0**:e000031. doi:10.1136/bmjsem-2015-000031

► Prepublication history for this paper is available online. To view these files please visit the journal online (<http://dx.doi.org/10.1136/bmjsem-2015-000031>).

Accepted 2 August 2015



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ABSTRACT

Background: The aim of this article is to report the findings of a secondary analysis of a previous injury study to consider previous injury as a risk factor for reinjury in rock climbing.

Methods: We completed a secondary analysis of 201 questionnaires that were gathered as part of a retrospective cross-sectional cohort survey that investigated the epidemiology of injuries in a representative sample of British rock climbers. Participants had actively engaged in rock climbing over the previous 12-month period and were recruited from six indoor climbing centres and five outdoor climbing venues (men n=163, mean±SD, age=35.2±11.8 years, participating in rock climbing=13.88±11.77 years; women n=38, mean±SD, age=35.1±10.7 years, participating in rock climbing=11.62±9.19 years).

Results: Of the 101 participants who sustained a previous injury, 36 were found to have sustained at least one reinjury. The total number of reinjuries was 82, with the average probability of sustaining at least one reinjury being 35.6% (95% CI 34.71% to 36.8%; p<0.001, McNemar's χ^2 test) with the relative risk of reinjury being 1.55 (95% CI 1.34 to 1.80). The fingers were the most common site of reinjury (12 participants, 26%; $\chi^2=43.12$, df=5, p<0.001).

Conclusions: Previous injury was found to be a significant risk factor for reinjury, particularly at the site of the fingers. Technical difficulty in bouldering and sport climbing behaviours were significantly associated with repetitive overuse reinjury. As participatory figures increase, so does the likelihood that a high proportion of climbers may sustain a reinjury of the upper extremity.

Rock climbing represents one of the fastest growing sporting activities in Britain reflected by an increase in the number of registered indoor climbing walls in the UK from 40 in 1988 to 353 in 2014.¹ There are a variety of different types of climbing behaviours which take place both at indoor and outdoor climbing venues. For example,

Summary box

- Rock climbers operating at the highest levels who have sustained a previous injury are at significant risk of reinjury.
- The fingers are a common site of reinjury due to repetitive overuse.
- Fall-related reinjuries are comparatively infrequent.

traditional climbing takes place outdoors and utilises a rope which is attached to safety equipment, placed during the ascent, as protection in the event of a fall. Sport climbing takes place both indoors and outdoors and utilises a rope that during the ascent is attached to permanent safety anchors, as protection in the event of a fall. Soloing is where the climber ascends a traditional climb unroped, and is considered a riskier form of climbing behaviour as serious injury or death may result in the event of a fall. Bouldering is also performed unroped and takes place both indoors and outdoors. It involves approximately 6–8 movement sequences performed at relatively low heights with a safety mat placed below the climber to reduce the risk of injury as a result of a fall.

Rock climbing is widely regarded as a 'high-risk' sporting activity because of the inherent risk of serious injury or fatality, with a high prevalence of acute and overuse injuries to the fingers and hand being reported.^{2 3} A recently published study found comparable rates, types and mechanisms of injury in youth rock climbers as compared with adult rock climbers.⁴ Interestingly they identified injuries sustained during other sports as a risk factor for future injury. Previous injury within the same sport has been found to be

a risk factor for reinjury.^{5 6} To our knowledge, there have been no studies that have investigated the epidemiology of reinjury for different types of climbing behaviour.

Previously we published the findings of a retrospective cross-sectional study that investigated the nature, prevalence and predictors of climbing injuries in a diverse group of active rock climbers. We found that 101 of 201 (50%) rock climbers sustained at least one injury in a 12-month period. The cause of these injuries were repetitive overuse (67 of 201 (33%)), acute trauma from undertaking a strenuous climbing move (57 of 201 (28%)) and falls (21 of 201 (10%)). We concluded that climbing frequency and technical difficulty were associated with climbing injuries, particularly to the upper limb, occurring at both indoor and outdoor climbing venues.

We did not conduct analysis of reinjury in the original study as the specific aim was to investigate the relationship between climbing behaviour and injury mechanism, that is, fall, strenuous move, repetitive overuse. The study by Woollings *et al* has highlighted the need to consider previous injury as a risk factor for reinjury in rock climbing and the need to account for the complexities of individual climbing behaviour. A greater understanding of these factors may contribute to reduce, control or eliminate reinjury occurrence and the development of appropriate rehabilitation strategies.

The original study is representative of British rock climbers across a range of climbing behaviours and standards in performance. The data capture tool used (Climbing Inventory Questionnaire) gathered data on injury occurrence, site of injury and mechanism of injury enabling calculation and analysis of previous injury, reinjury and multiple reinjury of the same anatomical site via the same mechanism. Thus, study data are ideal for secondary analysis. The aim of this article is to report the findings of a secondary analysis of previous injury as a risk factor for reinjury in rock climbing.

METHODS

Study design

We completed a secondary analysis of 201 questionnaires that were gathered as part of our retrospective cross-sectional cohort survey that investigated the epidemiology of injuries in a representative sample of British rock climbers. The original study gathered data on demographics, operational measures of climbing behaviour and injury.

Participants

Participants had actively engaged in rock climbing over the previous 12-month period and were recruited from six indoor climbing centres and five outdoor climbing venues in Britain (men $n=163$, mean \pm SD, age=35.2 \pm 11.8 years, participating in rock climbing=13.88 \pm 11.77 years; women $n=38$, mean \pm SD, age=35.1

\pm 10.7 years, participating in rock climbing=11.62 \pm 9.19 years). The 163 male climbers and 38 female climbers did not differ significantly in age ($t=0.05$, $p=0.964$) or in the number of years of climbing experience ($t=1.09$, $p=0.275$). Participants completed a Climbing Injury Questionnaire developed by the authors that gathered information about the prevalence and nature of climbing injuries that had occurred in the past 12 months including site, frequency and cause of the injury and whether medical attention or withdrawal from participation was necessary.

Participants also completed the Background Climbing Questionnaire developed by the authors to gather information about the type, frequency and performance level of climbing behaviour which were used as proxy measures of exposure and ability. Data analysis examined associations between potential risk factors and climbing injuries while controlling for the influence of key demographic variables. The reader is referred to the Methods section in Jones *et al* for a full description.

Data processing procedure

Data were used in its original format without the collection of any additional raw data. Previous injury was categorised as those resulting from a fall, those resulting from repetitive overuse and those resulting from a strenuous move. Participants were dichotomised as reinjured or not reinjured through reanalysis of individual responses to questions relating to the cause and site of injury. Those individuals who reported an injury at the same anatomical site precipitated by the same cause on at least two occasions within the 12-month reporting period were categorised as reinjured. Multiple reinjury was defined as those individuals who reported an injury at the same anatomical site precipitated by the same cause on at least three occasions or greater within the 12-month reporting period. Epidemiological incidence proportion (IP) provides an average measure of injury risk for the 12-month reporting period. Clinical incidence provides a useful measure of incidence in terms of clinical resource utilisation.

Reinjury was considered as the dependant variable and climbing behaviour in terms of frequency and grade as the independent variables. Variables for correlational analysis were treated as continuous data, including gender, which was considered a 'dummy variable'. Prior to analysis, variables were examined for accuracy of data entry, missing values, and fit between their distributions and the assumptions of parametric analysis. Three variables whose departure from normality was severe (number of reinjuries as a result of (1) a fall, (2) repetitive overuse and (3) strenuous climbing moves) were dichotomised in order to reduce levels of skewness.⁷

All data analysis was performed using SPSS V.21.12.0.1 statistical software (SPSS Inc, Chicago, Illinois, USA). The epidemiological IP and clinical incidence were calculated with 95% CIs. Correlational analysis was performed using one-tailed Pearson's r test to analyse the

strength of the relationship between reinjury and climbing behaviour as a positive directional hypotheses had been proposed.⁷ McNemar's χ^2 test with Yates correction was utilised to calculate the association probability between previous injury and reinjury.

RESULTS

Of the 201 participants who completed the original survey, 101 sustained at least one injury from climbing in the past 12 months. Of these 101 participants, 36 sustained at least one reinjury. The total number of reinjuries in these 36 participants was 82, with a clinical incidence of 1.78 reinjuries per climber. The epidemiological IP for reinjury was 0.356 (95% CI 0.347 to 0.368). Thus, the average probability of sustaining at least one reinjury as a result of climbing was 35.6% (95% CI 34.71% to 36.8%).

Three participants sustained at least one reinjury as a result of a fall; 29 participants sustained at least one reinjury as a result of repetitive overuse and 14 participants sustained at least one reinjury as the result of a strenuous climbing move. The IP for reinjury for falls was 0.065 (95% CI -0.006 to 0.136); the IP for reinjury for repetitive overuse was 0.630 (95% CI 0.49 to 0.77); the IP for reinjury for a strenuous move was 0.304 (95% CI 0.171 to 0.437). Thus, the average probability of sustaining at least one reinjury as a result of a fall was 6.5% (95% CI -0.6% to 13.6%); the average probability of sustaining at least one reinjury as a result of repetitive overuse was 63.0% (95% CI 49.0% to 77.0%) and the average probability of sustaining at least one injury as a result of strenuous overuse was 30.4% (95% CI 17.1% to 43.7%).

Participants who had sustained a previous injury were more likely to sustain a reinjury ($p < 0.001$, McNemar's χ^2 test) with the relative risk of reinjury being 1.55 (95% CI 1.34 to 1.80).

The main findings in relation to figure 1 show the fingers were the most common site of reinjury as a result of repetitive overuse (12 participants, 26%) and a strenuous move (8 participants, 17%).

There was a significant difference between the observed and expected frequencies of the site of reinjury including multiple reinjuries. There were 31 reinjuries including multiple reinjuries to the fingers ($\chi^2 = 43.12$, $df = 5$, $p < 0.001$).

Table 1 shows the correlation coefficients between climbing reinjury and climbing behaviours. Age and number of years climbing were negatively associated with reinjury as a result of a strenuous move (table 1). Reinjury as a result of a fall was significantly associated with (1) solo grade; (2) outdoor sport lead frequency; (3) outdoor sport lead grade; (4) indoor sport lead grade. Reinjury as a result of repetitive overuse was significantly associated with (1) solo grade; (2) outdoor sport lead grade; (3) indoor sport lead grade; (4) bouldering frequency; (5) bouldering grade. Reinjury as a

result of a strenuous move was significantly associated with (1) outdoor sport lead grade; (2) bouldering grade. Although the magnitude of the associations were small, they were statistically significant.

DISCUSSION

This secondary analysis represents the first attempt to assess previous injury as a risk factor for reinjury in adult rock climbers in the UK. Previous climbing injury studies have exclusively recruited participants at indoor climbing facilities,⁸ climbing events³ and through postal questionnaires.⁹ The participants within our secondary analysis were recruited in their naturalistic environment at a variety of indoor and outdoor climbing venues in the North of England and Scotland. Thus, we believe that our results can be generalised to the wider climbing population.

Reinjury

Reinjury was a common occurrence with 36 of 101 participants experiencing at least one reinjury with the average probability of sustaining at least one reinjury being 35.6% (95% CI 34.71% to 36.8%). Injury incidence rates are often expressed in sports such as football and rugby in the number of injuries per 1000 h of exposure. Incidence rates in climbing studies have been reported using a modified version of this method,⁸ but in doing so this may misrepresent the statistic as calculations do not accurately account for time spent not actively climbing. Climbers spend substantial periods of time mentally preparing for routes, warming up on easier climbs, involved in climbing-related activities such as belaying or surveying routes as well as resting between attempts. We suggest that frequency counts of routes ascended and the performance level attained in terms of grade may be more informative, as they allow researchers to consider both exposure and loading of anatomical structures.

Clinical incidence is a statistic that provides information useful for estimating resource costs for healthcare providers. We found the clinical incidence of reinjury to be 1.78 per climber with a relative risk of sustaining a reinjury following a previous injury of 1.55. We were unable to compare either the clinical incidence or the relative risk of reinjury with other climbing studies due to paucity of literature within this subject area.

The average probability of sustaining a reinjury through repetitive overuse was high, 63.0% (95% CI 49.0% to 77.0%). Reinjuries sustained through repetitive overuse accounted for 80.5% of the total reinjuries reported and was positively associated with solo grade, bouldering grade, outdoor sport lead grade and indoor sport lead grade. Individuals who performed a high standard were more likely to sustain a repetitive overuse reinjury, and we suspect that this was due to subclinical intratendinous changes leading to the development of a degenerative tendinopathy. Although associations were

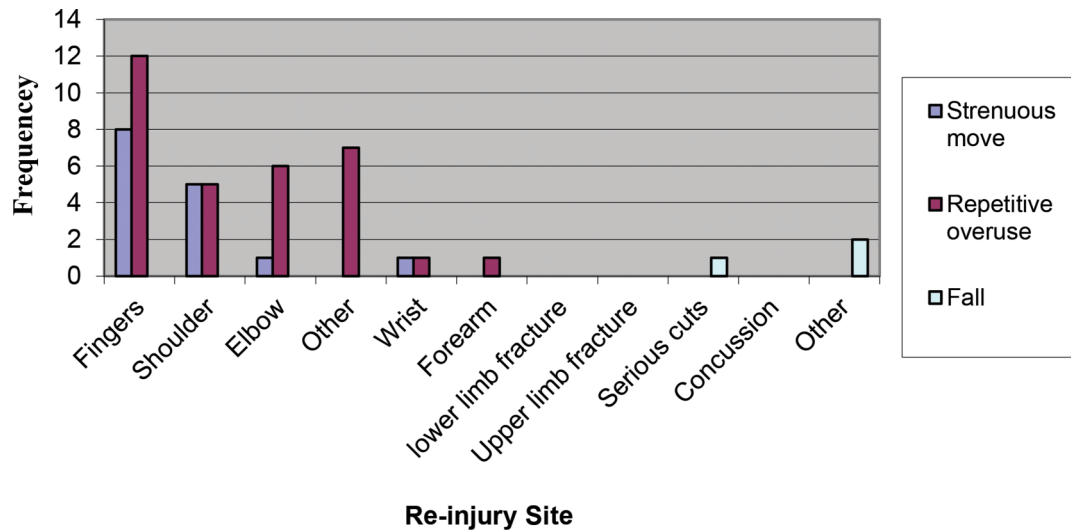


Figure 1 Frequency and location of fall, strenuous move and repetitive overuse.

found between repetitive overuse injuries and individual climbing behaviours, many climbers within our sample operated across several types of climbing behaviour. Repetitive overuse injuries are multifactorial in their aetiology, and it may be that exposing oneself to a particular set of climbing behaviours elevates individual risk. Therefore, we suggest that higher frequencies of

climbing may not be so likely to occasion a repetitive overuse reinjury in participants who perform at relatively moderate levels of intensity.

The popularity of bouldering has increased markedly over the last decade and together with indoor sport climbing represents the competitive elements of the activity. Both bouldering frequency and bouldering

Table 1 Correlation coefficients between climbing reinjury and climbing behaviours

	Reinjury fall	Reinjury strenuous move	Reinjury repetitive overuse
Solo grade			
Pearson correlation	0.246*	0.022	0.147†
Significance (1-tailed)	0.002	0.403	0.048
N	130	130	130
Out sport lead frequency			
Pearson correlation	0.140†	-0.034	-0.008
Significance (1-tailed)	0.024	0.318	0.458
N	201	201	201
Out sport lead grade			
Pearson correlation	0.219*	0.188†	0.159†
Significance (1-tailed)	0.009	0.022	0.045
N	115	115	115
Indoor sport lead grade			
Pearson correlation	0.138†	0.087	0.165†
Significance (1-tailed)	0.031	0.122	0.013
N	183	183	183
Bouldering frequency			
Pearson correlation	-0.017	0.077	0.175*
Significance (1-tailed)	0.406	0.139	0.007
N	201	201	201
Bouldering grade			
Pearson correlation	0.081	0.189*	0.231*
Significance (1-tailed)	0.156	0.009	0.002
N	158	158	158

*Correlation is significant at the 0.01 level (1-tailed).

†Correlation is significant at the 0.05 level (1-tailed).

grade were positively associated with repetitive overuse reinjuries. This may be attributed to large volumes of bouldering activity, limited recovery between bouts of activity and that performance is often at the limit of individual's physical and technical ability. In contrast, no association was found for traditional climbing. Traditional climbing utilises holds of varying types on differing angles of climbing surface with climbers generally operating at a lower technical standard as compared with their individual sport climbing or bouldering grade. Therefore, the strain and load on musculoskeletal structures may be more varied and reduce the development of repetitive overuse syndromes.

The number of reinjuries as a result of a fall was positively associated with both outdoor and indoor sport grade. High-grade sport routes are often steep and overhanging in nature. Climbers may incur injury due to contact with the climbing surface during or following a fall. During a fall, the force transmission to the climbers' body can vary greatly and is largely dependent on the relative length of the fall as compared with the amount of rope paid out, termed fall factor.¹⁰ However, the number of participants who sustained a reinjury as a result of a fall was low.

Site of injury

The fingers were the most common site of reinjury. The risk of recurrent and excessive loading of the fingers and their limitations as weight-bearing structures has been established.^{2 9 11 12} All climbing behaviours place high load demands on the fingers and their associated structures. Climbers often use the 'crimp' hand position during an ascent to grip the climbing surface. In this position, the wrist is extended to improve the mechanical advantage of the finger flexors, but in doing so paradoxically increases injury risk.¹³ Research evidence links the high load forces generated during the crimp grip position to discreet injuries of the annular pulley system within the fingers, particularly the A2.¹⁴ Damage to the annular pulley system is considered to be a climbing-specific injury, and functional deficit with regard to climbing performance may depend greatly on the extent of damage sustained, but remains inconclusive. A progressive warm up incorporating progressive loading in the crimp grip hand position has been suggested to prepare the tendons and pulleys of the fingers for the maximal forces to which they may be exposed.¹⁵

Study limitations

Further investigation is required to confirm the incidence, and patterning of reinjuries in climbing populations is warranted. It is important to recognise some methodological limitations when assessing these findings. Although the secondary analysis provides new information regarding climbing behaviour and previous injury as a risk factor for reinjury, the cross-sectional and correlational basis of the original study negates causal inferences. The original study also excluded those individuals

who were no longer actively engaged in climbing activity which may have been due to injury. This may bias the IP and clinical incidence rate for reinjury rate towards a lower reported value than is actually representative.

Summary

Climbing continues to be a popular sporting activity, and as participation figures increase, so does the likelihood that a high proportion of climbers may sustain a repetitive overuse reinjury of the upper extremity. Previous injury was a significant risk factor for reinjury, particularly of the fingers. Future research adopting a prospective design would shed further light on the potential effects of high level climbing performance and subsequent reinjury occurrence. Education of medical and climbing populations is paramount, so that these findings may be of consideration when planning rehabilitative and preventative strategies.

Contributors GJ was involved in writing of the manuscript, data analysis and submission. DL was involved in review of the manuscript. MJJ is the manuscript editor.

Competing interests None declared.

Ethics approval Leeds Beckett University Ethics Committee.

Provenance and peer review Not commissioned; internally peer reviewed.

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