Diagnosis of finger flexor pulley injury in rock climbers: A systematic review

Yasser El-Sheikh MD[1], Ivan Wong MD[1], Forough Farrokhyar PhD[1], Achilleas Thoma MD MSc FRCSC FACS[1,2]

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BACKGROUND: Closed injury to the finger flexor pulley system is found frequently in rock climbers. There are no evidence-based published guidelines on the diagnosis and treatment of these injuries.
OBJECTIVES: The present systematic review was undertaken to answer the following questions: what are the most commonly recommended diagnostic criteria for finger flexor pulley injury in rock climbers; and, based on the available evidence, what is the best diagnostic test for these injuries?
METHODS: Four electronic databases were searched using specific key terms, with limits set for language and date. Two reviewers independently identified potentially relevant titles based on inclusion criteria. Inter-reviewer variability was assessed using the Kappa statistic. The scientific quality of articles was assessed using validated scales.
RESULTS: Of the 93 articles identified, 29 were included in the present analysis. The inter-rater agreement for selection of potentially relevant titles was 88% (kappa=0.74). The most commonly cited diagnostic criterion for closed finger pulley injury was clinical bowstringing of the flexor tendons over the volar aspect of the proximal interphalangeal joint. However, the best study of diagnostic accuracy for these injuries supports the use of dynamic ultrasound.
CONCLUSIONS: Dynamic ultrasound is recommended for the diagnosis of closed finger pulley injuries in rock climbers. The prevailing notion that these injuries can be diagnosed by testing for clinical bowstringing is not supported by evidence.

Key Words: *Diagnosis; Pulley; Rock climbing; Systematic review*

Comment diagnostiquer les lésions des poulies des fléchisseurs des doigts chez les grimpeurs? Examen méthodique de la documentation

CONTEXTE : Les lésions fermées des poulies des fléchisseurs des doigts sont fréquentes chez les grimpeurs. Pourtant, il n'existe pas de lignes directrices publiées, fondées sur des preuves concernant le diagnostic et le traitement de ce type de lésion.
BUTS : Le présent examen systématique visait à répondre aux deux questions suivantes : quels sont les critères de diagnostic recommandés le plus souvent en ce qui concerne les lésions des poulies des fléchisseurs des doigts chez les grimpeurs, et, compte tenu des données probantes existantes, quels examens de diagnostic conviennent le mieux?
MÉTHODE : Une recherche a été effectuée dans quatre bases de données à l'aide de certains mots clés ainsi que de restrictions quant à la langue et aux dates. Deux examinateurs ont relevé, chacun de leur côté, les titres qui leur semblaient pertinents en fonction des critères de sélection. La concordance entre les examinateurs a été évaluée à l'aide de l'analyse statistique Kappa, et la qualité scientifique des articles, à l'aide d'outils validés.
RÉSULTATS : Sur 93 articles relevés au départ, 29 ont été retenus en vue de la présente analyse. La concordance entre les examinateurs en ce qui concerne la sélection des articles pertinents s'élevait à 88 % (Kappa=0,74). Le critère de diagnostic le plus souvent mentionné pour reconnaître les lésions fermées des poulies des fléchisseurs des doigts était la compression clinique des tendons fléchisseurs sur la face antérieure de l'articulation interphalangienne proximale. Cependant, l'étude la plus sérieuse sur la fiabilité diagnostique dans le contexte étayait plutôt le recours à l'échographie dynamique.
CONCLUSIONS : L'échographie dynamique est l'examen recommandé pour le diagnostic des lésions fermées des poulies des fléchisseurs des doigts chez les grimpeurs. L'idée selon laquelle ces lésions peuvent être diagnostiquées à partir du test de la compression clinique n'est étayée par aucune donnée probante.

Modern sport rock climbing started in the late 1970s and has rapidly gained in popularity over the past 15 years. With the advent of indoor climbing gyms and more reliable safety equipment, the sport has become more accessible, particularly to people in large urban centres. In 1988, there were three climbing gyms in the United States. Today, there are more than 700 climbing gyms and an estimated one million climbers in the United States alone (1).

Sport rock climbing differs from mountaineering in that it puts less emphasis on adventure and danger and focuses more on training, strength and technique. As a result, it is associated with fewer traumatic injuries and more upper limb soft tissue injuries than traditional mountain climbing. A survey (2) of elite competitive rock climbers in the United States found that 95% had upper limb soft tissue injuries and 63% of these were found in the hand. Twenty-six per cent of these climbers were found to have flexor pulley injuries, which were thought to be A2 pulley tears (2).

Closed injury of the finger flexor pulley system is a pathology found most commonly in rock climbers. It was first described in 1988 by Bollen (3) and has come to be known as 'climber's finger'. Bollen reported on the prevalence of upper limb soft tissue injuries in rock climbers at the time and was the first to suggest that A2 pulley disruption was associated with the 'crimp' grip used by climbers. The crimp grip is used by most climbers when grasping small holds. It involves pressing the volar aspect of the distal phalanges of the fingers onto the hold, with the distal interphalangeal joints hyperextended and the proximal interphalangeal (PIP) joints held in approximately 90 degrees of flexion (Figure 1).

[1]Department of Surgery and [2]Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Ontario
Correspondence: Dr Achilleas Thoma, Division of Plastic Surgery, Department of Surgery, McMaster University, 101-206 James Street South, Hamilton, Ontario L8P 3A9. Telephone 905-523-0019, e-mail athoma@mcmaster.ca

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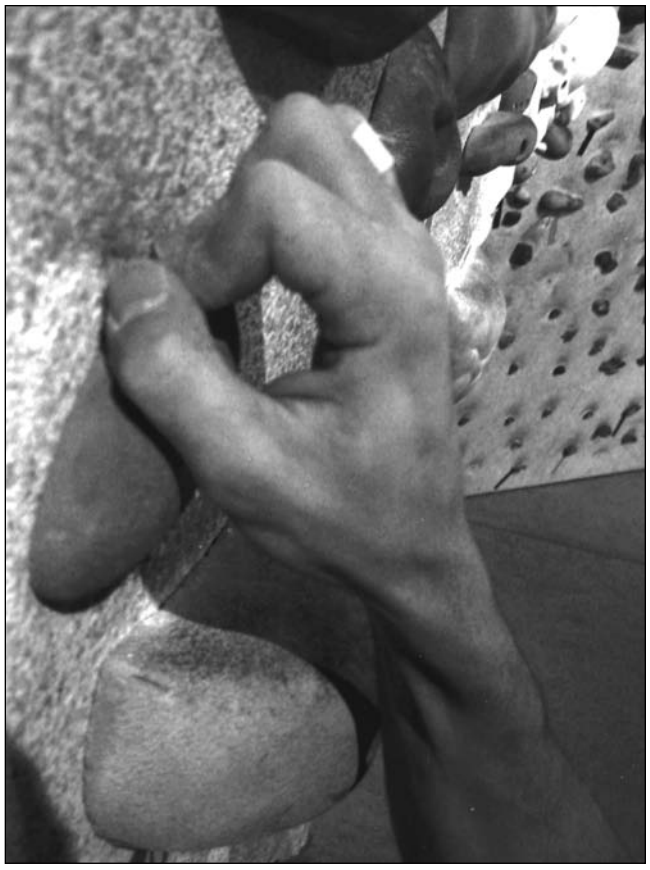

Figure 1) *A climber's right hand grasping a hold using the 'crimp' grip. This gripping technique is used by most climbers when grasping small sharp holds. Crimping involves pressing of the volar aspect of the distal phalanges of the fingers onto the hold with the distal interphalangeal joints hyperextended and the proximal interphalangeal joints held in approximately 90 degrees of flexion. The crimp grip is thought to be responsible for the finger flexor pulley injuries found in rock climbers*

While the body of descriptive literature on closed finger flexor pulley injury in rock climbers is growing rapidly, there are very few published clinical trials evaluating management strategies for this condition. As a result, it is not clear what the diagnostic criteria and best treatment for this clinical entity are. This systematic review was undertaken to answer the following questions:

1. What tests have been cited in the literature for the diagnosis of finger pulley injuries in rock climbers?
2. What is the best test for the diagnosis of finger pulley injuries in rock climbers and what is the quality of evidence to support its use in clinical practice?
3. What is the overall scientific quality of the literature to date on finger flexor pulley injuries in climbers?

It is hoped that answering these questions will provide valuable information for use in future investigations evaluating treatment options for finger flexor pulley injuries in rock climbers.

METHODS

Literature search

A systematic review was conducted through a literature search of the following computer databases: MEDLINE/PubMed, EMBASE, Cinahl and Sport Discus. Searches were performed combining the term "rock climbing" with "A2 pulley", "finger injury", or "tendon injury". In Sport Discus, the above-mentioned key terms yielded zero articles, so "rock climbing" was combined with "finger" or "tendon". In PubMed, the "related articles" function was used within the combined search described above. Search limits included language (English only) and date published (1980 to 2004).

Inclusion criteria

Two reviewers (YE and IW) independently scanned the titles yielded by the above searches to identify potentially relevant papers. Inclusion criteria for titles of potential relevance were: mention of "rock climbing" or "A2 pulley" and "injury" in the title; or any title that was too ambiguous to indicate the paper's relevance to the present study questions. Because it was suspected that the studies yielded by the search would be heterogeneous in design, it was decided that study design, participants, interventions or outcomes would not be specified in the inclusion criteria, to capture all the published articles on pulley injuries in climbers.

Inter-reviewer variability was assessed using the Kappa statistic. Any disagreement between reviewers regarding article relevance was resolved through discussion and review of the abstract. A third reviewer (AT) was available to resolve any disagreement if consensus could not be reached.

Methodological quality assessment

Methodological quality of the selected papers was assessed using well-validated, design-specific tools.

Studies of diagnostic accuracy were assessed independently by two different reviewers (YE and IW) using the tool for Quality Assessment of Studies of Diagnostic Accuracy Included in Systematic Reviews (QUADAS) (4). For overview papers, quality assessment was performed using Oxman's Overview Quality Assessment Questionnaire (5). The quality of comparative studies was assessed using the scale developed by van Tulder et al (6).

RESULTS

The search of four electronic databases yielded 93 article titles. Of these, 35 potentially relevant articles were selected and reviewed. There was disagreement on potential relevance in 11 of these articles. After discussion, consensus was reached to include six of them. This left 30 articles to be read in their totality. The inter-rater agreement for selection of potentially relevant titles was 88% (kappa=0.74), indicating very good interobserver consistency.

The 30 remaining articles were read and it was decided to exclude one because it was a letter summarizing results from another paper (7). This left 29 papers from which to extract data for the present analysis (2,3,8-34). Two papers were studies of diagnostic accuracy (18,19). The remainder of the articles included seven reviews (10,13,15-17,24,34), two case studies (8,9), eight comparative studies (12,14,22,23,27,28,30,31), and 10 noncomparative studies (2,3,11,20,21,25,26,29,32,33), of varying quality. The findings are presented below in three sections corresponding to the three research questions.

Question 1: What tests have been cited in the literature for the diagnosis of finger flexor pulley injury?

Of the 29 reviewed articles, 20 described diagnostic criteria for finger flexor pulley injury (Table 1). The most commonly cited criterion was clinical bowstringing of the flexor tendons across the PIP joint on physical examination. This sign was mentioned in 13 papers but no studies of diagnostic accuracy to

TABLE 1
Summary of criteria recommended for the diagnosis of a finger flexor pulley injury

	Diagnostic criteria cited			
Reference	Clinical bowstringing	U/S	CT	MRI
Schoffl et al, 2003 (26)		+		+
Klauser et al, 2002 (19)		+		
Rohrbough et al, 2000 (2)	+			
Klauser et al, 1999 (18)		+		
Gabl et al, 1998 (14)				+
Marco et al, 1998 (21)	+			
Rooks, 1997 (24)	+			
Holtzhausen and Noakes, 1996 (16)				+
Wyatt et al, 1996 (33)	+			
Haas and Meyers, 1995 (15)	+			
Bollen, 1990 (9)	+			
Bollen, 1990 (10)	+			
Bollen, 1988 (3)	+			
Yates, 1998 (34)	+			
Jebson and Steyers, 1997 (17)			+	+
Bollen and Gunson, 1990 (11)	+			
Clemes, 1993 (13)	+			
Schweizer, 2000 (27)			+	+
Schweizer, 2001 (28)	+			
Warme and Brooks, 2000 (31)	+			
Total	13	3	2	5

CT Computed tomography; MRI Magnetic resonance imaging; U/S Dynamic ultrasound

TABLE 2
Quality scoring of studies of diagnostic accuracy using the tool for Quality Assessment of Studies of Diagnostic Accuracy Included in Systematic Reviews*

Criteria	Klauser et al, 2002 (19)	Klauser et al, 1999 (18)
Representative patients	Yes	Yes
Selection criteria described	Yes	No
Accurate reference standard	Yes	Yes
Reasonable time between reference and index tests	Yes	Unclear
Whole sample or random selection of sample received reference standard test	No	No
Patients received same reference test regardless of index test results	Yes	No
Reference test independent of index test	Yes	Yes
Index test described	Yes	Yes
Reference test described	Yes	No
Index test interpreted blindly	Yes	Unclear
Reference test interpreted blindly	Yes	Unclear
Results interpreted in light of clinical data that would be available in clinical practice	Yes	Yes
Uninterpretable/intermediate results reported	Yes	Yes
Withdrawals explained	Yes	Yes
Scientific quality score	13/14	8/14

**An explanation of the tool for Quality Assessment of Studies of Diagnostic Accuracy Included in Systematic Reviews is found in reference 4*

support its use were found. The next most commonly cited diagnostic test was magnetic resonance imaging (MRI), mentioned in five papers. Other tests recommended were dynamic ultrasound and computed tomography, cited in three papers and two papers, respectively.

Question 2: What is the best test for the diagnosis of finger flexor pulley injury, and what is the quality of evidence to support its use in clinical practice?

Of the 29 articles included in the present study, two were studies of diagnostic accuracy. Both studies were conducted by Klauser et al (18,19) and evaluated dynamic ultrasound in the diagnosis of finger flexor pulley injuries in rock climbers. Table 2 shows a breakdown of the QUADAS scoring for scientific quality of these two studies. Table 3 summarizes the design and findings reported in the two studies of diagnostic accuracy included in the present analysis.

In 1999, Klauser et al (18) looked at the ability of dynamic ultrasound to differentiate between the fingers of 34 extreme rock climbers and 20 healthy control subjects. They found significantly increased flexor tendon thickness, flexor pulley thickness and phalanx-to-flexor tendon distance in the fingers of the rock climbers compared with controls. This paper was of poor scientific quality, however, with a QUADAS score of 8/14.

In 2002, the same group conducted a well-designed study to again assess the accuracy of dynamic ultrasound in diagnosis of finger flexor pulley injury in extreme rock climbers (19). Using MRI as the reference standard, they found an overall sensitivity of 98% and specificity of 100% for dynamic ultrasound in the diagnosis of 15 incomplete and 16 complete A2 pulley injuries, nine complete A4 pulley injuries and seven surgically proven complete combined A2/A3 pulley injuries in 64 rock climbers (19). Furthermore, subgroup analysis revealed that dynamic ultrasound detected a significant difference in phalanx-to-flexor tendon distance in normal fingers and groups with each of the four injury patterns mentioned above ($P<0.001$) (19). This study was of high scientific quality, with a QUADAS score of 13/14.

Question 3: What is the methodological quality of the literature to date on finger flexor pulley injury in climbers?

Overall, the scientific quality of the research published to date on this subject is very low. Using Oxman's scientific quality assessment tool for review studies, the seven reviews in the present study had scores ranging from 0/9 to 1/9. Using van Tulder's scientific quality assessment tool for comparative studies, the eight comparative studies included in the analysis had scores ranging from 4/18 to 9/18. Using the QUADAS tool for assessment of studies of diagnostic accuracy, the two papers in this category scored 8/14 and 13/14 (Table 2). The latter was the Klauser et al 2002 study (19) evaluating dynamic ultrasound, which represents the only high-quality study found in the present review.

The remaining original studies included 10 noncomparative studies and two case studies, all of which did not possess the basic elements of an experiment. Because they were noncomparative studies, they could not be evaluated using van Tulder's tool. They are considered to be of poor quality in terms of strength of scientific evidence.

TABLE 3
Summary of studies of diagnostic accuracy for finger flexor pulley injury

Reference, QUADAS score	Subjects	Index test	Reference test	Results
Klauser et al, 2002 (19) QUADAS* score: 13/14	64 extreme climbers	Dynamic U/S: >1 mm between phalanx and flexor tendon: positive test	MRI for all symptomatic patients; surgical findings for seven patients	U/S differentiated incomplete, complete and complete combined pulley tears (sensitivity 98%, specificity 100%)
Klauser et al, 1999 (18) QUADAS* score: 8/14	34 extreme climbers, 20 healthy controls	Dynamic U/S: any measurable distance between phalanx and flexor tendon: positive test	MRI in suspected pulley rupture (ie, >3 mm at rest or >5 mm during forced flexion)	Significant difference in tendon and pulley thickness, and in distance between phalanx and flexor tendon in climbers versus controls

**An explanation of the tool for Quality Assessment of Studies of Diagnostic Accuracy Included in Systematic Reviews (QUADAS) is found in reference 4. MRI Magnetic resonance image; U/S Ultrasound*

DISCUSSION

Of the 29 papers we reviewed, 20 recommended a diagnostic test for closed finger flexor pulley injury in rock climbers. Clinical bowstringing over the volar aspect of the PIP joint on physical examination was mentioned in 13 papers (2,3,8-11,13,15,21,24,31,33,34) and, therefore, represented the most commonly recommended diagnostic criteria. Our findings suggest that the prevailing thought in the literature regarding diagnosis of these injuries in climbers is misleading for several reasons.

First, bowstringing is found in magnitudes ranging from 0.5 mm for an isolated partial pulley rupture to 8 mm in some complete combined ruptures (35). With the swelling and pain present in the acute phase of this injury, it is conceivable that many of the less severe lesions in the spectrum of this pathology will be missed on clinical examination. In fact, Marco et al (21) found that isolated or combined rupture of the A2 and A4 pulleys did not result in detectable bowstringing, as visualized by fibreoptic camera in cadaver fingers. Only combined ruptures that included the A3 pulley resulted in either subtle or obvious bowstringing over the PIP joint. Second, a high-quality study of diagnostic accuracy that tests clinical bowstringing against an acceptable reference standard test has yet to be conducted.

Klauser et al (18,19) published two studies evaluating the accuracy of dynamic ultrasound in the diagnosis of finger flexor pulley injury in rock climbers. Their first study in 1999 (18) demonstrated that this modality was able to differentiate between the fingers of rock climbers and normal healthy controls. Significant differences were measured in flexor tendon thickness and pulley system thickness. Furthermore, only in climbers was there an increase in the distance between phalanx and tendon from 0.14 cm (+0.07 cm) to 0.30 cm (+0.09 cm) during forced flexion, which was thought to represent chronic reparative changes. In three climbers with complete A2 pulley ruptures, this distance was as high as 0.51 cm (+0.15 cm). These findings represented convincing preliminary evidence of the accuracy of dynamic ultrasound, but without comparison of index test results to a reference standard, the study received a poor QUADAS score for scientific quality (8/14) and cannot be considered good evidence.

In 2002, Klauser et al (19) published a second paper to determine the accuracy of dynamic ultrasound in diagnosis of finger pulley injury in rock climbers. This time, dynamic ultrasound was compared with MRI in all 75 symptomatic fingers in the study. Surgical correlation was available in seven patients who were given an MRI diagnosis of complete combined A2/A3 pulley rupture and underwent surgical repair. Dynamic ultrasound depicted 100% of complete A2 and A4 pulley injuries, 86% of surgically proven complete combined A2/A3 pulley and 100% of incomplete A2 pulley ruptures (19). Overall sensitivity and specificity of dynamic ultrasound for identification of finger pulley injuries was 98% and 100%, respectively (19). This study received an excellent QUADAS score (13/14) and represents the best evidence to date for a diagnostic test of finger pulley injury in rock climbers.

The 2002 study by Klauser et al (19) did not receive a perfect QUADAS scientific quality score because the investigators failed to perform the same reference test on all patients. As previously described, all patients had MRI evaluation of their injuries but surgical correlation of dynamic ultrasound findings was only available for the seven patients found to have sonographic and MRI evidence of complete combined A2 and A3 pulley ruptures. Differential application of the reference test to patients in this study introduces verification bias, which means that Klauser's results may overestimate the accuracy of the index test (dynamic ultrasound).

In studies where verification bias has been introduced, investigators can construct an alternative reference standard to be applied to patients with negative or low probability index test results. For example, long-term follow-up can be performed on these patients to see if they develop clinical evidence of disease progression. For finger flexor pulley injuries, however, this would not work well because the clinical findings are nonspecific. Also, less severe injuries can resolve with time rather than progressing.

In the 2002 study, Klauser et al (19) used MRI as an alternative reference standard test that was applied to all the patients in their study. Although its accuracy has not been tested against surgical findings in climbers' fingers specifically, Hauger et al (35) found MRI to be 100% sensitive and specific for simulated A2 and A4 injuries in cadaver fingers. These findings suggest that although tissue diagnosis (ie, surgical findings or biopsy) is the ideal reference standard, MRI may be a valid alternative when practical considerations preclude the availability of surgical correlation. Therefore, though not perfect, the 2002 study by Klauser et al (19) represents the best evidence to date for the diagnosis of closed finger flexor pulley injuries in rock climbers.

Our final objective was to determine the overall scientific quality of the literature to date on finger pulley injuries in rock climbers. As previously stated, there were two studies of diagnostic accuracy included in the present review (18,19). These studies, conducted by Klauser et al in 1999 and 2002, received scores of 8/14 and 13/14 respectively, using the QUADAS tool for scientific quality assessment in studies of

diagnostic accuracy. The latter of these two studies represents the only high-quality paper read in the present review (18,19).

The seven review papers we assessed, using Oxman's criteria for scientific quality of reviews, received scores ranging from 0/9 to 1/9. Most of these papers were strictly descriptive in nature and did a poor job of reporting items such as inclusion criteria, search methodology and methods for combining of data.

The eight comparative studies we assessed using van Tulder's criteria for scientific quality of comparative studies also scored poorly. These papers received scores ranging from 4/18 to 9/18. The remaining studies consisted of 10 noncomparative studies and two case studies. These studies could not be assessed using van Tulder's tool because it was validated for comparative studies only. Many of van Tulder's assessment criteria were therefore not applicable to these pre-experimental studies. Nonetheless, the lack of a comparison group makes all 12 of these studies poor quality in terms of strength of scientific evidence.

While it was not the aim of the present review to determine the best treatment for pulley injuries in climbers, a study was found that likely represents the prevailing thought on the management of these lesions (26). Schoffl et al (26) suggested conservative treatment for strains, partial ruptures or complete isolated ruptures (ie, grades 1 to 3), quoting earlier work that consistently shows good functional results with rest, ice, anti-inflammatories and return to easy sport-specific activity with circumferential taping over the proximal phalanx (26). Surgical repair was recommended for complete combined rupture (ie, grade 4) (26). It has been suggested that grade 4 injuries are more likely to result in fixed flexion contractures in the long term if they are treated conservatively (2).

A high-quality, randomized control trial has yet to be conducted comparing conservative treatment with surgical repair of finger pulley injuries in rock climbers. Future studies should aim to compare quality of life, functional and radiographic outcomes in patients with pulley injuries treated conservatively and surgically. The findings of the present review suggest that dynamic ultrasound is a highly accurate test for the diagnosis of pulley incompetence. We therefore recommend that it be used in future studies and in clinical practice, when assessing patients with this interesting and increasingly common condition.

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