Rock Climbing Injuries Treated in US Emergency Departments 2008-2016

Running Head: Rock Climbing Injuries

Peter Buzzacott MPH, PhD,[1,2*] Isabelle Schöffl MD, PhD, MSc,[3] James Chimiak MD,[1] Volker Schöffl MD, MHBA [4,5,6]

[1] Divers Alert Network, Durham, North Carolina, USA.

[2] School of Sports Science Exercise and Health, University of Western Australia, Crawley, Western Australia, Australia.

[3] Department of Pediatrics, Klinikum Bamberg, Bamberg, Germany.

[4] Department of Orthopedic and Trauma Surgery, Klinikum Bamberg, Bamberg, Germany.

[5] Department of Emergency Medicine, Section of Wilderness Medicine, University of Colorado School of Medicine, Aurora, Colorado, USA.

[6] Department of Trauma Surgery, Friedrich Alexander University Erlangen-Nuremberg, Erlangen, Germany.

*Corresponding author

Peter Buzzacott, MPH, PhD.

School of Sports Science Exercise and Health, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia.

Ph: +61 (423)-989-846

E-mail: peter.buzzacott@uwa.edu.au

Abstract word count 249 words; Manuscript word count including references 4,336;

50 References; 4 Tables; 1 Figure.

Rock Climbing Injuries Treated in US Emergency Departments 2008-2016

Abstract

Introduction: Previous research identified a trend for increasing numbers of injuries sustained while rock climbing. This study investigates if that trend continued, and describes characteristics of climbing injuries. **Methods:** The National Electronic Injury Surveillance System registry was searched for rock climbing injuries in US emergency departments (ED) 2008-2016, among patients aged ≥7 y. Variables included each patient's age, diagnosis, injured body part, mechanism of injury and disposition. Injuries were graded using International Mountaineering and Climbing Federation injury grades. National estimates were generated using sample weighting. **Results:** There were an estimated 34,785 rock climbing injuries seen in ED nationally, a mean of 3,816 per year (SD 854). Median age of injured climbers was 24 y (range 7-77), with those aged 20-39 accounting for 60%, and males for 66 %, respectively. Fractures (27%), then sprains and strains (26%) were the most common types of injuries. The most frequently injured body parts were lower extremities (47%), followed by upper extremities (25%). The most commonly fractured body part (27%) was the ankle. The knee and lower leg accounted for 42% of all lacerations and were 5.8 times as likely as lacerations to other body parts. Falls were the most common mechanism, accounting for 60% of all injuries. **Conclusions:** This study reports continued increase in annual numbers of climbing injuries. Whether this is based on a higher injury rate or on a higher number of climbers overall cannot be stated with certainty as no denominator is presented to estimate the injury rate among climbers.

Keywords: Trauma severity indices, accidental falls, fracture dislocation, lacerations

Introduction

Rock climbing, and especially indoor climbing, is an increasingly popular sport world-wide.[1] With climbing's inclusion into the Olympic program for Tokyo in 2020 this trend will likely continue.[2] With the increased popularity of competitive sport climbing, an increase in injury rate and severity may be expected.[3] While the sport of rock climbing originated from mountain climbing, it was developed into a sport in itself within the 1980s and early 1990s, based on the free climbing scene in Yosemite Valley. A parallel development occurred in the Elbsandstein, in former East Germany.[4, 5] An analysis of the separate disciplines of climbing shows that overall, alpine (traditional) climbing has higher injury risk than sport and indoor climbing.[6-10] Alpine and ice climbing have more objective dangers that affect climber safety.[5] In alpine climbing, injuries mostly occur through falls and affect the lower extremity.[1, 5, 11, 12] Most injuries in sport climbing are overstrain injuries of the upper extremity while performing a strenuous move.[5, 11, 12] In bouldering many injuries are related to the foot and ankle, resulting from falls.[3] Objective reporting of injury site and severity vary between studies according to injury definition and methodology used.[5, 12] This creates differences in injury/fatality metrics and conclusions which, in turn, make inter-study comparisons difficult.[5, 13] To minimize these differences, in 2011 the International Mountaineering and Climbing Federation (UIAA) Medical Commission developed an injury grading system which was proposed to be used in future climbing studies.[13] The six UIAA grades of injury severity are shown in Table 1.

Modern belay and safety equipment evolved and studies in the 1990s on rock climbing injuries showed a higher injury rate and severity than more recent analyses[5, 11, 14-16] With improved belay and safety equipment, injury rates may be expected to decline, while on the other hand new techniques and dynamics (e.g. high indoor climbing walls) may increase injury rates.[2, 3] Thus, regular re-evaluation of injuries associated with climbing is necessary. This may be through studies of climbing populations,[7, 12, 17-24] patients in certain centers which focus on climbing injuries,[25, 26] injuries at certain climbing walls over time,[8] competition,[10, 27] a competition circle,[21] web based questionnaire,[17] or analysis of national data banks.[1] National datasets, in particular, offer the chance for longitudinal research.

Nelson et al.[1] evaluated the National Electronic Injury Surveillance System (NEISS) registry for rock climbing injuries treated in US emergency departments (ED) in the years 1990 to 2007. Within this period there was a rise in annual ED presentations for rock climbing injuries, from an estimated 1617 cases in 1990 to an estimated 2,637 cases in 2007.[1] Following the same criteria as Nelson et al.,[1] this study aimed both to establish if growth in rock climbing injuries continued after 2007, and if the demographic/distribution of the injuries differed between the previous study and 2008-2016. In addition, injuries were graded with the UIAA score,[13] to enable comparison with other studies presenting or reviewing injury severity.[5, 11, 28]

Methods

The Consumer Product Safety Commission (CPSC) maintain the NEISS, a national register of ED presentations collected from around 100 hospitals in US and US Territories. Probability weighting enables the sample to extrapolate national estimates for the ~5000 EDs in the wider US and US territories. In essence, the NEISS sampling frame consists of five strata; four according to hospital size and the fifth being children’s hospitals. Hospital weightings are initially equal to the inverse of the probability of selection at the stratum level, which are then adjusted for non-response or hospital mergers. The total number of ED visits each year is used to generate a ratio adjustment to the weighting of each hospital, based on the anticipated number of hospital visits for the NEISS sample of hospitals. In this way the weightings are adjusted each year to match the actual number of ED visits to hospitals in the NEISS sampling frame, which are a known quantity suitable for calibrating the weights.[29] Whenever a hospital is removed from the sampling frame the highest ranked hospital within the same stratum is invited to replace the departing hospital. Since weights are recalibrated each year, longitudinal analyses of national estimates are possible even with a dynamic sampling frame and, each year, the previous year's de-identified data are made available through the CPSC website.

NEISS data for 2008-2016 were imported into Windows Notebook as tab-delineated text. Product code 1258 identifies injuries related to "climbing gear/equipment" in the NEISS dataset.[1] Initially 1,089 cases were identified as involving product code 1258. Each case narrative was read and cases involving children aged six y or less (n=27) were excluded, as were cases not involving rock climbing (n=178), such as injuries from ice climbing, mountaineering or other activities not associated with rock climbing. The remaining dataset included 884 presentations to US ED for rock climbing injuries in persons aged 7 y or older. A human research ethics application was submitted to the institutional review board of the Divers Alert Network but this analysis of publicly available de-identified data was ruled exempt from requiring approval.

Variables

As with the Nelson study,[1] data regarding each patient's age, diagnosis, injured body part and disposition were classified into categorical variables. Three age groups were formed: 7-19 y, 20-39 y and ≥40 y. Diagnoses were classed as soft tissue (including abrasions, contusions, hematomas and crush injuries), lacerations (including punctures and avulsions), sprains and/or strains, dislocations, fractures and amputations, concussions and other. All injuries were graded using the UIAA score for injury severity.[13] Injured body parts were classed as involving the head (including the neck, face, ears, eyes and mouth), torso (including the upper and lower trunk, hips and pubic region), upper extremities (including the shoulders, arms, hands and fingers), lower extremities (including the legs, ankles, feet and toes) or other (including injury codes for other, internal injuries, 25-50% of the body and all parts of the body). Disposition was classed as not hospitalized (left without being seen, treated and released, or held for observation for <24 h) or hospitalized (admitted or transferred to another hospital). Each case narrative was read and, where noted, fall height was classed as ≤6m (20ft), or >6m (20ft). The mechanism of injury was classed as an overexertion (e.g. felt pain while performing a move), struck by an object, a hit or strike, a fall, or other.

Analysis

Data were imported into SAS version 9.4 (SAS, Cary, NC) for analysis. With the exception of the total number of NEISS cases, reported data represent national estimates and all statistical tests were performed on national estimates. The dataset met CPSC criteria for reliability, I.E. >20 actual cases in any one cell, >1,200 estimated cases nationally and a coefficient of variation <0.3.[30] Parametric bootstrapping was performed to estimate the mean number of rock climbing injuries seen nationally each year in US EDs, with a 95% confidence interval and standard deviation. Linear regression was performed to assess any trend in the annual estimated number of injuries. Variables of interest were compared between binary variables using chi-square tests with Cochran-Mantel-Haenszal odds ratios and 95% confidence intervals. No tests for significant differences were performed in this study however the number of odds ratios presented requires that readers exercise caution when interpreting 95% confidence intervals that approach zero at either limit.

Results

Between 2008 and 2016 there were 3,441,545 ED presentations recorded, representing a national estimate of 127,206,510 injuries. Of these, 884 (0.03%) were attributed to rock climbing, representing 34,785 nationally (0.03%), a mean of 3,816 per year (95% CI 2,107, 5,525, SD 854). The estimated annual number of cases are presented in Figure 1, with linear trendline. The gradient of the trend for the increasing number of cases per year is given in Equation 1, where year = the number of years after 2007 and n = the national estimate of cases.

$$n = 2541 + 265(year) \tag{1}$$

The median age of the injured climbers was 24 y (range 7-77), with those aged 20-39 accounting for 60% of the ED presentations. Males accounted for two thirds of injured climbers (Table 2).

Injury Diagnosis and Injured Body Part

Fractures, then sprains and strains were the two most common types of injuries, at 27% and 26% respectively, followed by soft tissue injuries, lacerations, and dislocations (Table 2). Other injuries (21%) made up the remainder. The most frequently injured body parts were lower extremities (47%), and upper extremities (25%), followed by the torso and the head (Table 2). Of the fractures, the most commonly injured body part (27%) was the ankle (n=2,533, OR=1.48, 95% CI 1.40, 1.56). The ankle also accounted for 48% of the sprains and strains (n=4,435, OR=9.98, 95% CI 6.60, 7.38). The knee and lower leg accounted for 42% of all lacerations (n=1,583) and were 5.8 times as likely as lacerations to other parts of the body (95% CI 5.4, 6.2). The shoulder accounted for 27% of all upper extremity injuries (n=2,400), the elbow 16% (n=1,425), and wrist 15% (n=1,276). Among lower extremity injuries, the ankle was again the most commonly injured (n=7,527, 46%), followed by the foot (n=3,135, 19%), and lower leg (n=2,978, 18%). Table 2 presents injured body parts and diagnosis by age group.

Mechanism of Injury and Fall Height

Falls accounted for 60% of all rock climbing injuries, followed by hitting or striking, overexertion and being hit or struck by an object. Compared with other causes of injury, the odds of falling as the cause decreased with age (Table 3). Of the 20,802 falls, 8,262 (40%) resulted in a fracture (OR 6.8, 95% 6.4, 7.3), and 4,930 (24%) resulted in a sprain or strain. Among climbers who did not suffer a fracture, the risk of a sprain or strain was 1.3 times as likely as suffering another type of injury (95% CI 1.3, 1.4). Climbers injured by hitting or striking (n=1,800, 26%) were 4.7 times as likely to suffer a laceration as another type of injury (95% CI 4.4, 5.0). Among injuries resulting from overexertion, sprains and strains were the most common consequence (n=2,467, 48%, OR 3.2, 95% CI 3.0, 3.4).

Fall height was identified from case narratives in 10,140 cases, (29%). Among those, falling from a height >6m (20ft) (n=2,711, 27%) increased the odds of a fracture by a factor of 2.5 (95%

CI 2.3, 2.8). Falling from a height ≤6m (20ft) (n=7,428, 73%) increased the odds of a sprain or strain by a ratio of 3.9 (95% CI 3.3, 4.5). Fractures (21%) were 8.3 times as likely as other types of injuries to result in hospitalization (n=2,040, 95% CI 7.6, 9.0). There were also an estimated 1,418 lower leg injuries that resulted in hospitalization, which were 1.1 times as likely to result in hospitalization as other injuries (95% CI 1.0, 1.2).

Injury grading

There were <1,200 estimated cases with a UIAA grading of 1, 30,922 with grade 2, 3,485 with grade 3 and <1,200 with grade 4. Therefore, only grades 2 and 3 were further investigated (Table 4). Compared with other grades of injury, grade 2 injuries were 1.4 times (95% CI 1.2, 1.5) as likely to involve the ankle as the injured body part and grade 3 injuries were 5.5 times (95% CI 5.0, 6.1) as likely to result from falling.

Disposition

An estimated 2,851 patients (8%) were hospitalized. Of the 1,953 of those for whom the fall height was determinable from the case notes, 50% fell 6m (20ft) or less and 50% fell >6m (20ft). Among those hospitalized, the odds of the injured being male were 1.6 times that of being female (95% CI 1.5, 1.7).

Discussion

Our study is a follow up analysis of NEISS data to be compared with a prior analysis of these data from 1990–2007.[1] Since 2007 there has been an accumulation of an additional 265 cases per year (Eq. 1), almost doubling the number seen in ED over the study period from around 2,500 to nearly 5,000. This may be due to the ever increasing popularity in climbing overall,[3, 31] or to an increase in relative difficulty, or to some combination of both. This trend will likely continue with the inclusion of climbing into the Olympic program for Tokyo 2020.[2] It must be noted that the Nelson study included children under 7 years of age, while we considered these as "playground injuries" since children so young are not considered sport climbers.[28] The mean age in the Nelson study was 26 y and, while the distribution of age was not normal in our sample, the mean age in this study was 26.7 y (SD 76.1).

From 1990–2007 the lower extremities were the most frequently injured body parts, accounting for 46% of all injuries; ankle injuries accounted for 19%.[1] In our follow up analysis a similar 47% of all injuries also involved the lower extremity. The ankle was also leading in numbers of fractures and sprains, as well as in UIAA grade 3 injuries. Falls accounted for 60% of all rock climbing injuries, followed by hitting or striking an object and overexertion (15%). In the prior study, falls were the mechanism of injury in more than three quarters of all rock climbing injuries (77.5%) and overexertion was the cause in only 3.1%.[1]

The proportion of injuries caused by hitting or striking an object increased from about 7% in the prior study,[1] to about 20% nowadays. Classifying case narratives can be relatively subjective, e.g. when "hitting or striking an object" is implied but not explicitly stated. Falling and hitting the wall through the pull of the rope, which produces a so called "rock hit" trauma [32], is technically both, a fall and collision with an object. Thus, any difference in studies may be, at least in part, due to different injury mechanism classifications.

In the present analysis, we classified injuries in accordance with the UIAA grades (Table 1).[13] Given these data were from US ED, UIAA grade 1 injuries were almost not found in the data. Other studies even exclude grade 1 injuries completely from the injury analysis,[5, 8, 24] as they mostly receive self-therapy. Grade 2 injuries were the most common and, by definition, were 106 times as likely to involve sprains or strains than other UIAA grade injuries. Similarly, compared with other UIAA grade injuries, UIAA grade 3 injuries were 12 times as likely to involve fractures. The ankle was more likely injured among grade 2 injuries than among other grades, and the mechanism was nearly four times as likely due to a hit or strike than in other UIAA grade injuries. In UIAA grade 3 injuries the mechanism was 5.5 times as likely the result of a fall than in other UIAA grade injuries, meaning that falls resulted in more serious injuries. Grade 4 injuries were rare, and grade 5 and 6 not reported (as grade 6 injuries are defined as immediate death they could not enter this study).[13] Also grade 5 injuries, which are defined as: "Acute mortal danger, polytrauma, immediate prehospital doctor or experienced trauma paramedic attendance if possible, acute surgical intervention, outcome: death",[13] were not detected in this analysis as there were no such outcomes reported. In a recent analysis of data from the National Emergency Department Sample it was reported that less than 1% of climbing-related ED visits resulted in death.[33]

In comparison with other analyses of climbing injuries,[5, 8-12, 15, 17-19, 21-25, 27, 34-42] the NEISS data unfortunately do not give any information about the specific type of rock climbing being performed during the act of getting injured. It is well known in the climbing literature that various types of climbing, e.g. alpine or traditional climbing, versus indoor climbing and bouldering result in different injury incidence rates, severity, grading and injury types.[5, 28] Also, they present with different injury causes. While in traditional and alpine climbing the most frequent injury cause is a fall, and the injury is based on the lower extremity, in sport climbing the most frequent cause is performing a strenuous move and the injury is to an upper extremity.[5, 11] Concerning sex distribution, studies in general show no influence of sex.[5, 12, 22, 43] Our present study showed 66% were male, but no information about sex distribution among the US climbing population is known, thus these numbers may just represent the distribution among climbers. Nelson et al.[1] report a mean age for rock climbing injuries of 26 y (95% CI 25-27) and Schöffl et al.[44] of 28 y (13-52), which is similar to our findings. Concerning the injury location, so far most research indicates the upper extremity to be the most injured body regions in non-alpine rock-climbing.[35, 38, 39, 43-47] Schöffl et al.[48] reported 247 of 604 (41%) climbing injuries (sport climbing, indoor climbing) treated in a climbing injury specialised unit involved the hand, a finding which was reproduced in a more recent analysis,[25] although that clinic specializes in the diagnoses of hand and finger injuries.[49] Two studies that analysed climbing injuries treated in American hospitals or ED reported most climbing injuries involved the lower extremities and resulted from big swings into a wall or big falls.[1, 15] In another recent study on rock climbing injuries, trauma involved the lower extremities (foot, toe and ankle) in 50% of injuries, while upper extremities accounted for 36% of the injuries.[46] Neuron et al.[43] found an even injury distribution between the upper (43%) and lower extremities (41%) for sport climbing injuries.

Chief among the limitations of this study are that national estimates may not accurately reflect the true occurrence of rock climbing injuries. While climbing gyms may be founded in any location, the geographical distribution of natural cliffs may not match the distribution of hospitals in the NEISS sample. Even so, since the weightings are adjusted annually to allow time series analyses, the main finding still stands that climbing injuries are on the rise and have been since the Nelson study, which used the same sampling frame. Another limitation is that it is likely not all rock climbing injuries present at an ED and many are likely treated by other facilities, e.g. at urgent care facilities. Fatalities are also not routinely recorded in NEISS, because, post mortem, they are often not taken to an ED. Therefore, the true burden of rock climbing injuries is likely greater than reported in this study. It should also be acknowledged that without reliable participation denominators such as the number of climbers in each year, or the number of hours spent climbing, the incidence rate of rock climbing injuries cannot be estimated. Such estimates were beyond the scope of this study. In addition, because NEISS data are de-identified multiple presentations cannot be accounted for when describing injured climbers.

Conclusion

Our present analysis of US ED patients treated due to rock climbing injuries confirms a continued increase in overall numbers of climbing injuries, as predicted in a prior analysis.[1] Whether this is based on a higher injury rate or on a higher number of climbers overall cannot be answered by this study. Late reports are finding an increasing number of climbers and increasing severity of rock climbing injuries, based on the so called “newbie” syndrome (non-sportive beginners climbing, falling and getting injured because of a lack of overall muscular status and coordination) and increased dynamic movements with greater heights in “new age” commercial bouldering gyms.[3, 50] Only time will tell if this trend will continue, given climbing’s addition as an Olympic sport.[51]

Author contributions

PB, IS, JC and VS conceived and designed the study as a team.

PB collected the data from the CPSC and analyzed the data.

PB, IS, JC and VS interpreted the results of the analysis, wrote and/or revised the manuscript and approved the final submission.

Financial material support

None.

Disclosures

No financial disclosures were reported by the authors of this paper.

References

1. Nelson NG, McKenzie LB. Rock climbing injuries treated in emergency departments in the US, 1990-2007. Am J Prev Med. 2009;37(3):195-200.

2. Lutter C, El-Sheikh Y, Schöffl I, Schöffl V. Sport climbing: medical considerations for this new Olympic discipline. Br J Sports Med. 2017;51(1):2-3.

3. Schöffl V, Lutter C. The "Newbie" syndrome. Wilderness Environ Med. 2017;28(4):377-80.

4. Schöffl V, Hochholzer T, Lightner S. One move too many. Boulder CO, USA: Sharp End Publishing; 2016.

5. Schöffl V, Morrison A, Schöffl I, Küpper T. Epidemiology of injury in mountainering, rock and iceclimbing. In: Caine D, Heggie T, (eds). Medicine and Sport Science - Epidemiology of Injury in Adventure and Extreme Sports. Karger; 2012:17-43.

6. Addiss DG, Baker SP. Mountaineering and rock-climbing injuries in US national parks. Ann Emerg Med. 1989;18(9):975-9.

7. Bowie WS, Hunt TK, Allen HA, Jr. Rock-climbing injuries in Yosemite National Park. West J Med. 1988;149(2):172-7.

8. Schussmann LC, Lutz LJ, Shaw RR, Bohnn CR. The epidemiology of mountaineering and rock climbing accidents. Wilderness Environ Med. 1990;1(4):235-48.

9. Schöffl V, Morrison AB, Schwarz U, Schöffl I, Küpper T. Evaluation of injury and fatality risk in rock and ice climbing. Sport Med. 2010;40(8):657-79.

10. Watts PB, Joubert LM, Lish AK, Mast JD, Wilkins B. Anthropometry of young competitive sport rock climbers. Br J Sports Med. 2003;37(5):420-4.

11. Backe S, Ericson L, Janson S, Timpka T. Rock climbing injury rates and associated risk factors in a general climbing population. Scand J Med Sci Sports. 2009;19(6):850-6.

12. Schöffl VR, Hoffmann G, Kupper T. Acute injury risk and severity in indoor climbing-a prospective analysis of 515,337 indoor climbing wall visits in 5 years. Wilderness Environ Med. 2013;24(3):187-94.

13. Schöffl V, Winkelmann HP. [Accident statistics at "indoor climbing walls"] Unfallstatistik an indoor-kletteranlagen". Sportverletz Sportschaden. 1999;13(1):14-6.

14. Schöffl V, Küpper T. Injuries at the 2005 world championships in rock climbing. Wilderness Environ Med. 2006.17(3):187-90.

15. Jones G, Johnson M. A critical review of the incidence and risk factors for finger injuries in rock climbing. Curr Sports Med Rep. 2016;15(6):400-9.

16. Schöffl V, Morrison AB, Hefti U, Ullrich S, Küpper T. The UIAA Medical Commission injury classification for mountaineering and climbing sports. Wilderness Environ Med. 2011;22(1):46-51.

17. McDonald JW, Henrie AM, Teramoto M, Medina E, Willick SE. Descriptiveepidemiology, medical evaluation, and outcomes of rock climbing injuries. Wilderness Environ Med. 2017;28(3):185-96.

18. Chang CY, Torriani M, Huang AJ. Rock climbing injuries: acute and chronic repetitive trauma. Curr Probl Diagn Radiol. 2016;45(3):205-14.

19. Woollings KY, McKay CD, Kang J, Meeuwisse WH, Emery CA. Incidence, mechanism and risk factors for injury in youth rock climbers. Br J Sports Med. 2015;49(1):44-50.

20. 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;1(1):bmjsem-2015-000031.

21. Schöffl V, Burtscher E, Coscia F. Injuries and medical incidences during the IFSC 2012 Climbing World Cup Series. Med Sport. 2013;17(4):168-70.

22. Josephsen G, Shinneman S, Tamayo-Sarver J, Josephsen K, Boulware D, Hunt M, et al. Injuries in bouldering: a prospective study. Wilderness Environ Med. 2007;18(4):271-80

23. Jones G, Asghar A, Llewellyn DJ. The epidemiology of rock climbing injuries. Br J Sports Med. 2008;42(9):773-8.

24. Neuhof A, Hennig FF, Schöffl I, Schöffl V. Injury risk evaluation in sport climbing. Int J Sports Med. 2011;32(10):794-800.

25. Schöffl V, Popp D, Küpper T, Schöffl I. Injury trends in rock climbers: evaluation of a case series of 911 injuries between 2009-2012. Wilderness Environ Med. 2015;26(1):62-7.

26. Schöffl V, Hochholzer T, Winkelmann HP, Roloff I, Strecker W. [Pulley injuries in sport climbers] Verletzungen des Ringbandapparates bei Sportkletterern. Handchir Mikrochir Plast Chir. 2004;36(4):224-30.

27. Hosaini SA, Atri AE, Kavosi A. Injuries at the Iranian championship in indoor rock climbing. Wilderness Environ Med. 2013;24(2):167-8.

28. Schöffl V, Lutter C, Wollings K, Schöffl I. Pediatric and adolescent injury in rock climbing. Res Sports Med. Pediatric and adolescent injury in rock climbing. Res Sports Med. 2018;26(sup1):91-113.

29. Schroeder T, Ault K. The NEISS sample (design and implementation) 1997 to present. US Consumer Product Safety Commission. 2001.

30. Centers for Disease Control and Prevention. Definition for WISQARS Nonfatal. Centers for Disease Control and Prevention; 2016 [cited 2016 7th December]; Available from: http://www.cdc.gov/NCIPC/wisqars/nonfatal/definitions.htm .

31. DAV. DAV Unfallstatistik 2014-15. Munich: Deutscher Alpenverein; 2016.

32. Schöffl V, Küpper T. Rope tangling injuries--how should a climber fall? Wilderness Environ Med. 2008;19(2):146-9.

33. Forrester JD, Tran K, Tennakoon L, Staudenmayer K. Climbing-Related Injury Among Adults in the United States: 5-Year Analysis of the National Emergency Department Sample. Wilderness Environ Med. 2018. (In Press)

34. Gronhaug G, Norberg M. First overview on chronic injuries in sport climbing: proposal for a change in reporting of injuries in climbing. BMJ Open Sport Exerc Med. 2016;2(1):e000083.

35. Gerdes EM, Hafner JW, Aldag JC. Injury patterns and safety practices of rock climbers. J Trauma. 2006;61(6):1517-25.

36. Stam C. Climbing injuries in the Netherlands. Inj Control Saf Promot. 2003;10(4): 251-2.

37. Wright DM, Royle TJ, Marshall T. Indoor rock climbing: who gets injured? Br J Sports Med. 2001;35(3):181-5.

38. Paige TE, Fiore DC, Houston JD. Injury in traditional and sport rock climbing. Wilderness Environ Med. 1998;9(1):2-7.

39. Rooks MD. Rock climbing injuries. Sports Med. 1997;23(4):261-70.

40. Haas JC, Meyers MC. Rock climbing injuries. Sports Med. 1995;20(3):199-205.

41. Limb D. Injuries on British climbing walls. Br J Sports Med. 1995;29(3):168-70.

42. Hubicka E. [Rock climbing injuries sustained at the training centre in Cesky Raj (author's transl)]. Acta Chir Orthop Traumatol Cech. 1977;44(1):77-82.

43. Neuhof A, Hennig FF, Schöffl I, Schöffl V. Injury risk evaluation in sport climbing. Int J Sports Med. 2011;32(10):794-800.

44. Schöffl V, Hochholzer T, Winkelmann HP, Strecker W. Pulley injuries in rock climbers. Wilderness Environ Med. 2003;14(2):94-100.

45. Rooks MD, Johnston RB 3rd, Ensor CD, McIntosh B, James S. Injury patterns in recreational rock climbers. Am J Sports Med. 1995;23(6):683-5

46. Backe S EL, Janson S, Timpka T. Rock climbing injury rates and associated risk factors in a general climbing population. Scand J Med Sci Sports. 2009;19(6):850-6

47. Schöffl V, Schöffl I, Schwarz U . Injury-risk evaluation in water ice climbing. Med Sport. 2009;2(2):32-8.

48. Schöffl V, Hochholzer T, Winkelmann HP, Strecker W. [Differential diagnosis of finger pain in sport climbers] Differentialdiagnose von Fingerschmerzen bei Sportkletterern. D Z Sportmed. 2003;54(2):38-43.

49. Schöffl VR, Schöffl I. Finger pain in rock climbers: reaching the right differential diagnosis and therapy. J Sports Med Phys Fitness. 2007;47(1):70-8.

50. Schöffl V, Lutter C, Popp D. The “heel hook”-a climbing-specific technique to injure the leg. Wilderness Environ Med. 2016;27(2):294-301.

51. Schöffl V. Rock and ice-climbing medicine. In: Feletti F, Hrsg. Extreme Sports Medicine. Switzerland: Springer International Publishing; 2017:109-21.

Figure Legends

Figure 1: Estimated number of rock climbing injuries by year, 2008-2016 (range 2,426 to 4,983)

Tables

Table 1: International Mountaineering and Climbing Federation injury classifications[16]

Table 2: Characteristics of rock climbers presenting at US Emergency Departments

Table 3: Injured body parts, diagnosis and mechanism by disposition, age and sex, among rock climbing injuries

Table 4: Analysis of injury grading