

Hand Injuries in Rock Climbers

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Abstract

Rock climbing, whether practiced in nature on cliffs and boulders or indoors on walls made of resin and wood, has grown in popularity in recent years. An estimated five million people participate in "rocking" at least three times a year. Climbing places unique demands on the upper extremity, especially the hands. The flexor tendons and flexor pulleys are prone to sprains and ruptures. Pulley injuries occur in up to 20% of climbers. The A2 pulley of the ring finger is the most frequently injured. Most pulley injuries can be successfully treated with a week of immobilization, followed by a range of motion (ROM) exercises for one week. Isometric training on a finger board can be started once ROM exercises are painless. A return to climbing can be initiated when the climber is able to avoid grip positions that produce pain; however, the closed crimp grip should be avoided at this time. Surgical reconstruction using the technique described by Widstrom is recommended for acute injuries with clinical evidence of bowstringing. Ultrasound and MRI are the current modalities best suited for confirming clinical findings.

Rock climbing is an exciting and challenging sport that has grown rapidly in recent years. The current growth in popularity of the sport has been associated with the increase in exposure and awareness that has occurred in recent years through television coverage and

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extreme sports competition. An estimated five million people climb either indoors or outdoors at least three times a year.^{1,2} The increase in popularity of indoor climbing facilities has made the sport accessible to a larger portion of the population, especially those in the "flat lands". Climbing is not restricted to any age, race, or gender group, and as the popularity of the sport grows so does the diversity of its participants.

The unique, high demands placed upon the upper extremities during rock climbing have created, in turn, a unique set of sport-related injuries for the orthopaedic community to address and to treat. Many of these injuries, while common in rock climbers, are rare in nonclimbers and information regarding diagnosis and treatment can be limited. As the popularity of climbing continues to increase, the orthopaedic surgeon is likely to see a growing number of these difficult injuries.

Climbing

Three basic types of rock climbing are currently practiced: bouldering, top roping, and lead climbing. Bouldering is a common way people train and practice, and generally involves climbs of 15 feet or less. Climbers use mats and spotters for protection. The advantage of bouldering is that it allows for a quick repetition of climbs and for the climber to focus on specific problems. However, this approach often results in high stress and fatigue to the climber, as it involves repeated attempts at difficult moves. Additionally, bouldering falls are relatively unprotected, often occurring from above 15 feet and many times from heights equivalent to jumping two building stories to the ground.

Top roping involves climbing with a pre-placed rope that is secured at the top of the climb. Top roping allows for climbs up to about 80 feet or approximately half the distance of a standard rope, which is 165 feet. One end of the rope is secured to the climber and the other to a belayer at the bottom. The belayer uses a high friction system to

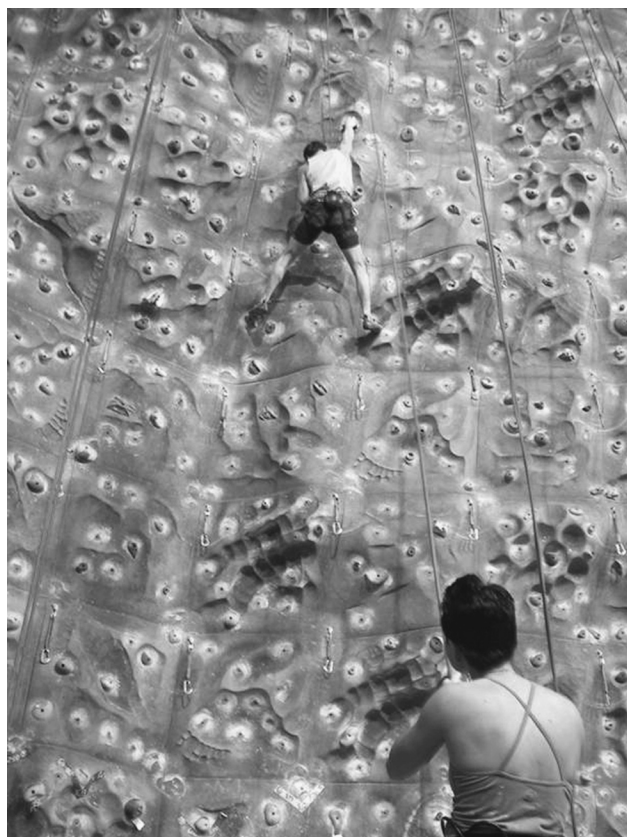


Figure 1 Top-roping in a commercial gym. The rope is always overhead, preventing long falls. The belayer on the ground controls the rope.

prevent the climber from falling. As a result, this is the safest approach for climbing, with falls generally limited to several feet. This is the type of climbing used in all climbing gyms (Fig. 1).

Lead climbing is the most advanced type of climbing and potentially the most dangerous. In lead climbing, the first climber places protection (temporary anchor points) into the rock and the second climber removes them as he climbs up behind. There is no height limitation associated with lead climbing, as with bouldering and top-roping. Although safety and assistive devices are used, high levels of skill and experience are required to prevent injury. The greatest danger with lead climbing is that falls are always twice the distance to the last piece of protection that holds securely, plus the stretch of the rope.

Holds

To understand the injuries common to rock climbers, it is important to understand the basic grip positions used to cling to holds. There are basically four grips used: 1) open grip (Fig. 2); 2) open crimp (Fig. 3); 3) pinch grip; and 4) closed crimp (Fig. 4).

The pocket grip involves inserting one or two finger



Figure 2 Open grip in a two finger isolated position. In this position, the distal interphalangeal joint is the only joint flexed.



Figure 3 Open crimp grip. The distal interphalangeal joints and metacarpal phalangeal joints are extended. High loads are conveyed to the A2 and A3 pulleys adjacent to the flexed proximal interphalangeal joints.

tips into a small pocket in the rock. These holds place an extremely large stress on one or two flexor tendons, which may be supporting the entire weight of the body. This grip is commonly associated with flexor digitorum profundus (FDP) avulsions; particularly when the climber falls and the finger or fingers remain trapped within the pocket.³ Isolated fingers can be positioned in any of the primary hand positions listed above (Fig. 5).

The crimp grip is used to maximize force against a small ledge or hand hold. In the crimp grip, the proximal



Figure 4 With a closed crimp, the thenar muscles splint the index finger and the middle finger to some degree. This places a very high load on the extended proximal interphalangeal joint of the index finger.

interphalangeal (PIP) joints are flexed to 90° and the distal interphalangeal (DIP) is fully extended or hyperextended.⁴ This is the grip commonly associated with pulley ruptures.

A pinch grip is used to pinch a small outcropping or ledge between the thumb and fingers. This grip is associated with first metacarpophalangeal (MCP) joint pain.⁵

Finally, there is crack climbing, which involves wedging the fingers or entire hand into cracks of varying size and depth that are within the climber's reach and occur as part of the topography. This type of climbing commonly involves finger tip injuries and avulsion amputations. Additionally, it has been suggested that crack climbing may be associated with the high incidence of carpal tunnel syndrome, due to the sustained position of wrist flexion.^{1,6-8}

Training

Training for competitive or even recreational climbing involves dedication and discipline. Serious climbers spend many hours in the gym; many also train at home on "finger boards." These training devices are made of polyester resin molded into different shapes to simulate natural holds. During training, the climber will hang from these holds, thereby, performing isometric exercises with weight added or subtracted to body weight. Many times, climbers will 'train through' injuries, which often leads to chronic overuse injuries. Understanding and acknowledging the dedication that climbers have to their sport will enable the physician to prescribe treatment plans with which patients are more likely to comply. The position of the fingers plays a role in the pattern of finger injury, both while climbing and training.



Figure 5 A one finger open grip is the most extreme grip position. At times a climber's entire body weight will be supported with the finger in this position.

Pulley Ruptures

Pulley ruptures are an injury unique to rock climbers. Studies of competitive climbers report a 19% to 26% incidence in population surveys.⁹⁻¹² Ruptures most commonly affect the ring finger. Much of the literature supports that the A2 pulley is first to rupture although there is some literature to support A4 being involved first.

The presenting history and physical exam findings are relatively consistent in patients after pulley rupture. Typically, patients will hear a loud pop with a feeling of giving way of the PIP joint. Generally, there is severe pain at the base of the proximal phalanx, followed several hours later by swelling and pain. Patients usually complain of pain on finger flexion. Bowstringing is best demonstrated when the finger is flexed against resistance. Clinically apparent bowstringing requires the rupture of the A2 through A4 pulleys.^{9,13,14}

Pulley ruptures occur most commonly following falls with the hand in the crimp grip position. The crimp grip maximizes contact between the finger tip and shallow ledges or holds. This position places the FDP and flexor digitorum sublimis (FDS) tendons at or near maximal contraction to resist body weight.

To best understand pulley rupture, an understanding of pulley anatomy is essential. James Doyle, in 1988, described his anatomic findings regarding the pulley system in 61 cadaver fingers.¹⁵ In a similar article, Lin and colleagues, in 1989, dissected 55 cadaver fingers and then loaded 15 of them before and after sectioning the pulleys with radiographic markers in place.¹⁶ They concluded that the pulley system includes five dense annular pulleys (A) and three thinner cruciform pulleys (C). The A2 and A4 pulleys arise

from the periosteum of the proximal and middle phalanx, respectively. The A2 and A4 function to maintain a constant relationship to the joint axis and shorten less than 25% with finger flexion. The palmer aponeurosis pulley, described by Manske and coworkers, may function in a similar fashion to the A2 and A4 pulleys.¹⁷ The A1, A3, and A5 pulleys arise from their respective volar plates. These three pulleys shorten 50% with finger flexion and play little role in the prevention of bowstringing. The cruciate pulleys serve to modulate force transmission as the finger flexes and the palmer plate moves. The pulley system functions to shorten the distance between the flexor tendon and the joint, increasing the joint motion with similar tendon excursion. Pulleys therefore maximize the moment arm upon which the flexor tendon acts.

The A2 and A4 are the most significant biomechanically. Loss of either the A2 or A4 pulley can result in a substantial loss of digital motion and power. Injury can also result in flexion contracture at the IP joints. Clinically apparent bowstringing requires the rupture of both the A2 and A4 pulleys.

Pulley strength is another significant issue when considering pulley ruptures. Manske and Lesker first tested pulley strength by loading the pulleys from ten cadaver fingers using a loop of flexor tendon with weight applied. They concluded that A1 was the most strong with a maximal breaking strength of 80.8 kg for the middle finger A1, followed by A4>A2>A3.¹⁸ Lin and colleagues performed a similar experiment using five fresh cadaver hands; however, they used a curved hook to load the pulleys in a way that more closely simulated actual pulley loading in situ. There is an order of pulley strength, A2>A4>A1>A3, which is consistent with our clinical expectations, and are based on the functions of the individual pulleys. Additionally, they found that the A2 and A4 pulleys had less deformity under similar load.¹⁹

In order to better understand pulley ruptures, Marco and coworkers loaded 21 cadaver fingers in the crimp position to failure. They found the sequence of pulley rupture was A4 first in 14 fingers, A2 first in 3 fingers, simultaneous rupture of A3 and A4 in one finger, and simultaneous ruptures of A2, A3, and A4 in one finger. From this study, they concluded that isolated pulley rupture did not produce clinically evident bowstringing. A3 never ruptured first, most likely, because it serves to transfer forces to the stiffer A2 and A4 pulleys. Finally, they found that rupture occurred with much lower forces in the ring finger, which may help to explain why the ring finger is the most commonly involved in pulley rupture.³ This study was then repeated by Warme and Brooks, using the same loading apparatus with young cadaver specimens between 20 and 47 years of age, with slightly different results. They found that 55% of the fingers failed at A2-3-4 simultaneously. Twenty-seven percent of the time A2 failed first. A4 failed first only 16% of the time.²⁰ This study, done with younger specimens, better simulates the climbing population that sustains these injuries and more closely

corresponds to what has been observed clinically.

Following a careful history and physical examination, further diagnostic studies are indicated if the diagnosis is unclear. MRI is the current gold standard. For patients with pulley ruptures, a fluid space is present between the phalanx and tendon and is seen on both sagittal and transverse cuts. The tendon sheath also may be thickened, with an accumulation of fluid present.

Computed tomography (CT) scans have also been proposed as a tool for evaluation of pulley rupture. Le Viet and coworkers studied CT scans for assessment of pulley ruptures with a small series of seven patients. The protocol imaged both affected and contralateral sides, statically and dynamically, using 1.5 mm slices. A positive test was indicated by lack of adherence of the tendon to the bone when compared with the contralateral side. The investigators also concluded that the dynamic images were superior for diagnostic purposes. They proposed that CT may offer several advantages over magnetic resonance imaging (MRI), including the ability to obtain dynamic images as well as contralateral images, the availability of thinner slices than with MRI, and cost, in that CT is less expensive. It was commented as well by the investigators that CT is less operator dependent than ultrasound.²¹

Ultrasound has also been proposed as a useful tool for evaluating possible pulley ruptures. Klauser and colleagues designed an excellent study to evaluate the role of ultrasound by comparing the images of 34 climbers with pulley injuries and 20 normal controls. Patients with 0.3 cm at rest or 0.5 cm on dynamic images of space between their flexor tendon and the phalanx were diagnosed with a pulley rupture. All positive ultrasounds were confirmed by MRI. In addition, climbers were noted to have thicker pulleys when compared with controls. In the control group, the pulley thickness was less than 0.1 cm. Relative to climbers' asymptomatic fingers, 49% had pulleys greater than 0.1 cm in thickness; in symptomatic fingers, 94% were thicker than 0.1 cm with 64% thicker than .13 cm. Additionally, unsuspected synovial cysts, thickened joint capsules, fibrous tissue, and fluid collections were seen only in climbers. Based on this study, Klauser and coworkers concluded that ultrasound was a safe and effective method to evaluate pulley ruptures. A major disadvantage of ultrasound is that it is operator dependent. Finally, the evidence of pulley thickening and changes to the sheath and joint capsules suggest that pulley rupture is likely an acute on chronic injury.^{9,13}

The treatment of pulley ruptures has not yet been clearly established. Prevention of rupture is the most important approach in this patient population. Recommendations regarding training modification and allowing full recovery after more minor injuries before returning to climbing may help reduce the incidence of pulley ruptures. Taping over the proximal and middle phalanx is a technique used by many climbers to prevent ruptures. Warme and colleagues compared two groups of cadaver fingers, one with tape and one

without, and loaded them until pulley rupture occurred. The study concluded that there were no differences in outcome between the two groups.²⁰

The initial treatment of pulley ruptures includes ice, NSAIDs, and occupational modalities. There are no clear guidelines or outcome studies regarding the indications or outcomes of operative or nonoperative treatment. Generally, for patients without clinically apparent bowstringing, a nonoperative treatment protocol is indicated. Holtzhausen and Noakes recommend one to two weeks of splint immobilization with the MPs in flexion and the IPs in extension or slight flexion, followed by a progressive range of motion and strengthening program with occupational therapy. Once the patient has completely pain free motion and 80% of their prior strength, usually at a minimum of 6 weeks, a gradual return to climbing is permitted. Patients are instructed to gradually increase the difficulty and duration of their climbs over an eight-week period. Patients are not permitted to use a crimp grip for a minimum of at least 6 weeks post-injury.⁸ Schoffl and coworkers,¹⁰ in a 2003 prospective study of 604 climbers with hand injuries, found excellent outcomes and a return to previous climbing level within one year for those without bowstringing who were treated conservatively. Climbers with complete pulley ruptures, indicated by clinical bowstringing and confirmed with ultrasound, attained the best functional outcomes with reconstruction using the technique described by Widstrom.²²

Multiple surgical techniques have been described for pulley reconstruction.²²⁻²⁵ The Kapandji technique involves mobilization of the two ends of the ruptured pulley with relaxing incisions, followed by direct repair.²⁶ The Klinert technique involves using a tendon graft woven through the remnant of the pulley.²⁵ Other techniques involve weaving free tendon graft or fascia lata graft either around the phalanx or through the phalanx. When passing graft around the proximal phalanx, the graft is placed deep to the extensor tendon, and when passing graft at the middle phalanx, it is passed superficial to the extensor tendon. Lister proposed using a portion of the extensor retinaculum for pulley reconstruction.²⁷ He concluded that the extensor retinaculum repair was strong enough to allow early motion and provides an excellent gliding surface. Multiple synthetic grafts have been proposed including Dacron, silicone rubber sheeting, xenograft and polytetrafluoroethylene, and woven nylon mesh.

Conclusion

Pulley injuries in climbers occur with a high degree of frequency yet often go undiagnosed. Untreated injuries frequently lead to chronic pain with activities of daily living and chronic, swollen PIP joints. Conservative treatment with rest, ice, taping, and gradual return to activity is indicated in those patients who lack clinically evident bowstringing. Primary surgical repair is indicated

for acute injuries with bowstringing, and reconstruction is indicated with those patients who have chronic bowstringing. Increased awareness and understanding of these injuries will allow for early diagnosis and appropriate treatment of these challenging problems.

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