Title

Incidence, Diagnosis and Management of Injury in Sport Climbing and Bouldering: A Critical Review

Authors: Gareth Jones (g.j.Jones@leedsbeckett.ac.uk) [1], Volker Schöffl (volker.schoeffl@me.com) [1, 2, 3, 4] & Mark I. Johnson (m.johnson@leedsbeckett.ac.uk) [1]

Author affiliations

1. Centre for Pain Research, School of Clinical and Applied Sciences, Leeds Beckett University, Leeds, U.K.

2. Department of Orthopedic and Trauma Surgery, Klinikum Bamberg, Germany

3. Department of Emergency Medicine, Section of Wilderness Medicine, University of Colorado School of Medicine, USA

4. Department of Trauma Surgery, Friedrich Alexander University Erlangen-Nuremberg, Germany

Corresponding author

Dr Gareth Jones, School of Clinical and Applied Sciences, Leeds Beckett University, Leeds, LS1 3HE,

U.K., Telephone: +44 113 81 25727, Fax: +44 113 2833124, e-mail: g.j.Jones@leedsbeckett.ac.uk

Abstract

Competition climbing as an Olympic sport will debut at the 2020 summer games in Tokyo. The aims of this article are to critically review the incidence of injury in sport climbing and bouldering; the pathophysiology and presentation of finger and shoulder injuries; and the diagnostic and therapeutic algorithm for finger injuries. A semisystematic approach in reviewing literature on incidence was applied. Articles were identified after searches of the following electronic databases: Discover, Academic Search Complete (EBSCO), PubMed, Embase, SPORTDiscus, and ScienceDirect. Despite methodological shortcomings of the included studies, we estimated the mean ± standard deviation of the incidence rate of injury in sport climbing and bouldering from the eight studies to be 2.71 ± 4.49/1000hrs. Differential diagnosis and the clinical management of finger and shoulder injuries in climbers is challenging. An updated diagnostic and therapeutic algorithm for the clinical management of finger injuries in climbers is presented.

1.0 Introduction

Competition climbing as an Olympic sport will debut at the 2020 summer games in Tokyo. The competitive disciplines are sport lead climbing, speed climbing and bouldering. Sport lead climbing utilises a belayed dynamic rope that is attached to the climber. The belayed rope is connected to pre-fixed anchor points during the ascent by the climber and acts as a safeguard in the event of a fall. Speed climbing utilises a mechanically assisted belay device from above to protect the climber in the event of a fall. Climbers attempt to complete the 15 metre standardised route in the fastest time. Bouldering involves movement sequences performed on a pre-determined direction of travel, without a rope, at a relative short distance from the ground. Safety mats safeguard the climber in the event of a fall. The popularity and professionalism of climbing is likely to result in an increase in climbing related injuries as part of the caseload presenting to sports injury physicians and other health care professionals (1).

Previously we conducted a critical review of the incidence and risk factors for injury in rock climbing (2). Analysis of 11 studies found the mean incidence of injury irrespective of climbing behaviour to be 5.81/1000h (SD ± 11.19), with a point prevalence found to vary between 10% and 81% irrespective of cause. The most commonly injured structure was the annular pulleys of the fingers and we reported evidence to suggest epiphyseal fractures in adolescent sport climbers was increasing. The aims of this article are to critically review research on the incidence of injury in sport climbing and bouldering; the pathophysiology and presentation of finger and shoulder injuries; the diagnostic and therapeutic algorithm for finger injuries originally presented in 2016 (2).

2.0 Methods

An electronic search of the following electronic databases was performed on 9th February 2018: Discover, Academic Search Complete (EBSCO), PubMed, Embase, SPORTDiscus, and ScienceDirect. Combinations of the MeSH headers ‘mountaineering’; ‘risk factors’; ‘athletic injuries’, and free text terms ‘rock climb*’ (Boolean Phrase); ‘climb*’ (Boolean Phrase); ‘injury*’ (Boolean Phrase) ‘risk factors*’ (Boolean Phrase) were used in the search. One reviewer (GJ) reviewed titles and abstracts for relevance according to the following eligibility criteria: A primary study on sport climbing and/or bouldering that reported an estimate of the incidence of injury.

3.0 Incidence of Injuries

We found eight primary studies with data to estimate the incidence rate of injury per 1000 hours of activity (Table 1). The maximum incidence rate was 13.04/1000hrs (3)and the minimum incidence rate was 0.02/1000hrs (4). We estimated the mean $\pm$ standard deviation of the incidence rate of injury in sport climbing and bouldering from the eight studies to be 2.71 ± 4.49/1000hrs. The mean $\pm$ standard deviation incidence rate of injury from five prospective studies was 3.40 ± 5.54/1000hrs (3. The mean + standard deviation incidence rate of injury from three retrospective studies was 1.56 ± 2.50/1000hrs {Limb, 1995 #82, 4-9). The mean $\pm$ standard deviation incidence rate of injury from six studies that sampled injuries from indoor climbing environments was 2.83 ± 5.14/1000hrs (3-7, 10). The mean $\pm$ standard deviation incidence rate of injury from two studies that sampled injuries from indoor and outdoor climbing environments was 2.32 ± 4.00/1000hrs (8, 9). The mean $\pm$ standard deviation incidence rate of injury from two studies that sampled injuries that occurred during competition climbing was 1.92 ± 1.67/1000hrs (5, 7). One study estimated the incidence rate of injury during competitive sport lead climbing as 0.29/1000hrs, competitive speed climbing as 0.00/1000hrs, and competitive bouldering as 1.47/1000hrs (5). Confidence in the precision of these estimates of the incidence rate of injuries is undermined because of heterogeneity in the methodology of the primary research studies including inconsistency in the use of injury terminology, level of injury reported, data collection procedures, calculation of exposure and operational measures of performance. There is a need to consolidate reporting standards for epidemiological cohort studies in rock climbing.

[Insert Table 1 here]

4.0 Shoulder Injuries in Climbing

The shoulder typically accounts for 17% of all climbing related injuries (3, 11). Sport climbers and boulderers are particularly susceptible to the development of shoulder injuries due to prolonged and repetitive upper limb movements on vertical or overhanging terrain. A cross sectional cohort study of 201 climbers found the shoulder injuries to be positively related to the frequency and difficulty of indoor and outdoor sport climbing and bouldering (12). An evaluation of injury trends in sport climbing and bouldering over a four-year period found superior labral anterior posterior tears and impingement of sub-acromial structures to be the most common diagnosis (11). The aetiology of impingement is often multifactorial with a complex biomechanical interaction between active and passive anatomical structures within the shoulder (13) with some authors now preferring to describe the condition as Subacromial Pain Syndrome. Definitive diagnoses may include thickening of the coracoacromial ligament, partial or full thickness tear of the supraspinatus, bursal hypertrophy and tendinopathy. Literature refers to structural narrowing of the sub-acromial space and dysfunction as ‘primary’ impingement and dynamic instability as ‘secondary’ impingement. Internal impingement refers to the entrapment of soft tissue such as the supraspinatus, infraspinatus, long head of the biceps tendon and joint capsule between the glenoid rim and the humeral head (14). Internal impingement may be further classified as posterior superior impingement or anterior superior impingement (14). Determining a differential diagnosis and the severity of pathophysiology of shoulder impingement can be challenging. A systematic review found insufficient evidence to support the use of physical tests to diagnose shoulder impingements and local lesions of bursa, tendon or labrum (15) Although simple physical tests, such as the painful arc, can provide valuable diagnostic information especially in remote settings (16). The British Orthopaedic Association patient care pathway recommends conservative treatment including injection therapy in the primary care setting and should a patient require referral to secondary care services the integrity of the rotator cuff may be assessed using ultrasound and/or magnetic resonance imaging (17).

Surgery may be considered when conservative treatment fails and for individuals with significant or consistent pain and/or loss of function. Arthroscopic repair of acute and chronic tears of the rotator cuff (Simon, et al., 2017) and Superior Labral Anterior Posterior repair with primary long biceps tenodesis (18) have produced favourable functional outcome with participants returning to high level climbing performance.

5.0 Epiphyseal Growth Plate Fractures of the Fingers in Adolescents

The average age of competition climbers has decreased significantly in the last 10 years (1). Adolescent competitive climbers engage in structured training programs designed to improve performance but paradoxically places large amounts of stress on an immature skeleton. There are few studies on adolescent climbing populations, although initial data suggests an increase in epiphyseal fractures of the promixal interpahalangeal joint (2, 11, 19, 20). A secondary analysis of adolescent climbing data found 50% (13/26) of all reported injuries were fractures of the growth plate (19). A case series of 22 injuries found a higher proportion of growth plate fractures in adolescent male climbers (n=14) than adolescent female climbers (n=4) with the middle finger to be affected in 95% of cases (20). Early identification of such injuries is desirable to avoid serious complications such as premature closure of the growth plate leading to asymmetrical deformity of the finger.

The risk of growth plate fractures is suggested to be associated with unrestricted use of dynamic finger training apparatus, failure to monitor training and competition load (2). Non modifiable risk factors may include growth velocity and hormone regulation (20). Clinical examination may reveal localised swelling, pain and/or tenderness on the dorsal aspect of the proximal interphalangeal joint usually of the middle or ring finger. Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) should be used to confirm diagnosis as plain radiographs may not 'rule out' a fracture (21). The most common fracture presentation reported in adolescent climbers to date is a Salter-Harris type III (21, 22). Conservative measures for non-displaced fractures usually allows most climbers to return to pre-injury activity levels. However, complications may arise due to injury severity (Salter-Harris type IV or V) and in cases of non-union. Surgical intervention using percutaneous spot drilling epiphsiodesis has shown encouraging results (23).

6.0 Annular Pulley Injuries

The annular pulleys of the fingers are the most commonly injured structures in climbing (11). Climbers usually present with pain and tenderness on the palmer aspect of the finger and an audible 'pop' may be reported to have occurred at the time of injury. When the finger is flexed discreet bowstringing of the tendon may be indicative of multiple pulley rupture (A2, A3 and A4). Ultrasound imaging confirms diagnosis of A2 and A4 pulley rupture when dehiscence between tendon and bone is greater than 2mm (24). Anatomical variation in the origin of the A3 pulley means a threshold dehiscence greater than 0.9mm between volar plate and tendon is predictive of A3 pulley rupture (24). Climbers with chronic degenerative change to the annular pulleys have been found to have a dehiscence greater than 2mm in absence of rupture (25). MRI may be considered in cases of high-grade injuries and when ultrasound is inconclusive (21). Surgical reconstruction using the loop and a half technique with an auto graft of the palmaris longus muscle is currently the preferred method for repair of the A2 and A4 pulleys in climbers (26) . A new transosseous variation of this repair has recently undergone a feasibility study with the authors concluding favourable outcomes as it reduces the likelihood of extensor tendon irritation with the extensor hood (27). Of note, conservative management of triple pulley rupture (A2, A3, and A4) using thermoplastic rings has also produced positive results (28). Treatment using thermoplastic rings should commence immediately, providing tendon bone distance can be satisfactorily reduced, and confirmed by ultrasound.

7.0 Diagnostic Algorithm for Finger Injuries

In 2016, we developed a diagnostic and therapeutic algorithm for finger injuries in climbers for the identification of annular pulley injuries and epiphyseal fractures in adolescents (2). We have updated the algorithm (see Figure 1) to reflect the latest research and practice based evidence including new surgical options for epiphyseal injuries, differential diagnosis consideration for chronic tendonitis and preference of MRI rather than plain x-ray for growth plate fractures.

[Insert Figure 1 here]

9.0 Summary

The findings from our critical review provide an estimate of the incidence of injury in sport climbing and bouldering. We estimated the mean ± standard deviation of the incidence rate of injury in sport climbing and bouldering from the eight studies to be 2.71 ± 4.49/1000hrs. Differences in injury terminology, data collection procedures, calculation of exposure and operational measures of performance used by authorship teams' likely accounts for the variance found. Differential diagnosis and the clinical management of finger and shoulder injuries in climbers is challenging. In particular, early identification of growth plate injuries in adolescent climbers is paramount.

References

1. Lutter C, El-Sheikh Y, Schöffl I, Schöffl V. Sport climbing: medical considerations for this new Olympic discipline. British Journal of Sports Medicine. 2017;51(1):2-3. doi: 10.1136/bjsports-2016-096871.
2. Jones G, Johnson MI. A Critical Review of the Incidence and Risk Factors for Finger Injuries in Rock Climbing. Current sports medicine reports. 2016;15(6):400-9. doi: 10.1249/JSR.0000000000000304. PubMed PMID: 27841811.
3. van Middelkoop M, Bruens ML, Coert JH, Selles RW, Verhagen E, Bierma-Zeinstra SM, et al. Incidence and Risk Factors for Upper Extremity Climbing Injuries in Indoor Climbers. Int J Sports Med. 2015;36(10):837-42. doi: 10.1055/s-0035-1547224. PubMed PMID: 25958937.
4. Schoffl 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. Epub 2013/07/24. doi: 10.1016/j.wem.2013.03.020. PubMed PMID: 23877045.
5. Schoffl V, Burtscher E, Coscia F. INJURIES AND MEDICAL INCIDENCES DURING THE IFSC 2012 CLIMBING WORLD CUP SERIES. Medicina Sportiva. 2013;17(4):168-70. PubMed PMID: 93543967.
6. Schoffl V, Winkelmann HP. [Accident statistics at "indoor climbing walls"]. Sportverletz Sportschaden. 1999;13(1):14-6. Epub 1999/07/17. doi: 10.1055/s-2007-993308. PubMed PMID: 10407959.
7. Schoffl VR, Kuepper T. Injuries at the 2005 World Championships in Rock Climbing. Wilderness Environ Med. 2006;17(3):187-90. PubMed PMID: 17078315.
8. Neuhof A, Hennig FF, Schoffl I, Schoffl V. Injury risk evaluation in sport climbing. Int J Sports Med. 2011;32(10):794-800. Epub 2011/09/14. doi: 10.1055/s-0031-1279723. PubMed PMID: 21913158.
9. Woollings KY, McKay CD, Kang J, Meeuwisse WH, Emery CA. Incidence, mechanism and risk factors for injury in youth rock climbers. British Journal of Sports Medicine. 2015;49(1):44-50. doi: 10.1136/bjsports-2014-094067.
10. Limb D. Injuries on British climbing walls. British Journal of Sports Medicine. 1995;29(3):168-70. PubMed PMID: 66079207.
11. Schoffl V, Popp D, Kupper T, Schoffl I. Injury trends in rock climbers: evaluation of a case series of 911 injuries between 2009 and 2012. Wilderness Environ Med. 2015;26(1):62-7. Epub 2015/02/26. doi: 10.1016/j.wem.2014.08.013. PubMed PMID: 25712297.
12. Jones G, Asghar A, Llewellyn DJ. The epidemiology of rock-climbing injuries. Br J Sports Med. 2008;42(9):773-8. doi: 10.1136/bjsm.2007.037978. PubMed PMID: 18065444.
13. Popp D, Schöffl V. Superior labral anterior posterior lesions of the shoulder: Current diagnostic and therapeutic standards. World Journal of Orthopedics. 2015;6(9):660-71. doi: 10.5312/wjo.v6.i9.660. PubMed PMID: PMC4610908.
14. Garofalo R, Karlsson J, Nordenson U, Cesari E, Conti M, Castagna A. Anterior-superior internal impingement of the shoulder: an evidence-based review. Knee surgery, sports traumatology, arthroscopy : official journal of the ESSKA. 2010;18(12):1688-93. Epub 2010/08/12. doi: 10.1007/s00167-010-1232-z. PubMed PMID: 20700579.
15. Hanchard NC, Lenza M, Handoll HH, Takwoingi Y. Physical tests for shoulder impingements and local lesions of bursa, tendon or labrum that may accompany impingement. The Cochrane database of systematic reviews. 2013(4):Cd007427. Epub 2013/05/02. doi: 10.1002/14651858.CD007427.pub2. PubMed PMID: 23633343.

16. Jones G, Johnson M. Painful shoulder? Remote clinical management of a Field Guide with shoulder pain and loss of shoulder function in Antarctica. Australasian Medical Journal. 2017;10(6):474-7.
17. Kulkarni R, Gibson J, Brownson P, Thomas M, Rangan A, Carr AJ, et al. Subacromial shoulder pain. Shoulder Elbow. 2015;7(2):135-43. Epub 2015/04/01. doi: 10.1177/1758573215576456. PubMed PMID: 27582969; PubMed Central PMCID: PMCPMC4935112.
18. Schöffl V, Popp D, Dickschass J, Küpper T. Superior Labral Anterior-posterior Lesions in Rock Climbers—primary Double Tenodesis?: Erratum. Clinical Journal of Sport Medicine. 2011. Epub April 9, 2011. doi: 10.1097/jsm.0000000000000387. PubMed PMID: 00042752-201609000-00016.
19. Schöffl V, Lutter C, Woollings K, Schöffl I. Pediatric and adolescent injury in rock climbing. Research in Sports Medicine. 2018;26(sup1):91-113. doi: 10.1080/15438627.2018.1438278.
20. Schoffle I, Schoffle V. Epiphyseal stress fractures in the fingers of adolescents: Biomechanics, Pathomechanism, and Risk Factors. European Journal of Sports Medicine. 2015;3(1):27-37.
21. Bayer T, Schoffl VR, Lenhart M, Herold T. Epiphyseal stress fractures of finger phalanges in adolescent climbing athletes: a 3.0-Tesla magnetic resonance imaging evaluation. Skeletal Radiol. 2013;42(11):1521-5. Epub 2013/08/07. doi: 10.1007/s00256-013-1694-4. PubMed PMID: 23917681.
22. Hochholzer T, Schoffl VR. Epiphyseal fractures of the finger middle joints in young sport climbers. Wilderness Environ Med. 2005;16(3):139-42. Epub 2005/10/08. PubMed PMID: 16209469.
23. El-Sheikh Y, Lutter C, Schoeffl I, Schoeffl V, Flohe S. Surgical Management of Proximal Interphalangeal Joint Repetitive Stress Epiphyseal Fracture Nonunion in Elite Sport Climbers. J Hand Surg Am. 2017. doi: 10.1016/j.jhsa.2017.10.009. PubMed PMID: 29146511.
24. Schöffl I, Deeg J, Lutter C, Bayer T, Schöffl V. Diagnosis of the A3 pulley injury using ultrasound. Sportverl Sportschad (in Press).
25. Chang CY, Torriani M, Huang AJ. Rock Climbing Injuries: Acute and Chronic Repetitive Trauma. Curr Probl Diagn Radiol. 2016;45(3):205-14. doi: 10.1067/j.cpradiol.2015.07.003. PubMed PMID: 26360057.
26. Schöffl V, Küpper T, Hartmann J, Schöffl I. Surgical Repair of Multiple Pulley Injuries—Evaluation of a New Combined Pulley Repair. Journal of hand surgery. 2012;37(2):224-30. doi: 10.1016/j.jhsa.2011.10.008.
27. Schoffl I, Meisel J, Lutter C, Schoffl V. Feasibility of a New Pulley Repair: A Cadaver Study. J Hand Surg Am. 2018;43(4):380.e1-.e7. Epub 2017/10/08. doi: 10.1016/j.jhsa.2017.08.028. PubMed PMID: 28985979.
28. Schweizer A. Conservative treatment of triple finger flexor pulley disruption. Precedings 4th Congress International Rock Climbing Research Association, Chamonix. 2018.

Captions

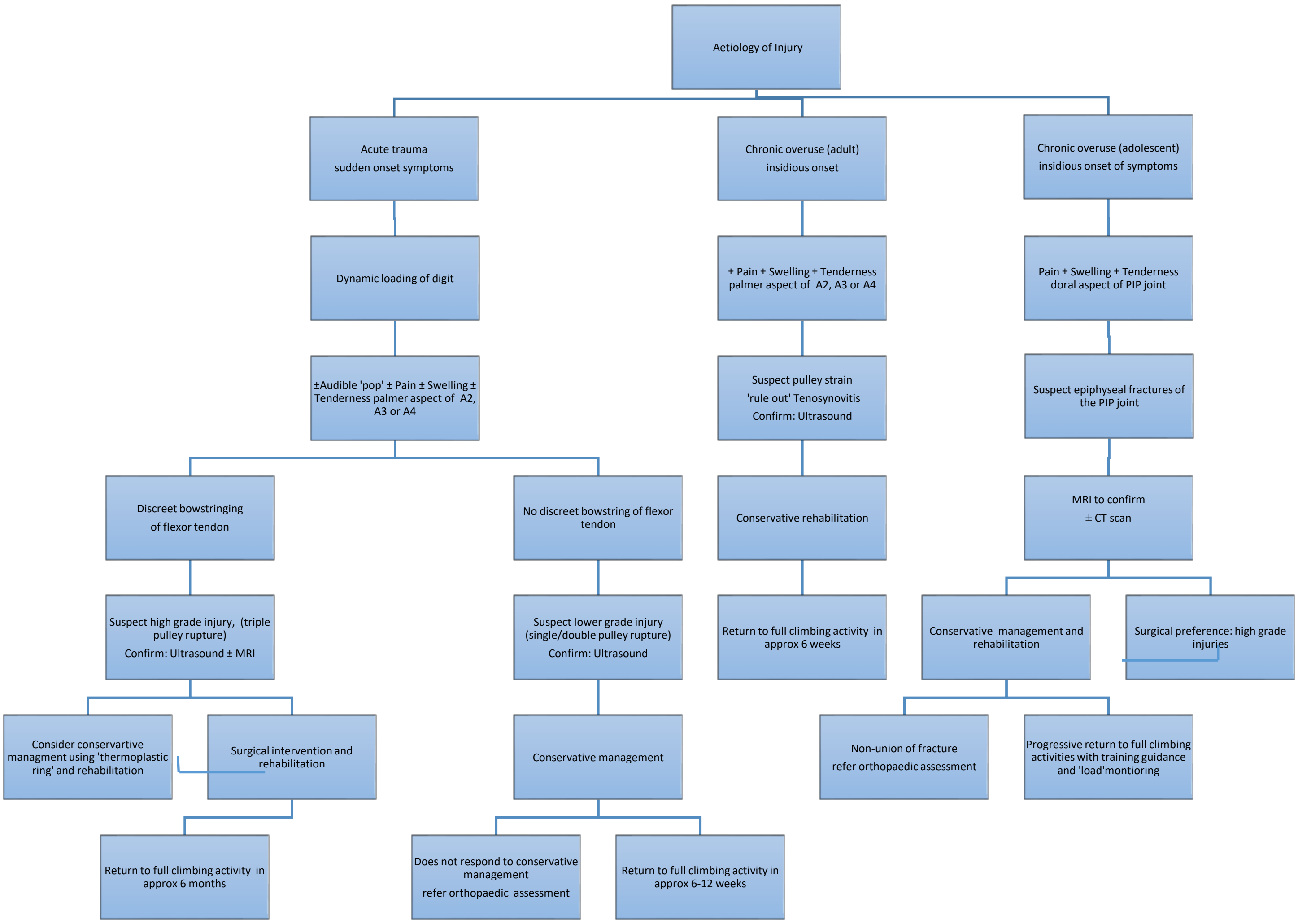
Table 1: Incidence rates and commentary of reviewed studies

Figure 1: Diagnostic and therapeutic algorithm for suspected annular pulley and epiphyseal injuries

Table 1: incidence rates and commentary of reviewed studies

Reference	Survey duration	Survey method	Sample type and number	Type of injury	Site of injury	Injury incidence rate	Comments
Limb, (1995)	Retrospective	Postal survey requesting data over a specified 2 year period from each climbing wall on significant injuries that resulted from indoor climbing and referral to an A&E department.	Location: 90 indoor climbing facilities Behaviour: indoor sport climbing Sample Size: 1.021 million indoor climbing visits	Impact and No Impact Acute trauma	Any site	0.027/1000hrs	Calculation of incidence rate by Shoffl et al (2010) for a secondary analysis. Authors based calculation on data reported in the study.
Shoffl& Winkelmann (1999)	Prospective	Data was collected from 10 climbing walls over a 6 month period. Exposure was calculated at time spent at the facility.	Location: indoor climbing facilites Behaviour: indoor sport climbing Sample Size: 25,163 registrants	Impact and No Impact Acute Trauma	Any site	0.079/1000hr	
Schoffl & Kuepper (2005)	Prospective	Data recorded during the course of the world championship finals by medical team.	Location: indoor climbing world championship Behaviour: indoor sport climbers Sample Size: 443	Impact and No Impact Acute Trauma	Any site	3.1/1000hrs	
Neuhof et al (2011)	Retrospective	Cross sectional, 5 year recall, Self-reported electronic survey. Authors analysed the five most significant injuries as reported by each participant	Location: internet survey site Behaviour: indoor sport climbing Sample Size: 1962	Impact and No Impact Acute Trauma	Any site	0.2/1000hrs	Study surveyed the 5 most significant injuries Injuries classified according to International Climbing and Mountaineering Federation MedCom classification
Schoffl et al. (2013)	Prospective	Single site study. Over a 5 year period. Climbing exposure was recorded as time spent from entry to the indoor climbing wall to leaving (capped at 5 hours maximum)	Location: indoor climbing facility Behaviour: indoor sport climbing & indoor bouldering Sample Size: total number of climbing wall visits 515,337	Impact and No Impact Acute Trauma	Any site	0.02/1000hrs	Injuries classified according to International Climbing and Mountaineering Federation MedCom classification

Schöffl et al (2013)	Prospective	Series of 22 indoor world cup climbing competitions. Injuries assessed and reported by medical team present at each event.	Location: indoor climbing facilities Behaviour: indoor sport climbing Sample size: Not stated; total hours of competition and total per individual type of climbing stated: sport lead climbing: 3405 hours; bouldering: 2707.5 hours; speed climbing: 637.5 hours	Impact, No Impact Acute Trauma and Chronic Overuse	Any site	Overall 0.74/1000hrs; Sport leading: 0.29/1000hrs; Bouldering 1.47/1000hrs; Speed climbing 0.00/1000hrs	Injuries classified according to International Climbing and Mountaineering Federation MedCom classification
van Middelkoop et al (2015)	Prospective	Initial self-reported baseline questionnaire. One year follow up study with data collection every 3 months by self-reported questionnaire	Location: indoor climbing facility Behaviour: recreational indoor climbers & indoor boulderers Sample Size: 426	Impact, No Impact Acute Trauma and Chronic Overuse	Upper limb Only	13.04/1000hrs	
Woollings et al (2015)	Retrospective	Cross sectional, self-reported questionnaire, 12 month recall period	Location: 10 indoor climbing walls Behaviour: recreational & competitive indoor & outdoor sport climbers & boulderers Sample Size: 116 youth climbers	Impact, No Impact Acute Trauma and Chronic Overuse	Any site	4.44/1000hrs	



Aetiology of Injury
Acute trauma
sudden onset symptoms
Chronic overuse (adult)
insidious onset
Chronic overuse (adolescent)
insidious onset of symptoms
Dynamic loading of digit
± Pain ± Swelling ± Tenderness palmer aspect of A2, A3 or A4
Pain ± Swelling ± Tenderness doral aspect of PIP joint
±Audible 'pop' ± Pain ± Swelling ± Tenderness palmer aspect of A2, A3 or A4
Suspect pulley strain
'rule out' Tenosynovitis
Confirm: Ultrasound
Suspect epiphyseal fractures of the PIP joint
Discreet bowstringing
of flexor tendon
No discreet bowstring of flexor tendon
Conservative rehabilitation
MRI to confirm
± CT scan
Suspect high grade injury, (triple pulley rupture)
Confirm: Ultrasound ± MRI
Suspect lower grade injury (single/double pulley rupture)
Confirm: Ultrasound
Return to full climbing activity in approx 6 weeks
Conservative management and rehabilitation
Surgical preference: high grade injuries
Consider conservative managment using 'thermoplastic ring' and rehabilitation
Surgical intervention and rehabilitation
Conservative management
Non-union of fracture
refer orthopaedic assessment
Progressive return to full climbing activities with training guidance and 'load'montioring
Return to full climbing activity in approx 6 months
Does not respond to conservative management
refer orthopaedic assessment
Return to full climbing activity in approx 6-12 weeks