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Review

Assessing Finger Flexor Pulley Injuries in Climbers: A Comprehensive Review of Clinical and Functional Testing Methods

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Abstract: Objectives: This systematic review addressed the following questions: what are the most recommended diagnostic criteria for pulley injuries in finger flexors among climbers? What is the best functional or classification clinical test for these injuries based on the available evidence? Materials and Methods: Following the PRISMA Statement checklist, a systematic literature review was conducted between August and September 2023, using a search on the PubMed database with a string of keywords and MeSH terms. The PEDro scale was used to analyze bias in the individual studies examined. Conclusions: Based on the exclusion criteria and research question, 14 articles with heterogeneous study designs were selected. Studies involving diagnosis through clinical examination or instrumental tests were analyzed. The data obtained provide an overview of different diagnostic and classification criteria for the injury under consideration. Ultrasounds remain the gold standard in diagnosing finger pulley injuries. The distance between the tendon and bone is the most used diagnostic criterion, with a distance greater than 2 mm corresponding to an A2 or A4 pulley injury. The clinical sign of bowstringing coincides with a multiple pulley injury involving A2, A3, and A4. Clinical signs, ultrasounds, and grip strength should be evaluated for a comprehensive diagnosis. A grip deficit of 41.4% corresponds to a pulley injury.

Keywords: climbers; sport

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1. Introduction

Rock climbing, an activity with roots in mountaineering, has evolved from exploration to a popular Olympic sport. It combines physical and mental challenges, requiring climbers to ascend vertical walls and rocks [1]. Making its Olympic debut in Tokyo 2021, climbing also featured in Paris 2024 and will feature in Los Angeles 2028, with disciplines like speed climbing, lead climbing, and bouldering gaining traction [2]. The sport's rise in popularity is seen in the growth of indoor climbing centers, making it accessible to a broader audience [3].

Climbing poses significant demands on the body, particularly the hands and fingers. The annular pulleys in the fingers are especially prone to injury due to the intense loads during climbing [4]. This thesis investigates various methods for diagnosing finger pulley injuries, focusing on the complex pulley system that enables efficient finger movement [5–7]. The system includes fibro-osseous sheaths through which tendons glide, with pulleys keeping the tendons close to the phalanges, allowing effective force transfer and preventing lateral tendon movement [8,9]. The pulleys in the fingers play a crucial role in keeping the flexor tendons close to the bones, preventing bowstringing, which can result in a loss of strength and range of motion. Each finger, except the thumb, has nine pulleys: five annular (A1–A5) and three cruciate (C1–C3). Pulleys A2 and A4 are the most robust, directly attaching to the bones, while A1, A3, and A5 attach to the volar plate rather than the bone [10]. The cruciate pulleys are located between the annular pulleys, ensuring the tendons remain aligned [11,12]. The lumbrical muscles, although small, are significant in evaluating injuries to the finger pulley system due to their proximity to the flexor tendons. The growing popularity of climbing has increased the technical and physical demands on the fingers, leading to greater stress on bones, joints, and soft tissues.

When climbing, a significant amount of body weight is often supported by the distal phalanx on small holds or pockets, sometimes just a few millimeters deep [12]. Climbers use various hand positions depending on the type of hold, with the most common being the crimp grip (which includes both half and full crimp) and the sloped grip [13]. The sloped grip is typically used for sloping holds and involves flexing the proximal interphalangeal joint (PIP) by about 50° and the distal interphalangeal joint (DIP) by around 20–30°, which is considered safer for the A2 pulley [14,15].

Table 90 of climbers, involves flexing the DIP joint between 90° and 100°, with the PIP joint in maximal hyperextension to grip small edges [16]. The full crimp position differs from the half crimp in that the thumb is actively used, resting over the first distal phalanx, sometimes partially over the second, which increases stress and the risk of injury to the finger [13]. The crimp grip also causes the wrist to extend slightly, adding to the force exerted by the flexor tendons, with additional ulnar deviation and supination of the carpal joint leading [1,2]. The first description of this type of injury was in a case report 1990 [10,17,18]. Over the years, documentation regarding finger pulley injuries in climbers has increased [9,12,14,16,19]. The fourth finger (ring finger) is the most affected, followed by the third finger (middle finger). The most frequently reported finger injury is the isolated A2 pulley lesion. The distal part of the A2 pulley starts to open, and the injury can progress to a complete or partial lesion, even before involving other pulleys. Biomechanical studies suggest that pulley injuries are more likely to occur when eccentrically loaded. In fact, patients with this injury report feeling a "pop" in the finger as soon as they lose foothold, and the entire body weight is loaded eccentrically on the finger, causing an injury. The etiology of these injuries is multifactorial and often associated with a combination of factors: frequency, intensity of training, grip type, and technical movement type influence susceptibility to pulley injuries. Insufficient recovery between climbing sessions can contribute to the accumulation of damage and lower the breaking threshold of the pulleys [13].

2. Methods

This systematic review was conducted following the PRISMA Statement checklist [20].

2.1. Eligibility Criteria

This systematic review was structured following the P.I.C.O. model as outlined below:
(P) Population: Rock climbers;
(I) Intervention: Diagnosis for finger flexor pulley injury.
(C) Comparison: None or diagnostic imaging.
(O) Outcome: Identification of finger flexor pulley injury diagnostic criteria (Figure 1).

2.2. Inclusion Criteria

This review included studies on diagnosing finger flexor pulley injury in rock climbers. The research scope of this study was not broad enough to allow for specific article type selection. Therefore, observational studies, case reports, case series, cross-sectional studies, and reviews specifically outlining protocols for future studies were included. There were no restrictions on the publication dates of the included studies.

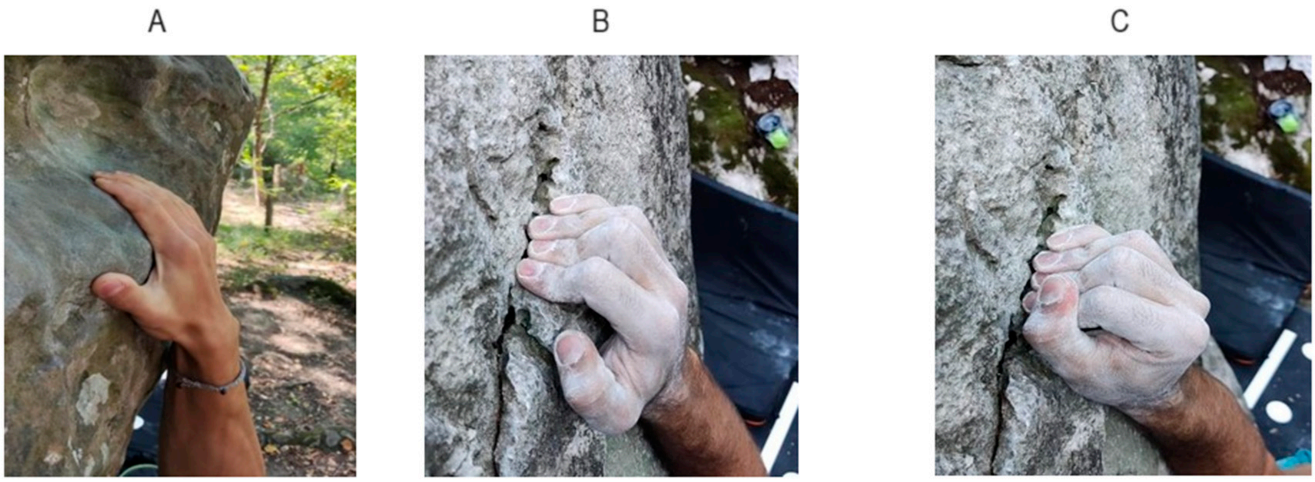

Figure 1. Panel (**A**) represents the slope grip, panel (**B**) the half crimp, and panel (**C**) the full crimp.

2.3. Exclusion Criteria

The searches were conducted until 15 September 2023. The database was PubMed, employing an advanced search strategy with MeSH and free-text terms. The search string used was as follows:

- Studies with the following characteristics were excluded:
- Articles that broadly discussed finger pulley injury without specifying the diagnosis.
- Articles not related to the review topic.

2.4. Study Search

((((((“pulley injuries”) OR pulley rupture) OR A2 finger flexor pulley) OR A2 pulley) OR A4 finger flexor pulley) OR flexor tendon) AND ((((((diagnosis) OR diagnostic) OR classification) OR bowstringing) OR “physical examination” [MeSH Terms]) OR “Finger Injuries/diagnosis” [MeSH Terms]) AND ((((“sport climbers”) OR “rock climbers”) OR climbing) OR “Mountaineering/injuries” [MeSH Terms]).

No additional filters were used.

2.5. Study Selection

The study selection was carried out individually by a single reviewer, following the process of Study Identification, Screening, Eligibility, and Inclusion. The remaining studies underwent title screening, excluding irrelevant ones. The eligibility process involved reading the abstract and, if necessary, the full text; studies not meeting the inclusion criteria were excluded. Finally, the remaining studies were used in this review. The entire selection process was outlined using the PRISMA Statement Flow Diagram.

2.6. Data Collection Process and Type of Extracted Data

Data were collected by a single reviewer, involving the full-text reading of each article and manual entry of items into Table 1. The following information was extracted from the studies: the first author’s name and publication date, the type of sample used in the study design, the study’s objective, the method used to diagnose the injury, the measurement or clinical examination method, and the results.

Table 1. Methods and results of the reviewed studies.

Article	Sample	Objective	Diagnostic Method	Methods	Outcome ±DS (Range)
Klauser et al. [21] 2002	34 climbers with injury; 20 normal (control group)	TBD	US 10 MHz (gel pad)	Measurement of TBD at rest and with active flexion	(a) CR A2: Rest: 3.1 ± 0.05 mm AFF: 5.1 ± 0.15 mm
Bodner et al. [22] 1999	32 patients (29 climbers, 3 non-climbers); control group (10 non-climbers)	Diagnosis of pulley injury with dynamic ultrasound compared to MRI	US 10 MHz (silicon pad) MRI	Measurement of TBD at rest and with active flexion	(a) CR A2: Rest: 3.1 (3.1–4.5) mm AFF: 5.1 (3.9–7) mm (b) PR A2: Rest: 1.7 (1.4–2) mm AFF: 2.2 (1.8–3) mm
Klauser et al. [21] 2002	64 climbers with injuries to pulleys A4 and A2	Diagnosis of pulley injury with dynamic ultrasound compared to MR	US 12 MHz (gel pad) RMN	Measurement of TBD at rest and with active flexion	(a) CR A2: Rest: 2.8 ± 0.7 (1.1–3.3) mm AFF: 4.6 ± 0.6 (3.0–4.9) mm (b) PR A2: Rest: 0.9 ± 0.7 (0–2.2) mm AFF: 1.5 ± 0.6 (1.0–3.1) mm (c) CR A4: Rest: 1.5 ± 0.4 (1.1–2.0) mm AFF: 3.1 ± 0.5 (2.5–3.7) mm
Schöffl V. et al. [19]. 2003	604 climbers	Pulley injury score	US 7.5 MHz (water tube) RMN optional		(a) CR A2: >2 mm (b) PR A2: <2 mm (c) CR A4: >2 mm (d) PR A4: <2 mm
Schöffl I. et al. [23] 2017	14 cadaver hands	Diagnosis of A2, A4, and A3 challenging	US 14 MHz	Measurement of TBD with active flexion (10 = N)	(a) CRA2 AFF: 1.9 mm (b) CR A2 AFF: 3.7 mm (c) CR A4 AFF: 1.8 mm (d) CR A4 AFF: 2.7 mm
Xeber I. et al. [24] 2023	30 fingers in vitro randomly assigned to 5 groups (G1–G5)	Diagnosis of partial A2 pulley injury	US 22 MHz (US gel)	Measurement of TBD for each group	G1: 0.95 mm (0.77–1.33) G2: 2.11 mm (1.78–2.33) G3:

2.7. *Risk of Bias in Studies*

The assessment of the risk of bias for each study was carried out by a single reviewer using the PEDro scale. This scale has proven to be a valid tool for measuring the methodological quality of clinical trials in physiotherapeutic interventions. The PEDro scale comprises 11 items, with only ten assigning points. Criterion 1 is related to external validity (or the "applicability" of the study) and is not used to calculate the score. Criteria 2 to 9 are related to the study's internal validity, and criteria 10–11 are related to the adequacy of statistical information. One point is assigned each time the response is "Yes" to the presence of a criterion within the study; the maximum score is 10.

3. Results

The initial search yielded 104 studies; two studies [22,25] were added through additional bibliography exploration in another article [13]. Subsequently, after reviewing the titles and abstracts, 86 articles were excluded. Following the full-text reading of the remaining 20 studies, 14 were deemed eligible, all in English and meeting the predefined inclusion criteria. The PRISMA Flow Diagram (Figure 2) depicts the entire research pathway, detailing the number of studies analyzed and the reasons for their exclusion.

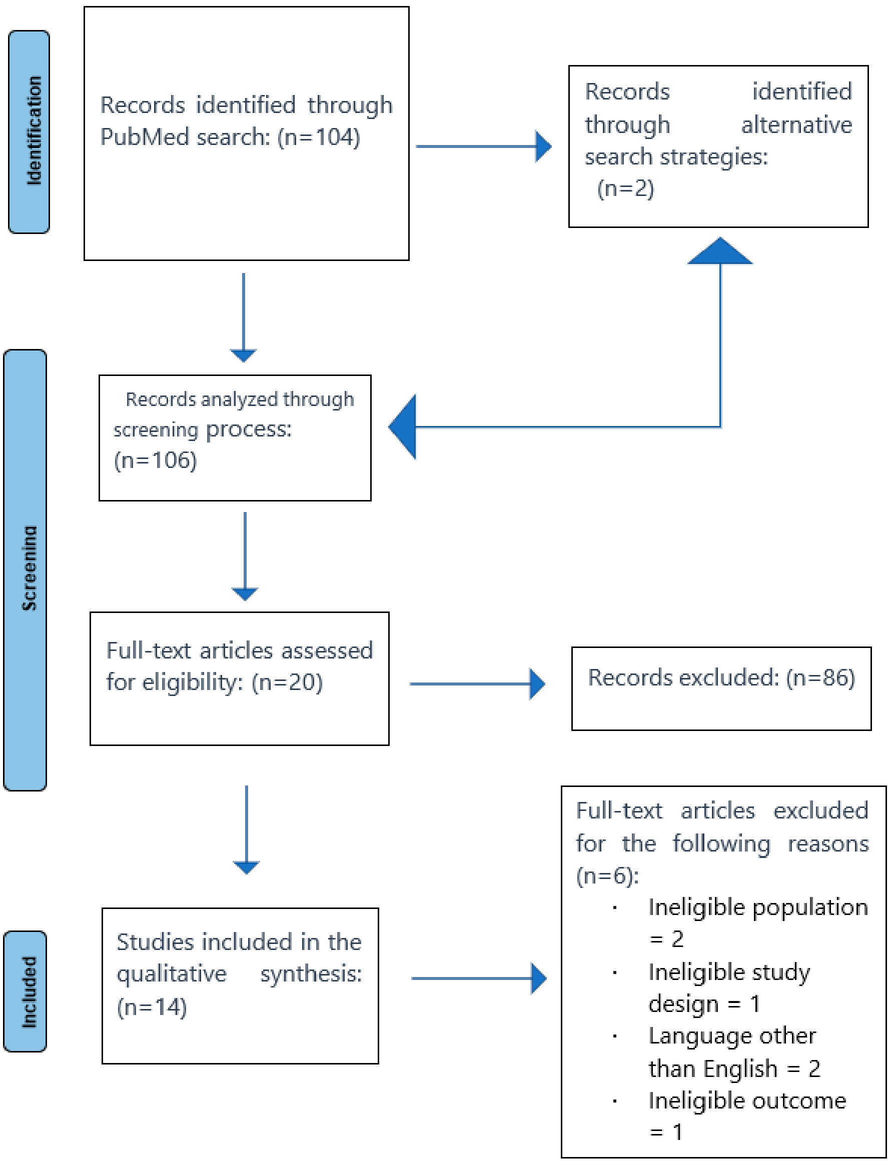

Figure 2. PRISMA Flow Diagram.

4. Characteristics of the Studies

In Table 1, the selected studies in the research are divided into two groups based on the type of diagnostic method: studies with instrumental evaluation are highlighted in light blue, while those with clinical examination evaluation are in light green. Ultrasounds are the gold standard for diagnosing finger flexor pulley injuries [23,26]. Many studies have focused on A2 and A4 pulley injuries as they are the most affected, making the diagnosis of A3 pulley injuries more challenging. The tendon-to-bone distance (TBD) has been used as a diagnostic reference, representing the distance between the flexor tendon and the phalanx. Following pulley injury, the mechanical property of the pulley to keep the tendon adjacent to the bone is lost, leading to a proper distribution of flexion force. An increased TBD, whether due to the severity of the injury or damage to multiple pulleys, can manifest as evident bowstringing during clinical examination.

5. Articles with Instrumental Evaluation

In the study by Klauser et al. (2002), a sample of 64 climbers with A2 and A4 pulley injuries was examined using a 12 MHz ultrasound. The aim was to determine if ultrasounds could detect pulley injuries compared to magnetic resonance imaging (MRI). The tendon-to-bone distance (TBD) was used as an indicator, measured at rest and during active flexion with resistance. A TBD greater than 1.0 mm was interpreted as a lesion. Ultrasounds detected 100% of complete A2 pulley lesions, 100% of A4 pulley lesions, and 100% of incomplete A2 pulley lesions. The study concluded that dynamic ultrasounds excellently illustrate pulley injuries in climbers with a sensitivity of 98% and a specificity of 100% [21]. Schöffl V. et al. (2003) conducted a prospective study on 604 climbers with hand injuries, classifying pulley injuries based on severity (scored from 1 to 4) by measuring TBD with ultrasound. Pulley injuries were the most frequent in this sample, with 39% Grade 1, 25% Grade 2, 30% Grade 3, and 6% Grade 4. Grades 1 to 3 responded well to conservative treatment, while Grade 4 required surgical repair [19]. Bodner et al. (1999) aimed to assess the accuracy of ultrasounds and MRI in diagnosing complete finger flexor pulley injuries. In a prospective study, 32 patients with suspected pulley injuries were evaluated using ultrasound and MRI, with a control group of 10 volunteers. Complete annular pulley injuries were diagnosed by ultrasound and MRI in 14 cases, confirmed by surgery. A TBD of 3 mm at rest and 5 mm with actively flexed fingers indicated complete pulley injury [22]. Klauser et al. (1999) dynamically examined 34 climbers with finger injuries using ultrasounds, comparing them with 20 healthy volunteers. Climbers' finger tendons were thicker than those of volunteers, demonstrating significant tendon stiffness. TBD was measured, confirming the validity of ultrasounds in diagnosing pulley injuries [27]. Schöffl I. et al. (2017) analyzed 34 cadaver fingers via ultrasound with constant forced flexion to assess A2 and A4 pulley injuries. A 100% detection rate was reported for A2 and A4 pulley injuries, while A3 pulley injuries were more challenging to evaluate. This study was one of the first to use cadaver ultrasound examinations for various pulley injuries, highlighting its efficacy for A2 and A4 pulleys but inadequacy for A3 pulley injuries [23]. Xeber Iruretegoiena et al. (2023) aimed to establish tendon-to-bone distance values for various sizes of partial A2 pulley injuries and compare these values with complete tears. They used 30 in vitro fingers randomly assigned to five groups simulating different degrees of injury. The results showed significant differences between intact pulleys and those with partial or complete injuries, suggesting that a TBD above 3 mm indicates a high or complete A2 pulley tear [24]. Leeflang et al. (2014) investigated the factors contributing to tendon bowstringing on the proximal phalanx. They used fresh cadaver arms and mechanically loaded flexor tendons and simulated A2 and A3 pulley injuries. Ultrasounds revealed significant bowstringing with a 30% A2 pulley removal, while partially removing the A3 pulley did not produce significant bowstringing [17].

6. Articles with Clinical Evaluation

Bollen SR (1990) examined athletes during a sport climbing competition, reporting 18 climbers with hand injuries out of 67 examined. Clinical examination revealed increased bowstringing of the finger flexor tendon during resisted flexion compared to the contralateral side, indicating a previous A2 pulley injury [18]. In the same year, Bollen published a clinical case of a climber with an A2 pulley injury. The patient exhibited visible and palpable bowstringing with resistance during finger flexion [28]. In Marco RA et al.'s study (1998), 21 cadaver fingers were used to simulate traumatic pulley ruptures by attaching tendons to a progressive loading system. A total of 17 of the remaining 19 fingers had an isolated A2 or A4 pulley rupture as the first event. This study suggested that clinical bowstringing for an isolated A2 or A4 pulley injury might be misleading [11]. Gabl M. et al. (1998) treated 13 experienced climbers for finger pulley injuries, diagnosing and treating based on clinical bowstringing, which MRI later confirmed. Only five patients with evident clinical bowstringing had a confirmed complete A2 pulley injury [29]. Bhat et al. (2019) presented a clinical case of a patient with an isolated A2 pulley middle finger injury. A silicone ring applied to the suspected injury region immediately restored the full range of motion, and the lesion resolved after three months without surgery. The proposed "Wedding Band Test" was potentially an accurate and cost-effective diagnostic tool for the clinical assessment of A2 pulley injuries [25]. Xeber I. et al. (2020) aimed to determine if a pulley injury implies a reduced grip strength and its relationship with clinical and sonographic signs. This observational study used a sample of 39 climbers with A2 or A4 pulley injuries in the third or fourth finger. The variables considered included palpation pain, ultrasound-calculated TBD, and grip strength reduction. The study suggested that a comprehensive diagnosis of finger pulley injuries involves considering clinical signs (pain), ultrasound findings, and grip strength measurement together [30]. Cooper et al.'s (2020) review proposed a potential classification scheme and approach for patients with A2 finger pulley injuries. The model is based on a pragmatic clinical analysis to help therapists distinguish patients who may benefit from treatments like rest and immobilization versus those who would benefit from an exercise and restorative resistance approach. The classification variables include pain, active range of motion (AROM), resistive finger flexion tests, and palpation [31].

7. Risk of Bias in Studies

The scores from the assessment of methodological quality of the studies are reported in Table 2 in ascending order

Table 2. Assessment of methodological quality of studies using the PEDro scale.

Studies	1 *	2	3	4	5	6	7	8	9	10	11	Total
Iruretagoiena-Urbieta 2020 [30]	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	8/10
Xeber 2023 [24]	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	7/10
Schöffl 2003 [19]	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	No	6/10
Klauser 2002 [21]	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No	Yes	5/10
Gabl 1998 [29]	Yes	No	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	5/10
Klauser 1999 [27]	Yes	No	Yes	Yes	Yes	No	No	Yes	No	No	Yes	5/10
Bodner 1999 [22]	Yes	No	Yes	Yes	No	No	No	Yes	No	No	Yes	4/10
Iruretagoiena 2023 [24]	No	Yes	No	Yes	Yes	No	No	No	No	Yes	No	4/10
Bollen 1990 [28]	No	Yes	No	Yes	Yes	No	No	No	No	Yes	No	4/10
Marco 1998 [11]	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10
Leeflang 2014 [17]	No	No	No	No	Yes	No	Yes	No	No	Yes	No	3/10
Bollen 1990 [18]	No	Yes	No	No	No	No	No	No	No	No	No	1/10
Bhat 2019 [25]	Yes	Yes	No	No	No	No	No	No	No	No	No	1/10
Cooper 2020 [31]	No	No	No	No	No	No	No	No	No	No	No	0/10

Was allocation concealed? Were the groups similar at baseline? Were all subjects blinded? Were the therapists blinded? Were the outcome assessors blinded? Did at least 85% of the sample complete the study? Was a intention-to-treat analysis conducted? Were group outcome comparisons reported? Does the study provide central tendency and variability values for at least one key outcome? * Criterion 1 is not calculated for the total score.

8. Discussion

This systematic review provides valuable information for diagnosing pulley injuries. Instrumental evaluation studies have extensively focused on ultrasound, establishing it as the gold standard for diagnosis [23,26]. Studies have primarily concentrated on diagnosing A2 and A4 pulley injuries, as they are the most affected and anatomically compatible with ultrasound diagnostic techniques (US). Studies, such as Schöffl, V.; et al., 2017 [23], attempted to diagnose A3 pulley injuries with limited success. Ultrasounds were compared with MRI in several studies, resulting in a sensitivity of 98% and a specificity of 100% [21]. Four reviewed studies utilized cadaver hands as samples, allowing for the simulation of injuries and applying a specific gradual tendon tensioning force but with limitations. Cadaveric tissue has different properties and ages compared to in vivo studies using ultrasound on younger patients and climbers. As confirmed in various studies [22], an athlete's climbing tendon will have greater thickness than a potential cadaver, leading to different biomechanical properties. In vitro studies always introduce biases compared to in vivo studies but offer the benefit of simulating an injury before data extraction. The image quality in ultrasounds depends on the transducer frequency and coupling agent used. The reviewed studies employed frequencies ranging from 7.5 MHz to 40 MHz, with many reports recommending a minimum of 14 MHz [23]. Various coupling agent types were used: a gel or silicone pad could hinder active finger flexion [21,22], which could be avoided using a water tube [19]. Direct contact between the transducer and finger could reduce TBD with operator pressure. In all studies, except for Iruretagoiena, X.; et al 2023 [24], conventional ultrasound gel was not used despite being more suitable than other agents. The ultrasound diagnostic method involved calculating TBD. This distance between the tendon and bone was measured by placing the probe above the affected pulley. Once the resting distance was measured, a measurement was taken with finger flexion against resistance, recreating a crimp grip as in climbing. However, there were differences in finger positions during measurements. For example, in three studies [21,27], the authors argued that metacarpophalangeal joint (MCP) flexion should be 0°, proximal interphalangeal (PIP) 40°, and distal interphalangeal (DIP) 10°. Other studies preferred a 30° flexion for DIP, while some positioned the MCP in maximum extension and the PIP and DIP with a 30° flexion [26]. Another difference in the evaluation protocol was the force exerted by fingers during active flexion: cadaver studies used variable passive force, while in vivo studies required patients to exert maximum resistance, which could be limited by pain and swelling caused by the injury. The most important value measured in individual studies using ultrasound was the minimum TBD to diagnose finger flexor pulley injury. Considering the TBD values for a healthy non-climbing subject, for A2 pulley in forced active flexion, it is 0.5 mm and at rest, 0.4 mm, while for A4 pulley, it is 1.4 mm in forced active flexion and 1.1 mm at rest [26]. For a complete A2 pulley injury, the TBD value in forced active flexion ranges from 1.9 mm to 5.1 mm, and at rest, it ranges from 1.1 mm to 3.1 mm. For a complete A4 pulley injury, the values in forced active flexion range from 1.8 mm to 3.1 mm; at rest, they range from 1.5 mm to 2 mm. However, it seems that the most accepted criterion as a threshold to diagnose both A2 and A4 pulley injuries is a 2 mm distance from the flexor tendon to the bone [19]. For a partial pulley injury, minimum TBD values start from 1.6 mm [24]. In the A3 pulley, TBD measurements showed low sensitivity (<50–76%) [23]. In diagnosing with only clinical examination, studies are highly heterogeneous. Four studies [11,18,28,29] focused on the clinical bowstringing sign. The bowstringing sign is visible in clinical examination when at least a total A2 pulley injury is present. However, this clinical sign is limited because pain and swelling follow the injury, leading to a false negative [29]. Clear bowstringing is possible after rupturing A2, A3, and A4 pulleys. A sole A2 pulley injury may not be sufficient, and no additional studies for certainty exist. A case report described diagnosing an isolated A2 pulley injury using a silicone ring on the suspected injury region, immediately regaining lost joint range of motion (ROM). However, if used alone, this method does not demonstrate the severity of the injury and may underdiagnose a more severe injury requiring surgical intervention. This silicone ring could also compromise the neurovascular bundle, making this diagnostic method questionable [13]. A review considered a classification scheme for A2 pulley injuries [31]. Unfortunately, this scheme lacks scientific evidence as it relies on empirical concepts but could be a good starting point for a primary study. This classification model could be very useful in clinical examination to identify the right degree of severity and, consequently, the right treatment. An observational study suggests that diagnosing finger pulley injuries is more comprehensive when clinical signs, ultrasounds, and finger grip strength are considered together [30]. Indeed, this study demonstrates that an A2 or A4 pulley injury significantly drops grip strength, specifically when crimping with a single finger. A single finger strength deficit exceeding 41.4% is equivalent to a high-resolution ultrasound measurement of a TBD greater than 2 mm. As mentioned, a TBD greater than 2 mm equals an A2 or A4 pulley injury.

9. Limitations of the Review

One limitation of this review is the lack of inter-operator and intra-operator reliability. As it is a thesis, the entire research process, including study selection, data extraction, and critical evaluation, was conducted individually by a single person without subsequent repetitions. For the same reason, a review protocol and its registration were not implemented. Another limitation is the narrative synthesis of results without a qualitative assessment of evidence. The inclusion of studies using different outcome measures and diverse scales, along with the sector-specific nature of the topic, resulted in the inclusion of studies with limited scientific evidence. Due to a lack of valid articles, it was impossible to follow every step of the PRISMA Statement checklist.

10. Conclusions

High-resolution ultrasound (US) remains the gold standard for diagnosing flexor tendon pulley injuries due to its reliability, cost-effectiveness, and practicality. In case of doubts, artifacts, or measurement issues, magnetic resonance imaging (MRI) can be used as an equally precise but more expensive and less practical alternative. The diagnostic criterion for such injuries involves measuring the tendon-to-bone distance (TBD) during finger flexion against resistance, simulating the crimp position. The threshold TBD value indicative of injury is 2 mm for both A2 and A4 pulleys. For partial A2 pulley injuries, the minimum TBD is 1.6 mm. A classification scheme for managing partial A2 pulley injuries or strains exists, but its empirical nature necessitates primary studies to establish its validity. Additional studies are required for A3 pulley injuries, as current ones have shown poor diagnostic sensitivity with ultrasound. Multiple A2, A3, and A4 pulley injuries can be diagnosed using the clinical bowstringing sign. Further research is needed to verify the reliability of the bowstringing sign in cases of isolated A2 or A3 pulley injuries.

Clinical signs, ultrasound TBD measurements, and grip strength should be considered together for an optimal diagnosis of flexor unit finger injuries. Grip strength is an excellent complement to ultrasound in diagnosing and following up on A2 and A4 pulley injuries. A 41.4% reduction in grip strength during the single-finger crimp position corresponds to pulley injury, and this measurement proves valuable in rehabilitation and return to sports. Before beginning any activity, always perform an adequate warm-up and stretching routine for the fingers. Maintain a regular conditioning regimen to strengthen the tendons and pulleys. Ensure proper technique during climbing or other activities to minimize stress on the fingers.

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