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Flexor tendon pulley injuries in climbing: causes, diagnosis and treatment

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Abstract

Finger flexor pulley injuries are the most common overuse injuries sustained by climbers. These injuries are caused by forceful gripping techniques specific to climbing, making them uncommon in non-climbing activities. With the growing popularity of climbing, there is a rising need for accurate diagnosis and improved treatment methods. This paper explores current diagnostic techniques, including physical examination, ultrasound, and magnetic resonance imaging. It also discusses treatment options, which range from conservative rehabilitation to surgery, depending on the severity of the injury. Finally, it emphasizes the importance of injury prevention through proper warm-up and avoiding excessive strain.

Keywords: flexor pulley injuries, rock climbing, flexor tendon, climbing injury prevention, pulley rupture, pulley reconstruction

Introduction

Flexor tendon injuries are a relatively newly recognized disease entity. The first scientific paper to appear on the subject was written in 1990 and concerned injury to the A2 pulley [1]. The growing popularity of climbing as a sport has led to a surge in these injuries [2–]. The inclusion of combined climbing in the 2020 Tokyo Olympics, which incorporates bouldering, speed climbing, and lead climbing, has further increased awareness. Bouldering, specifically, poses the highest risk of flexor tendon injuries due to its powerful, dynamic movements on several meters high (rock, artificial) walls without a rope for safety [5]. These acrobatic maneuvers require climbers to exert maximal force in a very short time frame. While climbing is a primary culprit, flexor tendon injuries can also occur in other sports like baseball and bowling, where forceful gripping with flexed position of the fingers is common [6,7,8].

Anatomy

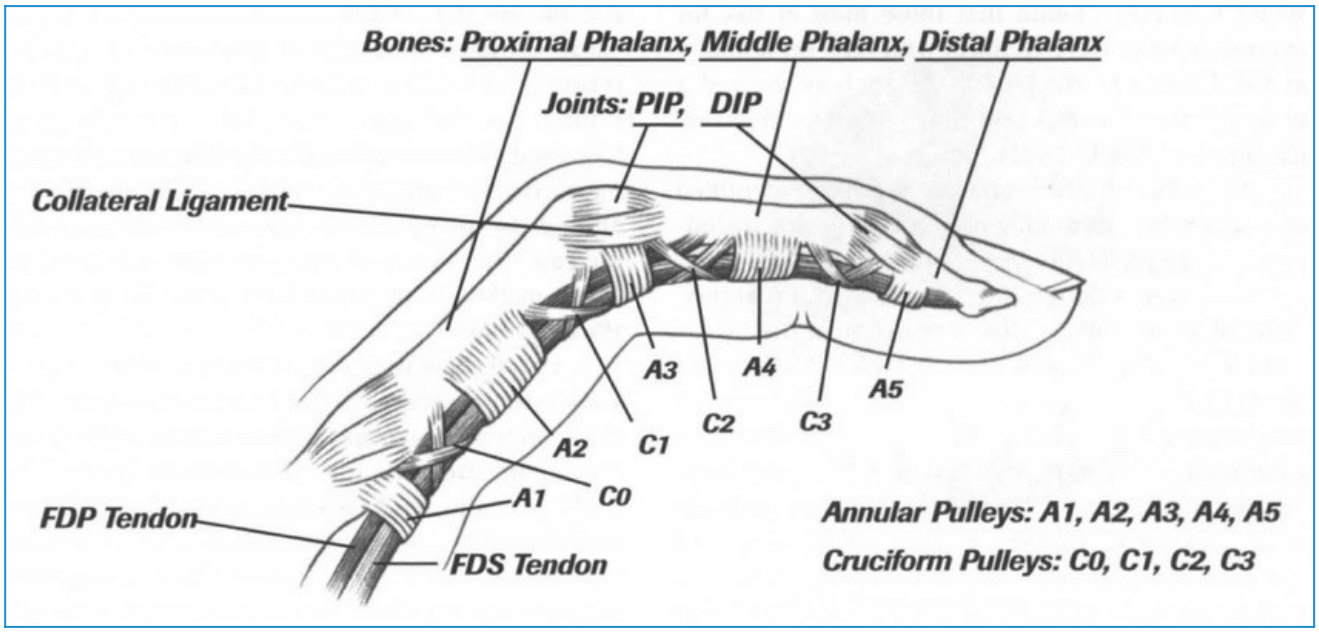

Figure 1: Anatomy of Finger Pulley (Horst, 2008) [9]

The illustration details the pulley system within the finger. Five ligamentous rings called annular pulleys (A1-A5) encircle the flexor tendons, holding them close to the bone. Three

additional cross-shaped ligaments, the cruciate pulleys (C1-C3), provide further support. By keeping the tendon close to the bone during both flexion and extension, these pulleys ensure smooth and efficient finger movement. They act as stabilizers, preventing the tendons from bowstringing (sliding away from the bone)[10].

The A2 is located between the metacarpophalangeal (MCP) and proximal interphalangeal (PIP) joint, while A4 sits between proximal interphalangeal (PIP) and distal interphalangeal (DIP) joint. The remaining pulleys, A1, A3 and A5 lie on the volay plate, positioned over each respective joint (MCP, PIP and DIP)[11].

Research using methylene blue injections has shown that the A2 and A4 pulleys are thicker and stronger than the others [12,13]. They are anchored directly to the bone, preventing finger hyperextension and converting the pulling force of the tendons into rotation and torque at the metacarpophalangeal and interphalangeal joints [14]. Since the greatest forces are acting on them[10], the A4 pulley is damaged first, followed by the A2 pulley, when maintaining grip position .

Injuries

Figure 2: Different types of grips, starting from the upper left corner and going clockwise: crimp grip position, closed crimp grip position, finger pocket grip, open hand grip.

A retrospective study involving 667 climbers revealed that over half (41.3%) sustained chronic injuries, with fingers being the most common site (compared to shoulders at 19.4% and elbows at 17.7%) regardless of gender. These injuries are more frequent among less experienced climbers who practice the sport recreationally compared to those who climb on elite level [2]. In bouldering, the difficulty of the route depends mostly on the size of the holds and wall overhang. As the grip size decreases and wall overhang increases, the required force for movement also rises, consequently placing greater strain on the fingers. Climbers at the elite level like William Bosi are able to perform a single arm hang on a 6-millimeter edge. During climbing, the entire body weight often rests on just one or two flexed fingers, significantly straining the pulleys. These injuries can result from either a single traumatic event (acute) or repetitive microtrauma [15]. Climbing on artificial walls carries a higher risk of injury compared to natural rock due to the prevalence of dynamic and acrobatic movements [5,16,17]. Climbers utilize various grips like crimp, open grip and pinch. The crimp grip involves using small edges with the proximal interphalangeal (PIP) joint flexed > 90° and distal interphalangeal (DIP) joint in hyperextension. This positioning exerts significantly more stress on the pulleys compared to an open grip, with forces reaching up to 36 times higher [6,18]. The severity of injury can range from a strain to a complete rupture of one or multiple pulleys, as detailed in the Schöffl grading scale shown in *Table 1*.

Table 1. Pulley injuries score [19].

Grade	Injury
1	Pulley strain
2	Complete rupture of A4 or partial rupture of A2 or A3
3	Complete rupture A2 or A3
4	Multiple ruptures (as A2/A3, A2/A3/A4) or single rupture (as A2 or A3) combined with lumbricalis muscle or collateral ligament trauma

Diagnosis

The diagnostic process of flexor tendon pulley injuries typically begins with a physical examination. The characteristic clinical presentation includes sudden sharp pain, possibly accompanied by a poping sound, during climbing. The patient may also report ongoing pain and tenderness of the area affected by the injury. Upon examination, a hematoma or bruise may be visible at the injury site [10,11].

If the physical examination result is inconclusive, imaging studies are necessary. While X-rays are excellent for visualizing bone abnormalities like fractures or avulsion injuries, they are not suitable for imaging soft tissues like flexor tendons [20,21]. Similarly, computed tomography (CT) scans primarily image bones, although they can depict pulley ruptures. An advantage of computed tomography is the ability to image passively and against resistance, and to examine the opposite finger for comparison [22]. The disadvantages are the high cost and long time to perform the test, the relatively high radiation dose, so this test is not routinely used.

Ultrasound (USG) and magnetic resonance imaging (MRI) are considered the preferred imaging modalities for diagnosing flexor tendon injuries due to their high sensitivity and specificity. These imaging techniques not only confirm the diagnosis but also help determine the severity of the injury [23–]. Prompt and accurate diagnosis is crucial for selecting the most appropriate treatment course, preventing degenerative changes and contractures, and facilitating a return to physical activity.

USG

Ultrasound examination is currently considered the preferred imaging modality for diagnosing flexor tendon injuries [26]. It is the most frequently used tool in diagnostics. This is influenced by its wide availability, low price, speed of performing the examination, lack of negative side effects and contraindications to its performance. Due to resolution when examining soft tissues, it is suitable for detecting a complete disruption of annual pulley ligaments [27]. Another advantage is the ability to perform dynamic assessments during finger movements. However, ultrasound results depend on the skill and clinical experience of the person performing it [28,29]. The results are also influenced by the equipment used and the type of ultrasound head [27]. During an ultrasound exam, the distance between the tendon and bone is measured. A separation <2 millimeters typically indicates a strain, while a greater separation suggests a tendon rupture [24]. When ultrasound findings are inconclusive, MRI is the next diagnostic step.

MRI

Several studies have shown that MRI can be used with significant effect in detecting pulley injuries [21,30]. During the interpretation of the examination results, two types of sequences are used. The T1 sequence allows us to measure the distance between the tendon and bone, while the T2 sequence can identify other potential causes of the condition, such as isolated flexor tendosynovitis [19]. MRI's high soft tissue contrast allows visualization of indirect signs of annular pulley rupture (APL) like bowstringing and localized hematoma [31]. While MRI offers valuable diagnostic information, it is important to consider its limitations, such as higher cost, limited availability, and longer exam times and lack of dynamic examination capability [11].

Treatment

Schöffl, in his work, proposed a 4-grade system for assessing the degree of damage and depending on the degree obtained, suggested a method and duration of treatment [26]. Classification has been updated by Lutter [5].

Table 2. Updated classification of finger pulley injuries and therapeutic guidelines [5].

	Grade I	Grade II	Grade III	Grade IV a	Grade IV b
	Pulley strain	Complete tear of A3 or A4 Partial tear of A2	Complete tear of A2	Multiple ruptures: A2/A3 or A3/A4 rupture if: • No major clinical bowstring • Ultrasound proven possibility of repositioning of the flexor tendon to the bone • Therapy starting <10 d after injury • No contracture	Multiple ruptures: • A2/A3 or A3/4 with obvious clinical bowstring • A2/A3/A4 rupture • Singular pulley rupture with FLIP phenomena • Singular rupture with increasing contracture • Singular rupture with secondary, therapy

					resistant, tenosynovitis
Therapy	Conservative	Conservative	Conservative	Conservative, if secondary onset of PIP contracture >20◦ secondary surgical	Surgical
Immobilization	None	Optional, <5 days	Optional, <5 days	Optional, <5 days	Postsurgical 14 days
Functional therapy with pulley protection (defined)	2–4 weeks H-tape (during daytime) or thermoplastic pulley ring	6 weeks thermoplastic pulley ring	6–8 weeks thermoplastic pulley ring	8 weeks thermoplastic pulley ring	4 weeks thermoplastic ring (after 2 weeks of immobilization)
Easy sport specific activities	After 4 weeks	After 6 weeks	After 8 weeks	After 10 weeks	After 4 months
Full sport specific activities	After 6 weeks	After 8–10 weeks	After 3 months	After 4 months	After 6 months
H-taping during climbing	3 months	3 months	3 months	>12 months	>12 months

In grade I-III injuries, treatment is conservative. Depending on the severity of the injury, it consists of rest, immobilization with a protective splint, taping, or the use of thermoplastic pulley rings. Functional therapy with pulley protection should last from 2 to 8 weeks, depending on the severity of the injury. Cooling compresses, anti-inflammatory ointments for topical use, and orthoses can also be used in conservative treatment [32]. While some studies advise against corticosteroid injections due to potential tendon damage, a recent study by Schöffl suggests effectiveness in chronic cases, provided the injection technique is precise to avoid pulley damage. Leech therapy may be considered for patients who fail to improve with steroid injections [33]. Recovery time varies depending on the severity. For pulley strains, return to sport may be possible within 4 weeks, with full finger loading achievable by 6 weeks. As the severity of the injury increases, healing-time lengthens. In cases of multiple ruptures, singular rupture with increasing contracture, lack of improvement after conservative treatment with loss

of active range of motion of finger flexion, surgical treatment might be necessary. In surgical treatment, the extensor retinaculum or other palmaris longus tendon is used as a replacement material for the damaged pulley [34]. There are several different surgical techniques such as: "belt loop", the "single loop", the "loop and a half" and the "triple loop" techniques [11]. The results of the above techniques are positive and not significantly different to each other. The choice of a specific one depends on the patient's case and surgeon's skill and experience [34–]. Following surgery, a splint and then taping will be used to immobilize the finger. Rehabilitation timelines and return to activity vary significantly based on the individual case, ranging from weeks to months [1,38].

Prevention

An article on climbing injuries in children and adolescents suggested the following methods for preventing finger injuries during bouldering: warm-up and cool-down, age- and gender-appropriate training intensity, predominance of static over dynamic movements, avoidance of frequent use of a clenched grip position and no preventive use of taping [39]. In contrast, other studies have failed to prove that general sports injury prevention measures, such as adequate warm-up before training or stretching after physical activity, lead to a reduction in pulley injuries [40–]. Preventive finger taping prior to injury is not recommended. However, taping fingers that have already been injured can help prevent reinjury; taping reduces the load affecting the pulleys up to 13% [32,38,44]. The most recommended method is the H-tape technique shown below [38].

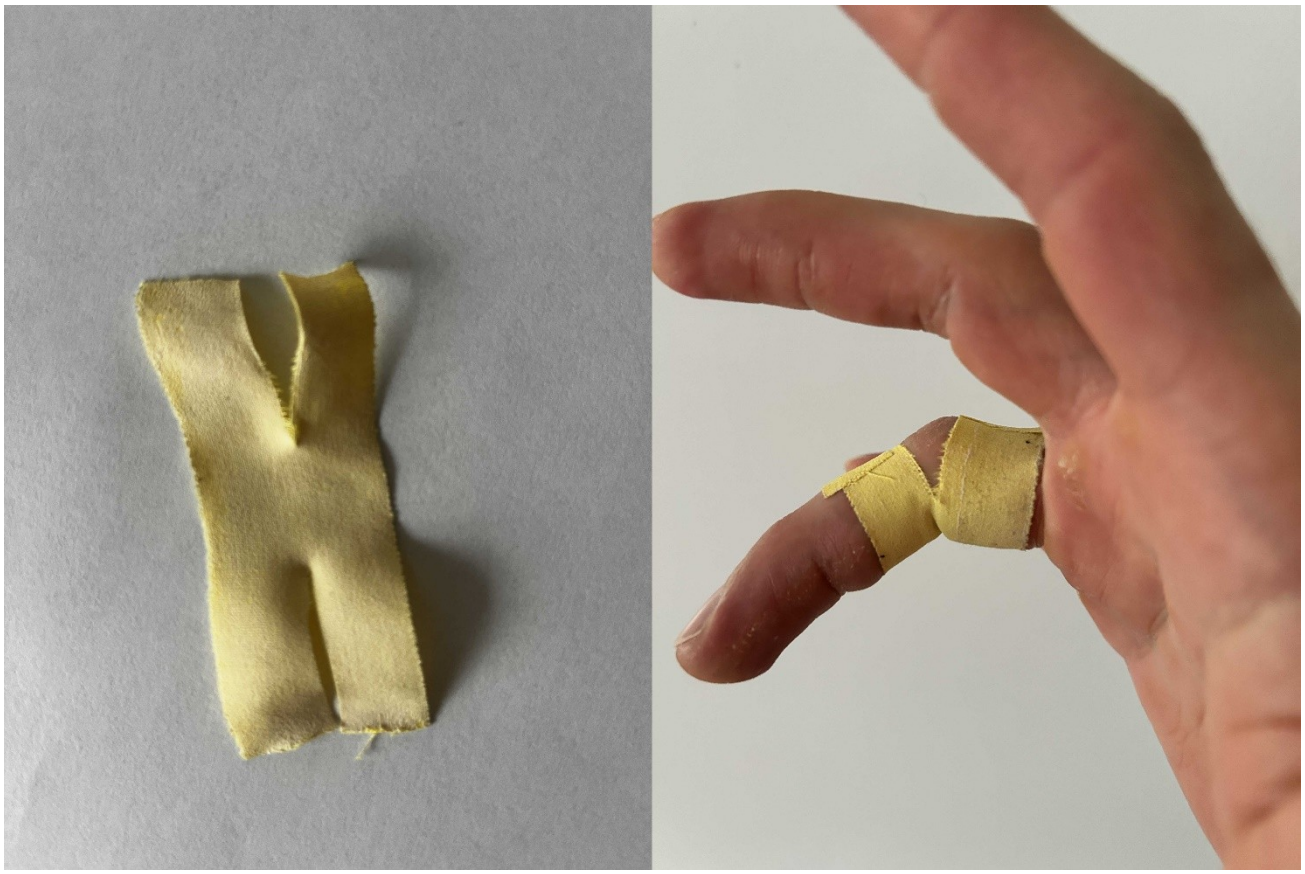

Figure 3: Example of H-type tape and applied on a finger.

Summary

The growing popularity of climbing has led to a surge in research on climbing-related injuries, with a particular focus on flexor tendon pulley injuries in the fingers. Ultrasound has emerged as the preferred diagnostic tool for these injuries, with MRI used in more complex cases. Treatment for grades I-III injuries typically involves conservative measures like splinting and rehabilitation, while surgical intervention may be necessary for grade IV injuries and severe cases. An ambiguous topic that needs to be further explored are ways to prevent pulley injuries and identify climber-specific risk factors.

Disclosure

Author's contribution

Conceptualization: Magdalena Pach and Mariola Dziedzic; Methodology: Justyna Dobrzańska; Software: Agnieszka Nowak; Check: Zuzanna Chmielowiec and Agnieszka Fugas; Formal

analysis: Karolina Smykiewicz and Alicja Partyka; Investigation: Aneta Michalczewska and Natalia Wierzejska; Resources: Mariola Dziedzic; Data curation: Alicja Partyka; Writing - rough preparation: Justyna Dobrzańska and Zuzanna Chmielowiec; Writing - review and editing, Magdalena Pach and Agnieszka Nowak; Visualization: Karolina Smykiewicz; Supervision: Natalia Wierzejska; Project administration: Aneta Michalczewska and Agnieszka Fugas; Receiving funding - no specific funding.

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References:

1. S. R. BOLLEN. INJURY TO THE A2 PULLEY IN ROCK CLIMBERS. Journal of Hand Surgery (British Volume, 1990) 15B: 268-270, 1990:

2. Grønhaug G. Self-reported chronic injuries in climbing: Who gets injured when? BMJ Open Sport Exerc Med. 2018 Jul 1;4(1).
3. Wright DM, Royle J, Marshall T. Indoor rock climbing: who gets injured? [Internet]. Vol. 35, Br J Sports Med. 2001. Available from: http://bjsm.bmj.com/
4. Artiaco S, Bosco F, Lusso A, Cioffi LL, Battiston B, Massè A. Flexor Tendon Pulley Injuries: A Systematic Review of the Literature and Current Treatment Options. Vol. 15, Journal of Hand and Microsurgery. Thieme Medical Publishers, Inc.; 2023. p. 247–52.

5. Lutter C, Tischer T, Schöffl VR. Olympic competition climbing: The beginning of a new era - A narrative review. Vol. 55, British Journal of Sports Medicine. BMJ Publishing Group; 2021. p. 857–64.
6. Berrigan W, White W, Cipriano K, Wickstrom J, Smith J, Hager N. Diagnostic Imaging of A2 Pulley Injuries: A Review of the Literature. Vol. 41, Journal of Ultrasound in Medicine. John Wiley and Sons Ltd; 2022. p. 1047–59.
7. Lourie GM, Hamby Z, Raasch WG, Chandler JB, Porter JL. Annular flexor pulley injuries in professional baseball pitchers: A case series. American Journal of Sports Medicine. 2011 Feb;39(2):421–4.
8. Patel P, Schucany WG, Toye L, Ortinau E. Flexor tendon pulley injury in a bowler Radiology Report. Vol. 25, Bayl Univ Med Cent). 2012.
9. Horst Eric. Training for Climbing: The Definitive Guide To Improving Your Performance. Globe Pequot Press; 2008.
10. King EA, Lien JR. Flexor Tendon Pulley Injuries in Rock Climbers. Vol. 33, Hand Clinics. W.B. Saunders; 2017. p. 141–8.
11. Miro PH, vanSonnenberg E, Sabb DM, Schöffl V. Finger Flexor Pulley Injuries in Rock Climbers. Vol. 32, Wilderness and Environmental Medicine. Elsevier Ltd; 2021. p. 247–58.
12. Doyle JR. Anatomy of the flexor tendon sheath and pulley system: A current review. 1989.
13. Doyle JR. Anatomy of the finger flexor tendon sheath and pulley system. Journal of Hand Surgery. 1988;13(4):473–84.
14. Peterson WW, Manske PR, Bollinger BA, Lesker PA, Mccarthy JA. Effect of Pulley Excision on Flexor Tendon Biomechanics. Vol. 4, Journal of Orthopaedic Research. Orthopaedic Research Society; 1986.
15. Bianchi S, Martinoli C, de Gautard R, Gaignot C. Ultrasound of the digital flexor system: Normal and pathological findings. J Ultrasound. 2007 Jun;10(2):85–92.
16. Schöffl V, Morrison A, Schöffl I, Küpper T. The Epidemiology of Injury in Mountaineering, Rock and Ice Climbing. Vol. 58, Epidemiology of Injury in Adventure and Extreme Sports. Med Sport Sci. Basel, Karger. 2012.
17. Wegner L, Pagel JE, Smit AW, Straszacker A, Swart SL, Taft SJ. Common neuromusculoskeletal injuries amongst rock climbers in the Western Cape. South African Journal of Physiotherapy. 2015 Apr 28;71(1).

18. Vigouroux L, Quaine F, Labarre-Vila A, Moutet F. Estimation of finger muscle tendon tensions and pulley forces during specific sport-climbing grip techniques. J Biomech. 2006;39(14):2583–92.
19. Schöffl V, Hochholzer T, Winkelmann HP, Strecker W. Pulley injuries in rock climbers. Wilderness Environ Med. 2003;14(2):94–100.
20. Crowley T. The Flexor Tendon Pulley System and Rock Climbing. J Hand Microsurg. 2016 Sep 5;04(01):25–9.
21. Gabl M, Md †, Rangger C, Lutz M, Fink C, Rudisch A, et al. Disruption of the Finger Flexor Pulley System in Elite Rock Climbers. 1998.
22. Le Viet D, Rousselin B, Roulot E, Lantieri L, Godefroy D. Diagnosis of Digital Pulley Rupture by Computed Tomography. 1996.
23. Klauser A, Frauscher F, Bodner G, Halpern EJ, Schocke MF, Springer P, et al. Finger pulley injuries in extreme rock climbers: Depiction with dynamic US. Radiology. 2002;222(3):755–61.
24. Schöffl I, Deeg J, Lutter C, Bayer T, Schöffl V. Diagnosis of A3 Pulley Injuries Using Ultrasound. Sportverletzung-Sportschaden. 2018;32(4):251–9.
25. Schöffl I, Hugel A, Schöffl V, Rascher W, Jüngert J. Diagnosis of Complex Pulley Ruptures Using Ultrasound in Cadaver Models. Ultrasound Med Biol. 2017 Mar 1;43(3):662–9.
26. Rainer Schöffl V, Schöffl I. Injuries to the Finger Flexor Pulley System in Rock Climbers: Current Concepts.
27. G. Bodner, A. Rudisch, M. Gabl, W. Judmaier, P. Springer, A. Klauser. Diagnosis of Digital Flexor Tendon Annular Pulley Disruption: Comparison of High Frequency Ultrasound and MRI. Ultraschall in Med 20 (1999) 131 – 136 © Georg Thieme Verlag Stuttgart • New York ISSN 0172-4614. 1999;
28. El-Sheikh Y, Wong I, Farrokhyar F, Thoma A, Facs F. Diagnosis of finger flexor pulley injury in rock climbers: A systematic review. Vol. 14, Can J Plast Surg. 2006.
29. Hauger O, Chung CB, Lektrakul N, Botte MJ, Trudell D, Robert Boutin RD, et al. Pulley System in the Fingers: Normal Anatomy and Simulated Lesions in Cadavers at MR Imaging, CT, and US with and without Contrast Material Distention of the Tendon Sheath 1. Vol. 217, Radiology. 2000.
30. Lucy-May Holtzhausen TDN. Elbow, Forearm, Wrist, and Hand Injuries Among Sport Rock Climbers. Clinical Journal of Sport Medicine 6:196-203. 1996;

31. J. Antoni Parellada, Avinash R. A. Balkissoon, Curtis W. Hayes, William F. Conway. Bowstring Injury of the Flexor Tendon Pulley System: MR Imaging [Internet]. 1996. Available from: www.ajronline.org
32. Zafonte B, Rendulic D, Szabo RM. Flexor pulley system: Anatomy, injury, and management. Vol. 39, Journal of Hand Surgery. W.B. Saunders; 2014. p. 2525–32.
33. Schöffl V, Strohm P, Lutter C. Efficacy of corticosteroid injection in rock climber's tenosynovitis. Hand Surg Rehabil. 2019 Oct 1;38(5):317–22.
34. 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 Feb;37(2):224–30.
35. Schöffl I, Meisel J, Lutter C, Schöffl V. Feasibility of a New Pulley Repair: A Cadaver Study. Journal of Hand Surgery. 2018 Apr 1;43(4):380.e1-380.e7.
36. Lin GT. Bone Resorption of the Proximal Phalanx After Tendon Pulley Reconstruction. 1999;
37. Arora R, Fritz D, Zimmermann R, Lutz M, Kamelger F, Klauser AS, et al. Reconstruction of the digital flexor pulley system: A retrospective comparison of two methods of treatment. Journal of Hand Surgery (European Volume). 2007;32(1):60–6.
38. Schoffl' I, Einwag F, Scho VR. Impact of "Taping" after Finger Flexor Tendon Pulley Ruptures in Rock Climbers. Journal of Applied Biomechanics, 2007; 23:52-62 © 2007 Human Kinetics, Inc. 2007;
39. Schöffl V, Lutter C, Woollings K, Schöffl I. Pediatric and adolescent injury in rock climbing. Vol. 26, Research in Sports Medicine. Taylor and Francis Inc.; 2018. p. 91–113.
40. 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.
41. Lion A, Van Der Zwaard BC, Remillieux S, Perrin PP, Buatois S. Risk factors of hand climbing-related injuries. Sport-Orthopaedie - Sport-Traumatologie [Internet]. 2015;31:160. Available from: http://dx.doi.org/10.1016/j.orthtr.2015.03.009
42. Van Middelkoop M, Rakhshandehroo S, Bruens ML, Koes BW, Bierma-Zeinstra MA. INJURIES OF THE UPPER BODY EXTREMITIES IN RECREATIONAL CLIMBERS: INCIDENCE AND RISK FACTORS. Br J Sports Med [Internet]. 2011;45:310–84. Available from: http://bjsm.bmj.com/

43. Schöffl VR, Möckel F, Köstermeyer C, Roloff I, Küpper T. Development of a performance diagnosis of the anaerobic strength endurance of the forearm flexor muscles in sport climbing. Int J Sports Med. 2006 Mar;27(3):205–11.
44. A. SCHWEIZER. BIOMECHANICAL EFFECTIVENESS OF TAPING THE A2 PULLEY IN ROCK CLIMBERS. Journal of Hand Surgery (British and European Volume, 2000) 25B: 1: 102±107. 1999;