FUNCTIONAL OUTCOMES AND MANAGEMENT FOR DISTAL BICEPS TENDON RUPTURE

FUNCTIONAL OUTCOMES AND MANAGEMENT FOR DISTAL BICEPS TENDON RUPTURE

By Pulak Parikh, B.Kin, MPT, DPT,

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy, Rehabilitation Science

McMaster University DOCTOR OF PHILOSOPHY (2020) Hamilton, Ontario, Canada (Rehabilitation Science)

TITLE: Functional outcomes and management for distal biceps tendon rupture

AUTHOR: Pulak Parikh B.Kin (McMaster University) MPT (Oakland University) DPT (Temple University)

SUPERVISOR: Dr. Joy C. MacDermid, PhD

PAGES: 264

LAY ABSTRACT

The biceps tendon is prone to rupture where it inserts into the elbow. While not a common injury, it does occur more often in middle aged men following a forceful movement. Most of the research regarding the prognosis and management of distal biceps ruptures is of poor quality and imprecise due to small sample sizes. This thesis examined management in a set of studies. A scoping review indicated that rehabilitation descriptions for distal bicep ruptures were of very poor quality for both surgical and non-surgical management for this condition. A cross-sectional analysis of 60 patients revealed that having a smoking history and weaker flexion strength was associated with poor outcomes after distal biceps repairs. A prospective cohort study of 34 patients found that having surgery on the non-dominant arm and weaker grip strength was associated with poor outcomes 6-12 months after surgical repair. Given the excellent outcomes after surgery and presumption of the need for surgery as standard practice, there has been little attention to the role of conservative management. We evaluated two cases where patients refused surgery and were able to recover full strength and functional abilities using a comprehensive rehabilitation program. This thesis confirms that excellent outcomes occur after this injury and raises the need for future trials comparing surgery and rehabilitation as treatment options. The fact that this injury often occurs in healthy men may partially explain the excellent outcomes with surgery or rehabilitation.

ABSTRACT

Although rare, distal biceps tears are common in middle-aged men in their 4th and 5th decades of life. The evidence surrounding prognosis, complications and rehabilitation interventions for distal biceps ruptures are of poor quality and therefore, many questions remain to be answered. This thesis includes four manuscripts describing studies that aim to improve our understanding of the rehabilitation of surgical and non-surgical management of distal biceps tendon rupture, prognostic factors associated with surgical repair and the outcomes for non-surgical management.

The first manuscript is a scoping review of rehabilitation procedures described in the literature for the management of distal biceps ruptures. Overall, rehabilitation descriptions for distal biceps ruptures are poor for both post-surgical and non-surgical management. The findings suggest heterogeneity, both on the reporting and the content of rehabilitation delivered as a stand-alone intervention or post-operatively.

The second manuscript is a cross-sectional study evaluating potential factors associated with reduced function post double incision surgical repair. The findings suggest that having a smoking history and weaker biceps flexion strength are associated with a poor prognosis and accounted for 50.4% of the variability in functional scores. These findings support existing studies that indicate a smoking history is associated with less favourable pain, function and disability outcomes follow distal biceps repair.

The third manuscript is a prospective study evaluating prognostic factors associated with reduced function for those undergoing double incision surgical repair. These findings suggest that the majority of persons undergoing a distal biceps repair

using a two-incision approach have minimal complications and good functional outcomes. In addition, having surgery on the non-dominant hand and having a weaker grip strength at baseline accounted for 43.4% of the variability of functional scores.

The fourth manuscript describes two cases of non-surgical management of a complete distal biceps rupture. Despite the common belief that surgical repair for biceps rupture results in superior elbow flexion and supination strength, these cases demonstrated that full recover of strength and function is possible through rehabilitation alone. This study contributes to the evidence-base by questioning the need for surgical repair for all cases of distal biceps ruptures.

ACKNOWLEDGEMENTS

This thesis would not have been possible if it were not from the support and on-going encouragement of my supervisor Dr. Joy MacDermid. You have not only taught me the value of hard work, but you have also given me the motivation to continue this journey through one of the toughest times in my life. You have led by example, instilling in me the dedication to produce high quality clinically important research. You have supported me throughout all my academic pursuits and have given me a skill set that I will cherish throughout my career as a clinician scientist.

I would also like to greatly thank my committee members: Dr. Julie Richardson and Dr. Luciana Macedo. You have both given me great feedback that has allowed me to develop the ability to think critically regarding all my research questions. Your patience and high standards have allowed me to grow into a dedicated and detailed researcher.

In addition, I would like to thank my good friend and fellow researcher Dr. Vikas Tuli. Without your on-going support and persistence for developing a research program at Southlake Hospital our research would not have been possible. In addition, this thesis would also not have been possible if it were not for Michele Manley and Pratima Sekhar. Whether it was through data collection, attending meetings or helping me with tables and figures within the manuscripts, your support and guidance were essential.

Finally, I would like to thank my family, especially Shilpa, my daughter Maya and my son Krish for their on-going support throughout these 6 years. Many nights, weeks and weekends were dedicated to this project and the love and support you have given me will always be remembered. I am eternally grateful for each of you every day.

DECLARATION OF ACADEMIC ACHIEVEMENT

All four manuscripts were conceptualized and written by Pulak Parikh. This included performing all data collection for studies, management of procedures and data analysis.

Chapter 2- Dr. MacDermid helped to refine the thesis objectives, methods and edited all manuscripts. Dr. Richardson and Dr. Macedo reviewed the design and overall objectives and edited the manuscript. Dr. Tuli helped with overall design and edited the manuscript.

Chapter 3- Dr. MacDermid helped to refine objectives and methods, develop a framework for data collection and analysis as well as edited the manuscript. Dr. Richardson and Dr. Macedo reviewed the design and overall objectives and edited the manuscript. Dr. Tuli, Michelle Manley and Pratima Sekhar helped with data collection and administration of functional measures.

Chapter 4 – Dr. MacDermid helped to refine objectives and methods, develop a framework for data collection and analysis as well as edited the manuscript. Dr. Richardson and Dr. Macedo reviewed the design and overall objectives and edited the manuscript. Dr. Tuli, Michelle Manley and Pratima Sekhar helped with data collection and administration of functional measures.

Chapter 5 – Dr. MacDermid reviewed the objectives and methods and edited the manuscript. Dr. Richardson and Dr. Macedo helped edit and provide feedback on the manuscript. Dr. Tuli helped conceptualize and design the study and edited the manuscript.

Table of Contents

List of tables

List of figures

List of appendices

CHAPTER 1. INTRODUCTION

Anatomy

The bicep brachii is a spindle shaped muscle located in the anterior compartment of the arm and consists of two segments (a short and long head). The long head arises from the superior aspect of the glenoid fossa and the short head originates from the coracoid process (Forthman, Zimmerman, Sullivan, & Gabel, 2008). Both heads are innervated by the musculocutaneous nerve and were previously thought to coalesce into a single distal tendon (Strandring, 2005). Recent cadaver studies have demonstrated that the two heads terminate distally as separate components (Athwal, Steinmann, & Rispoli, 2007; Cucca, McLay, Okamoto, Ecker, & McMenamin, 2010; Eames et al., 2007; Kulshreshtha, Singh, Sinha, & Hall, 2007; Van den Bekerom, Kodde, Aster, Bleys, & Eygendaal, 2016). The longer (head) component inserts into the ulnar margin of the radial tuberosity as the "common tendon of insertion" while the shorter head forms the flattened bicipital aponeurosis (Athwal et al., 2007). Unlike the anatomy and pathophysiology of the proximal biceps, the distal biceps has been poorly understood (Eames et al., 2007).

The lacertus fibrosus, otherwise known as the bicipital aponeurosis, is a connective tissue that originates at the anterior aspect of the distal biceps tendon and runs ulnarly, margining into the fascia of the forearm flexors (Sutton, Dodds, Ahmad, & Sethi, 2010). This structure is known to stabilize the biceps tendon (particularly the short head) and when intact may lessen the functional deficits of the distal biceps (Van den Bekerom et al., 2016). The bicipital aponeurosis has a wide insertion and involvement in the

forearm; it completely encircles the flexors of the forearm, has strong connections to the antebrachial fascia, particularly over the ulnar flexors and also crosses the median nerve and brachial artery (Eames et al., 2007).

The biceps musculotendinous unit rotates 90 degrees from its origin to its insertion (Athwal et al., 2007). The mean distal tendon length as measured by cadaveric studies has been reported to be approximately 57mm (min 32mm max 84mm, median 57mm, SD 12mm) with a diameter of 15mm (9-20mm, SD 3mm) (Cucca et al., 2010). The biceps brachii is the most superficial muscle in the arm. It acts on three joints: the glenohumeral, ulno-humeral and radio-ulnar joint. The long head is more efficient at generating elbow flexion with a supinated forearm in comparison to the short head that is most efficient when the forearm is in pronation and neutral pronation/supination (Jarrett et al., 2012). Biomechanically, the biceps is the strongest supinator in the forearm with its optimal supination strength achieved at 90 degrees of elbow flexion (Kokkalis, Ballas, Mavrogenis, & Soucacos, 2013). It is also a secondary elbow flexor to the brachioradialis when the brachialis muscle is insufficient (Stucken & Ciccotti, 2014).

Etiology

Distal biceps tendon injuries are rare occurring in 2.55-5.35 per 100,000 patient years (M. Kelly, Perkinson, Ablove, & Tueting, 2015). However, injury to the distal biceps is the most common tendinous injury at the elbow (Hutchinson, Gloystein, Gillespie, & Antonio, 2008). Rupture of the tendon occurs predominantly in dominant extremity men between 40 and 60 years of age (Ramsey, 1999). This uncommon injury frequently occurs with an eccentric load to the biceps often associated with a “pop” at the

time of injury (Morrey, Askew, An, & Dobyns, 1985; Safran & Graham, 2002). Ecchymosis most often extends proximally to distally preceding the injury (Stucken & Ciccotti, 2014). Risk factors for the rupture of the distal biceps have been reported to included manual labor (Morrey et al., 1985), weight training (Golshani et al., 2018; Wentzell, 2018), anabolic steroid use (Visuri & Lindholm, 1994) and smoking (M. Kelly et al., 2015; Safran & Graham, 2002; Waterman, Navarro-Figueroa, & Owens, 2017). Avulsion of the bicep tendon often occurs with rupture of the tendon from the bone as one unit, with the two heads often held together with loose areolar tissue and with the lacertus fibrosus usually remaining intact (Eames et al., 2007). If the lacertus fibrosus is intact, this structure has been hypothesized to be a positive predictor for prognosis as deficits of biceps can be significantly minimized (Sutton et al., 2010) .

The biological etiology of biceps tendon ruptures is likely multifactorial, involving a variety of mechanical (impingement), degenerative and arterial supply factors. Seiler and colleagues conducted an anatomic study to identify potential causes for rupture of the distal biceps tendon and assess the relationship of the proximal radioulnar joint during pronation and supination to identify potential sites of impingement of the tendon (Seiler, Parker, Chamberland, Sherbourne, & Carpenter, 1995). They identified a hypo-vascular zone within the distal biceps that corresponded to focal degeneration of the tendon through vascular injections. Three vascular zones were identified in the tendon with a 2.1cm hypovascularized zone between the proximal and distal zones (just proximal to its insertion into the radial tuberosity). In addition, radiographic imaging outlined mechanical impingement sites during excursion of the tendon from supination to

pronation. As the forearm rotated (from supination to pronation), the space available for the biceps tendon to pass between the radius and ulna was considerably decreased. In addition, another anatomic study found a knife-like margin on the radial tuberosity that produced hypo-trophic lipping and tearing of the distal biceps tendon (Davis & Yassine, 1956). Therefore, it can be hypothesized that those persons with repetitive activities of the elbow may be at greater risk of a tear.

It has also been postulated that the preponderance of male distal biceps lesions may be related to the increased cross-sectional muscle mass creating greater forces across the tendons (Haverstock, Athwal, & Grewal, 2015). Further, patients suffering a distal biceps lesion are more likely to sustain a second (contralateral) lesion implying that there may be a systemic cause (Green, Skaife, & Leslie, 2012; Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, 2009).

Diagnosis

Diagnosis of the distal biceps ruptures occurs through clinical exam, physical evaluation and diagnostic testing such as magnetic resonance imaging (MRI) or diagnostic ultrasound. Patients usually present with pain and weakness most predominantly in supination (Sleeboom & Regoort, 1991). Overall, the diagnostic accuracy of MRI (sensitivity 76% , specificity 50%) for detecting distal biceps tears is significantly better than diagnostic ultrasound evaluation (sensitivity 62.5%, specificity 20%) and thus MRI is considered the gold standard for this pathology (overall accuracy MRI 80.6% vs. US 51.6%, odds ratio 3.9) (Lynch, Yu, Chen, & Muh, 2019). Although the MRI is an effective tool for diagnosing complete tears, it is substantially less sensitive

in diagnosing partial tears (full tear sensitivity and specificity of 100% and 82.8% compared to partial tears 59.1% and 100%) (Festa, Mulieri, Newman, Spitz, & Leslie, 2010). Additional costs and time delays associated with acquiring an MRI have been known to compromise positive surgical results (Haldeman et al., 2008). Therefore, clinicians typically rely upon clinical examination and diagnostic ultrasound for surgical decisions (De la Fuente et al., 2018; Shamoon, Kotwal, Iorwerth, & Morgan, 2017).

As mentioned, patients with a distal biceps tendon rupture will have weakness in supination and with minimal loss of flexion strength (Miyamoto, Elser, & Millett, 2010). Therefore, in order to isolate the biceps tendon, supination strength needs to be assessed with the elbow flexed at 90 degrees to isolate the biceps muscle from the supinator (Savin et al., 2017).

The "hook test", first described by O'Driscoll (O'Driscoll, Goncalves, & Dietz, 2007) attempts to hook the distal biceps from lateral to medial, while the patient holds the arm in 90 degree elbow flexion and supination; and an intact tendon would allow the examiner to "hook" the tendon and pull it forward (See Table 1). With partially intact fibers the patient may experience pain with the anterior pull during the test. This test has been found to have higher specificity and sensitivity (100%) when compared to MRI (92% and 85%) (O'Driscoll et al., 2007).

A "Biceps Crease Interval Test" (BCI) (ElMaraghy, Devereaux, & Tsoi, 2008) has also been introduced for the measurement of the distance between the antecubital crease of the elbow and the cusp of the descent of the distal biceps muscle, comparing it to normal individuals . This test has demonstrated a sensitivity of 96% and specificity of

93% for identifying complete distal tears. Further, the "Biceps Squeeze Test", using the Thompson test for the achilles tendon as a model, was developed to test the integrity of the distal biceps tendon (Ruland, Dunbar, & Bowen, 2005). It consists of compression to the biceps brachii tendon in anticipation of eliciting supination of the forearm if the tendon is intact. The test has demonstrated good sensitivity (96%) in the clinical diagnosis of distal biceps ruptures.

If the lacertus fibrosus is intact, it has been noted that the hematoma and ecchymosis can become contained and minimized with distal biceps tears. Thus, an intact lacertus fibrosus has been known to be linked to misdiagnosis even with a complete avulsion of the tendon from the radial tuberosity (Miyamoto et al., 2010). In addition, if intact, it usually prevents proximal migration of the tendon, also known as the "Popeye Sign"(Quach, Jazayeri, Sherman, & Rosen, 2010). In most cases when the distal biceps tendon is intact or there is a partial tear in the tendon, the lacertus fibrosus is usually fully intact (ElMaraghy & Devereaux, 2013). When it ruptures, it most often occurs from the proximal origin on the short head of the biceps tendon (Kulshreshtha et al., 2007).

A "Bicipital Aponeurosis Flex Test" was developed to evaluate the integrity of the lacertus fibrosus and its implications for treatment of the distal biceps tendon ruptures (ElMaraghy et al., 2008). This test involves the palpation of the lacertus fibrosus on the medial side of the forearm. Contraction of the forearm is initiated with asking the patient to make a fist and actively flex the wrist with a supinated forearm. While maintaining a flexed wrist and hand, the patient is asked to then flex the elbow at approximately 75 degrees. With the lacertus fibrosus under tension, the examiner palpates the medial,

lateral and then central aspects of the antecubital fossa. If intact, the sharp thin ledge of the aponeurosis can be felt medially. This test has been found to have 100% sensitivity and 90% specificity with an overall diagnostic accuracy of 94%.

Complete rupture of the distal biceps tendon at the radial tuberosity is the most common type of injury for the distal biceps. However, other conditions to consider in the differential diagnosis of this elbow injury can include partial tears, bicipitoradial bursitis and tearing along the myotendinous junction (Alentorn-Geli, Assenmacher, & Sanchez-Sotelo, 2016).

Surgical Management

Over the last three decades, there has been a general consensus in the clinical community that surgery is most beneficial option to restore full strength, range of motion and function following full rupture of the tendon. However due to the rarity of this injury, current studies examining surgical and non-surgical outcomes have been of limited quality consisting primarily of retrospective and case series designs (Nyland et al., 2015). Historically, a non-anatomic surgical approach was used (attaching the tendon to the brachialis muscle and not to the radial tuberosity) but this technique has been discontinued given its increased complication rates (Schmidt, Savoie, et al., 2016).

Currently, two designs are used for surgical repair depending on surgeon preference: a single anterior incision approach with suture anchors or endobuttons to fixate the biceps tendon or a two-incision approach using a bone flap or burring out the bone.

Single Incision Approach

The single incision approach for repair of the distal biceps tendon was originally developed by Dobbie (Dobbie, 1941). This technique usually consists of a longitudinal or transverse incision into the antecubital fossa. Suture anchors or endobuttons are used to secure the tendon into the ulnar aspect of the radial tuberosity. A modified technique may include a single incision on the posterior aspect of the elbow and is primarily used for partial distal biceps ruptures (E. W. Kelly, Steinmann, & O'Driscoll, 2003).

Double Incision

The double incision approach for repair of the distal biceps tendon was developed in response to a higher complication rate and radial nerve palsy seen in the single incision approach (Boyd & Anderson, 1961). Historically, the first incision was made in transverse direction in the antecubital crease and the second incision is made with the identification of the radial tuberosity at the dorsal aspect of the proximal forearm. A burr is generally used to drill 2-3 holes into the ulnar aspect of the radial tuberosity passing the biceps tendon through, to be sutured and then tied. This earlier technique demonstrated complications related to loss of forearm rotation often secondary to the development of heterotopic ossification (abnormal growth of bone in non-skeletal tissues such as muscles tendons or other soft tissues) and radioulnar synostosis (an abnormal connection between the radius and ulna) (Bell, Wiley, Noble, & Kuczynski, 2000; Failla, Amadio, Morrey, & Beckenbaugh, 1990; Safran & Graham, 2002). A modified 2-incision technique, that is currently used today was developed in an effort to minimize the risk of muscle splitting in

the posterior approach to further avoid exposure or dissection of the proximal ulna (Morrey et al., 1985).

Fixation Techniques

There are multiple fixation techniques used to grip the biceps tendon into the radial tuberosity. The two incision approach uses a bone tunnel fixation method that is standard for surgical treatment (Morrey et al., 1985). This would entail drilling out the cortex of the bone with 2 or 3 small (2mm) holes on the lateral side of the radius with sutures tied after the tendon is passed through. For a single-incision approach many fixation techniques have been used such as a endo-button (Bain, Prem, Heptinstall, Verhellen, & Paix, 2000), suture anchors (Al-Taher & Wouters, 2014) and even a biotenodesis screw (Eardley, Odak, Adesina, Jeavons, & McVie, 2010) into the radial tuberosity. The endo-button fixation has been found to have the highest load and stiffness for all fixation methods (Chavan, Duquin, & Bisson, 2008).

It has also been suggested that there are benefits to a concomitant repair of the lacertus fibrosus during the repair of the biceps tendon for increased strength (Landa, Bhandari, Strauss, Walker, & Meislin, 2009). This is secondary to the hypothesis that it contributes to elbow flexion and is a stabilizing force for the tendon and all underlying neurovascular structures of the elbow (Nielsen, 1987).

Single vs. Double Incision Repair

There have been no distinct advantages found for single vs. double incision approach's (R. Grewal et al., 2012; Keener, 2011; Watson, Moretti, Schwindel, & Hutchinson, 2014). Historically, the trend for moving from single incision to double

incision repair was due to higher complications found with single incision. However, single-incision techniques have since returned to practice as result of higher complications of heterotopic ossification found in the double incision techniques (Bain et al., 2000; Goljan, Patel, Stull, Donnelly, & Culp, 2016; Peeters et al., 2009). Current practice patterns vary significantly with regards to which incision approach and fixation method is used. The relative merits of single vs. double incision repairs, in terms of preventing post-operative complications, have largely equilibrated and are similar between groups using modern surgical techniques (Keener, 2011). The choice of surgical approach and method of tendon fixation is largely dictated by surgeon experience and previous training (Watson et al., 2014).

Complication Rates

Although surgical re-insertion of the biceps has favourable outcomes in strength and range of motion, complications are not uncommon. Complications for this surgery have been known to include heterotopic ossification (formation of mature lamellar bone in nonosseous locations), re-rupture, wound infection, posterior interosseus nerve (PIN) palsy, lateral antebrachial cutaneous nerve (LAC) nerve injury, superficial radial, median and ulnar nerve injury, radioulnar synostosis, complex regional pain syndrome, brachial artery laceration, fascial dehiscence, persistent neuritis, loss of range of motion/stiffness, weakness, hardware failure with a possibility of a proximal radial fracture (Garon & Greenberg, 2016).

Complication rates have been reported to be between 5-63% (Cohen & Katolic, 2003; Haverstock, Grewal, King, & Athwal, 2017). Historically, the overall frequency of

complications were reported higher for single incision repairs rather than double incision repairs (Amin et al., 2016; Matzon et al., 2019). However, recent reviews have reported no difference in complication rates (Ford et al., 2018; Garon & Greenberg, 2016). A systematic review of 494 patients from a majority of retrospective and care series studies concluded there was no difference in functional outcomes between single and double incision procedures with complication rates being 23-26% (Watson et al., 2014) for both techniques. Although the rates did not differ significantly between single and double incision techniques, bone tunnel and cortical button methods had significantly lower complication rates compared with suture anchors and intraosseous screws.

It has been suggested that patient outcomes and complications may be strongly linked to the experience and comfort level of the surgeon as opposed to the actual type of repair that is done as performing this surgery has a steep learning curve (Garon & Greenberg, 2016; Shields et al., 2015).

Early vs. Late Repairs

Chronic biceps tendon ruptures typically involve tendon retraction, scarring and even compromised tissue. This includes a loss of the tunnel for passage of the tendon to the radial tuberosity, retraction of the tendon toward the shoulder, scarring of the tendon with attachment to an associated muscle and possible tendon degeneration (Hamer & Caputo, 2008). The timeline to repair the distal biceps tendon to prevent complications has been reported anywhere from 4-12 weeks post rupture. (Darlis & Sotereanos, 2006; Ding, Ryan, Strauss, & Jazrawi, 2016; E. W. Kelly, Steinmann, et al., 2003; Sharma, Goswami, & Wood, 2004). Subsequently, chronic tears can be reconstructed without a

graft (depending on the state of the tendon) or using grafts from the semitendinosus, tensor fascia lata, or achilles tendon (Bosman, Fincher, & Saw, 2012; Kale, Jazrawi, & Kale, 2018; Phadnis, Tr, et al., 2016; Sharma et al., 2004). Complication rates have been reported to be higher by 17% for those repaired chronically (>21 days) (E. W. Kelly, Steinmann, et al., 2003).

Non-Operative Decisions

Injuries to the distal biceps tendon, are usually treated surgically with acceptable functional outcomes and return to normal levels of strength. However, most of the outcomes data is based on case series reports and retrospective studies with few prospective studies and only one randomized control trial (Ruby Grewal et al., 2012),

Most of the literature in favour of surgical vs. non-surgical management has been based upon retrospective and case series studies. A historical case series first compared 10 repaired cases to 5 unrepaired (Baker & Bierwagen, 1985). Three of the unrepaired individuals had self-reported residual functional deficits for using a screwdriver and swinging a baseball bat. However, it was unclear if this group had any rehabilitation intervention. Biomechanical studies have demonstrated isolated strength loss with regards to elbow flexion and supination post distal biceps ruptures. These have been reported between 30-40% loss in flexion and up to 60% loss of supination (Morrey et al., 1985). A comparison of non-operative repairs vs. endo button repairs reported repair cases faired significantly better the those treated non-operatively (Legg, Stevens, Oakes, & Shahane, 2016).

In contrast, many studies that report on operative success have also reported that functional outcome scores and disability can remain the same for both operative and non-operative groups (Bauer, Wong, & Lazarus, 2018; Hetsroni et al., 2008). A case series of 16 non-operative patients with a historical control group (operative patients) found non-operative patients achieved satisfactory results as measured with strength testing and three functional outcome surveys (DASH, MEPI and Bromberg and Morrey Survey) (median duration 38 months) (Freeman, McCormick, Mahoney, Baratz, & Lubahn, 2009). These individuals had no loss of flexion strength with only modest loss of supination strength as compared to the controls. In addition, another retrospective cohort of ten cases found no difference in operative and non-operative patients with regards to functional outcomes and strength scores (Geaney, Brenneman, Cote, Arciero, & Mazzocca, 2010a). Supination was found to only be decreased by 3% in the non-operative group compared to those having an operative procedure. Another case series of non-operative musculotendinous partial ruptures had perfect scores on disability indexes on the Mayo Clinic performance index one year post rupture without the need for surgical repair (Lopez-Zabala, Fernandez-Valencia, López-Zabala, & Fernández-Valencia, 2013a). Unfortunately, there was limited description of the physical therapy provided and whether imaging was used to confirm a tear in all cases.

The most recent cohort study published regarding surgical outcomes for distal biceps repair using both single and double incision techniques reported an average of 20-40% decrease in supination strength for both group even with surgical repair (Stockton,

Tobias, Pike, Daneshvar, & Goetz, 2019). Previous reports indicated a supination loss of 20-30% without repair (Legg et al., 2016).

There remains substantial variation between surgeons with respect to their beliefs in regards to the need for surgery and timing for distal biceps repair (Ring, Lubahn, & Beredjiklian, 2017a). Non-operative management for this condition has been reserved for those with low-demand and low-endurance type occupations that refuse surgery or where the delay in diagnosis has led to concerns about retraction compromising the potential for a successful repair (Beazley, Lawrence, Drew, & Modi, 2017).

The majority of trials comparing operative vs. non-operative management have many methodological limitations primarily consisting of retrospective or case series designs.

Partial Tears

There is considerable controversy regarding the management of partial distal biceps tears. For tears that are less that 50% of the tendon, non-operative management is most often recommended (Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, 2000; Lopez-Zabala et al., 2013a). A systematic review reported that 94% of 86 partial tear cases managed surgically resulted in satisfactory clinical outcomes (Behun, Geeslin, O'Hagan, & King, 2016). Of these cases, 65 received a trial of nonsurgical management that ranged from complete arm casting or immobilization with a splint to stretching and strengthening exercises using a blanket term of "Physiotherapy". The outcomes for non-surgical management for these cases were not reported. Therefore,

conclusions on which rehabilitation intervention was most or least effective could not be established.

Bilateral Tears

The cumulative incidence of bilateral distal biceps has been reported to be greater than 8%-13% which is significantly larger than that of the national incidence reported (Green et al., 2012; Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, 2009). Regardless of the mechanism of injury, having a greater incidence of bilateral tears does suggest some sort of systemic etiology, chronic tendinosis or predisposition for tendon degeneration for certain individuals. The large incidence of bilateral tears suggests a potential intrinsic vulnerability and/or predisposing factors likely for injury as previously discussed. Individuals with bilateral injuries present with similar profiles to those with single biceps tears (middle aged males who participate in weight training and manual labour occupations), in addition to having greater nicotine history and use of anabolic steroids (Schneider, Bennett, O'Connor, Mehlhoff, & Bennett, 2009).

Rehabilitation

Post-Operative Procedures

For operative procedures, it difficult to establish any direct relationship between surgical method and post-operative physiotherapy regimen in patients after surgical anatomical reinsertion of the distal biceps (Królikowska et al., 2018). There is a significant gap in the literature with regards to types of rehabilitation programs used as well as to distinguish whether therapy is necessary after distal biceps reconstruction. A study comparing supervised therapy and unsupervised therapy after undergoing repair

allowed patients to use the operated limb to immediately perform daily tasks (Spencer, Tisdale, Kostka, & Ivy, 2008a). This contributed to faster restoration of range of motion without a risk to the repair. Early active range of motion has been documented to be safe with early full range of motion and strength without any clinical significant disability (Cil, Merten, & Steinmann, 2009). However, surgeons continue to remain conservative following surgery as the mean duration of postoperative joint immobilization is three weeks (ranging from 1-6 weeks) (Królikowska et al., 2018). Strengthening exercises are generally started 6 weeks post-surgery with return to normal levels of activities including sports at 12-20 weeks (Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, 2016; Citak et al., 2011). Strengthening has only been indicated once full range of motion is achieved (Horschig, Sayers, LaFontaine, & Scheussler, 2012).

Non-Operative Rehabilitation

With few studies comparing both operative vs. non-operative outcomes, there remains very limited research regarding rehabilitation protocols for those that have chosen to not undergo surgery. Some patients have been casted for 4 weeks with an above-elbow plaster cast (Chillemi, Marinelli, & De Cupis, 2007) while others have rested for a few days followed by active movements at 4 weeks followed by strengthening at 8 weeks (Hetsroni et al., 2008). Most studies use the term "conservative care" but fail to mention any details regarding rehabilitation exercises or education given (Bell et al., 2000; Geaney, Brenneman, Cote, Arciero, & Mazzocca, 2010b; Lopez-Zabala

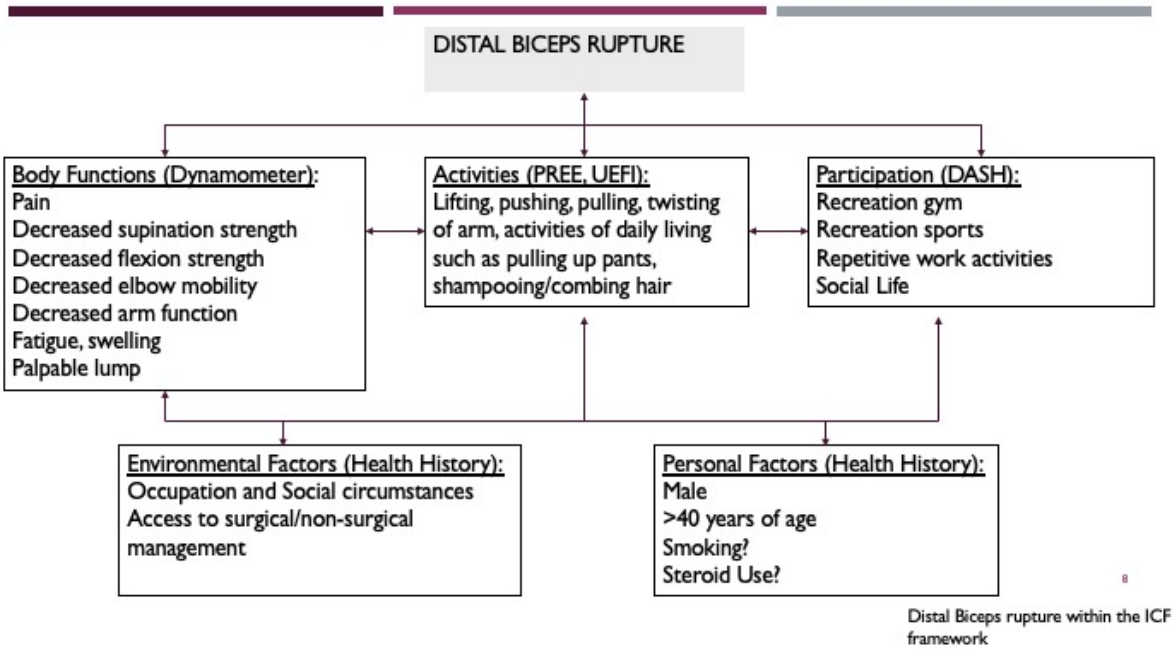
et al., 2013a; Ring et al., 2017a). The most current systematic review of the literature regarding distal biceps repair reported that within the 94 articles reviewed, only 3 had adequate descriptions of rehabilitation procedures (Nyland et al., 2015). Further description was not provided.

ICF and Distal Biceps Pathology

The International Classification of Functioning, Disability and Health (ICF), is a framework for describing and organizing information of functioning and disability. It has been approved by the World Health Assembly (2001) that integrates the major models of disability and recognizes the role of environmental factors in the creation of disability as well as the relevance of associated health conditions and their effects (Functioning and Disability Reference Group, 2010). The overall aim of the developers of the ICF was to provide a unified and standard language and framework for the description of all aspects of human health and some health-relevant aspects of well-being (Organization, 2001).

This conceptual framework was used to guide this thesis project for distal biceps injury (Figure 1). This classification was used secondary to its biopsychosocial model design that provided a direction for distal biceps pathology at the biological, individual and social level. These three perspectives underscore the importance of the interplay of both internal and external factors for distal biceps injury for an individual's overall health and well-being (Atkinson & Nixon-cave, 2011). Rather than treating disease and disability, the goal is to improve health and function. It can assist to identify gaps in the literature with the interactions of health, function, environment and personal factors to address each component for this thesis design.

Figure 1. Distal Biceps Rupture ICF Framework



Body functions that are limited by distal biceps injury include pain that is associated with the tear along with decreased flexion and supination strength, poor elbow mobility and arm function along with fatigue, swelling and a palpable lump. Activities that can be affected including lifting, pushing, pulling, twisting of the arm as well as activities of daily living. Participation may be limited for the gym, sports, work and social type activities. Environmental factors such as occupation and social circumstances along with access to surgical/non-surgical management may predicate outcomes for distal biceps ruptures. Personal factors such as gender, age, smoking and steroid may also be linked this injury as well. Body functions have been measured with a clinical examination (range of motion, swelling, quality of movement) and strength is measured by handheld dynamometer testing. The activities domain has been measured with the Patient Rated

Elbow Evaluation (PREE) (J. Vincent & MacDermid, 2012) and the Upper Extremity Functional Index (UEFI) (Chesworth et al., 2014). Participation is measured via the Disability of Arm, Shoulder and Hand (DASH) (Hudak, Amadio, & Bombardier, 1996). Environmental and personal factors are recorded with a comprehensive health history questionnaire.

The ICF model allows to generate hypotheses about the inter-relationships of the different components within the model. The key to the successful recovery from a distal bicep rupture, however, is understanding the relationship between the target problems and the components (impairments, functional limitations and psychosocial and environmental factors) and addressing those with appropriate interventions for improvement (Steiner, Ryser, Huber, & Uebelhart, 2002).

Gaps in Knowledge

The most obvious gap in the literature is that research regarding distal biceps ruptures consists of inferior study designs that can lead to a paucity of knowledge for many factors including prognosis, management and outcomes. In addition, considering the rarity of this condition, recommendations for surgical decisions have yet to be clarified. With small overall sample sizes and studies mostly consisting of retrospective and case series designs, there is significant risk of error, bias (random and sampling) and well as confounding factors that limit the validity and generalizability of the literature pertaining to this pathology.

Rehabilitation descriptions have been implicated to be poorly reported for both post-surgical care and non-surgical procedures. As positive outcomes for many

orthopaedic surgeries have been linked to compliance and participation in exercise, the quality for reporting exercise protocols needs to identified and subsequent recommendations need to be given for improvement.

The relationship between surgical repair and positive outcomes have been identified. However, there remains a need for clarification in comparing surgery and rehabilitation as treatment options. Given that positive outcomes have been described with nonoperative and operative management of biceps ruptures, there may be a need to explore the presumption that surgical repair is the gold standard. Better imaging, strength assessment and long-term follow-up of operative and nonoperative cases to understand the implications of these choices are needed. The fact that this injury occurs in healthy men may partially explain the excellent outcomes with or without surgery.

There has been minimal research to identify prognostic factors that are associated with positive/negative outcomes for distal biceps and if any significant risk factors exist that predict distal biceps injury. In addition, there are conflicting recommendations regarding if timing (acute vs. chronic) determines outcomes for repairs (Anakwenze, Baldwin, & Abboud, 2013; Haverstock et al., 2017).

Most of the literature for biceps repairs is estimated to have a high risk of bias considering most lead authors are the performing surgeons for the trials (Nyland et al., 2015). In addition, many of the recommendations for surgical repair are originating from countries from which surgeons charge a significant rate to conduct repairs. For example, the majority of studies for distal biceps ruptures are conducted within the United States of America where a national average of surgical costs for distal biceps repair is $19,676

(MDsave, 2019). In contrast, a Canadian surgeon practicing in Ontario is paid $350.00 to conduct a repair. Therefore, there may be an inherent bias or preference to do surgery vs. recommend conservative care.

Thesis Rationale

The goal for this thesis is to provide evidence-based information with regards to distal biceps ruptures to inform proper decision making in relation to the need for surgery, outcomes post-surgery and prognostic indicators for functional outcomes after surgical repair. The objective would be to decrease the amount of disability and reduce the need for surgery considering the high complications rates reported.

Therefore, these findings have led to the following objectives for this thesis:

1) To describe post-operative and non-operative rehabilitation procedures for persons that have sustained a distal biceps rupture
2) To investigate factors associated with poor prognosis post-surgical repair for individuals that have sustained a distal bicep ruptures
3) To identify demographic, social and personal factors associated with rupture of the distal biceps tendon
4) To investigate non-invasive options for patients that have chosen to not undergo surgical repair and identify outcomes associated with non-surgical management

Outline for thesis manuscripts

The first manuscript (Chapter 2) is titled "Rehabilitation interventions for operative and non-operative distal biceps ruptures: A scoping review". The purpose of this review was to present an overview of rehabilitation procedures for surgical and non-surgical management for distal biceps rupture and evaluate protocols using the CERT Consensus for Exercise Reporting Template) guidelines. .

The second manuscript (Chapter 3) is titled "Factors associated with poor outcomes following distal biceps reconstruction". This chapter's aim is to outline factors that are associated with poor prognosis post distal biceps reconstruction. To date, few studies regarding distal biceps have cross sectionally reviewed patients over time and measured both strength and functional outcomes. In addition, it is rare to have patients that have undergone reconstruction to come back for strength and functional outcomes 1-15 years post ruptures considering the majority of positive outcomes. This chapter will contribute to the existing literature for prognostic factors and outcomes post-surgery.

The third manuscript (Chapter 4) "Prognostic factors associated with distal biceps rupture: A prospective observational analysis". This study will be one of very few prospective evaluations conducted for surgical management of distal biceps ruptures. Very few studies have conducted analysis prior to surgical management without lengthy follow-ups (>1 year). This study has been on-going for four years that has followed those repaired over time to outline factors associated with prognosis. This study's objective is to identify factors associated with poor prognosis post distal biceps reconstruction.

The final manuscript (Chapter 5) is titled “Distal biceps tendon rupture: Is surgery the best course of treatment? Two case reports”. These case reports originated from a cross section of individuals that refused biceps surgical repair. An exploratory case series design was used for this paper to describe in detail non-operative management for complete distal biceps rupture. This chapter will contribute to the knowledge of non-surgical management of distal biceps ruptures as well as functional and strength outcomes post rehabilitation.

Together, the results of these manuscripts will contribute to the knowledge base for distal biceps tendon rupture and its management for surgical and non-surgical options. All of the papers included will outline functional outcomes with or without repair of the tendon. This knowledge will aid primary health providers and patients to make informative decisions regarding surgical management after injury to the tendon. The final chapter (6) titled “Discussion”, will discuss how these manuscripts will greatly add to the limited data base for distal biceps ruptures and contribute to the science for management of this debilitating condition.

REFERENCES

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps

Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and Elbow Surgery*, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375. https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J. W. (2003). Distal biceps tendon repair: Comparison of surgical techniques.

Journal of Hand Surgery, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D.

(2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps

tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147. https://doi.org/10.1097/JSA.0b013e3181824e76

Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5

Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003

Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009

Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025

Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130

Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336

Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287

Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687

Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001

Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.

Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper

Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and Head), *608*(1 996).

Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382

Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005

Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035

Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.

Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030

Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214

Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009

Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.

Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896

Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1

Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562

Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017.

https://doi.org/10.1177/0363546515587738
Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405
Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690
Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144
Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049
Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5
Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003
Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358
Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa
Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694
Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003
Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008
Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T. (2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291. https://doi.org/10.2343/geochemj.2.0468

Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7

O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016

Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.

Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6

Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004

Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349

Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017

Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5

Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032

Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries: Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2), 103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the “Salento technique”, a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence,

demographics, and the effect of smoking. *Clinical Orthopaedics and Related Research*, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-

008-9129-8
Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014
Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098
Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041
Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.
Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276
Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.
Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030
Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003
Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4
Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9
Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029
Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0
Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002
von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J.

(2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bulletin of the World Health Organization*, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623

Table 1. Diagnostic tests for distal biceps ruptures

Test	*Developer (Year)*	*Description*	*Positive/Negative Test*	*Measurement Properties*
Biceps Squeeze Test	Ruland, 2005	Compression of distal biceps tendon with forearm in a neutral position	(-) Observation of supination of forearm (+) No observation of supination of forearm	Sensitivity 96%
Hook Test	O'Driscoll, 2007	Attempt to hook distal biceps from lateral to medial with patient arm in 90 degree of elbow flexion	(-) Distal biceps present and has the ability to be "hooked" (+) Distal biceps not observed and unable to be hooked (+/-) Partial tear could be indicated if hooked and pain elicited with anterior pulling	Sensitivity 100% Specificity 100%
Biceps Crease Interval Test	ElMaraghy, 2008	Measurement of the distance between 1)antecubital crease of the elbow and 2) cusp of the descent of the distal biceps muscle	Greater than 6cm distance between the two endpoints indicates a full rupture	Sensitivity 96% Specificity 80% PPV: 96%% NPV: 80%
Biceps Aponeurosis Flex Test	ElMaraghy, 2013	Asking patient to make a fist while actively flexing arm (70 deg.) and supinating the forearm.	Examiner palpates medially, laterally and central part of antecubital fossa for aponeurosis on medial aspect of forearm	100% Sensitivity 90% Specificity

CHAPTER 2: REHABILITATION INTERVENTIONS FOR OPERATIVE AND NON-OPERATIVE DISTAL BICEPS RUPTURES: A SCOPING REVIEW

Target Journal: Journal of Hand Surgery (To be submitted)

Authors

Pulak Parikh[1], Joy C. Macdermid[2], Vikas Tuli[3], Luciana Macedo[4], Julie Richardson[5]

[1]School of Rehabilitation Science, McMaster University
parikhp@mcmaster.ca

[2]Hand and Upper Limb Centre, St. Joseph Hospital, London, ON
jmacderm@uwo.ca

[3]Full Radius Orthopaedics, Newmarket, ON
tulivik@yahoo.ca

[4]School of Rehabilitation Science, McMaster University
jrichard@mcmaster.ca

[5]School of Rehabilitation Science, McMaster University
macedol@mcmaster.ca

Corresponding Author
Pulak Parikh
School of Rehabilitation Science, McMaster University
1400 Main Street West
Hamilton, Ontario L8S 1C7

Email: parikhp@mcmaster.ca
Email 2: pulakpar@yahoo.com

Declaration of Interest: No conflicts of interest are declared by each of the authors, Pulak Parikh, Joy C. MacDermid, Vikas Tuli, Luciana Macedo and Julie Richardson

Acknowledgements: Joy MacDermid was supported by a Canadian Institutes of Health Research Chair in Gender, Work and Health and the Dr James Roth Chair in Musculoskeletal Measurement and Knowledge Translation.

Abstract

Background: Although rare, distal biceps ruptures are most common within the middle-aged male populations most predominantly within the 4th and 5th decades of life. Many questions surround this injury including the best descriptions for rehabilitation procedures for operative and non-operative cases. The purpose of this scoping review was to describe the state of the literature of rehabilitation protocols for the management of distal biceps ruptures. **Methods:** A scoping review of the literature was conducted using the databases PubMed, Embase, Medline Cochrane, CINAHL, ILC and LILACS with keywords to identify conservative management or surgical studies for managing distal bicep tears. A key search term strategy was employed using "distal biceps repair", "distal biceps", "biceps brachii", "tendon rupture", "tendon repair" and "elbow surgery". All searches were performed between January 2018- February 2019 with an update on November 2019. Two investigators screened article title, abstract and full text that met the inclusion criteria. Data was extracted on rehabilitation protocols for non-operative and post-surgical distal biceps repair. The immobilization length, medication recommendation, active and passive exercises timelines along with strengthening protocols were documented and compared. The number of sentences given to rehabilitation descriptions were recorded. Consensus on exercise reporting template (CERT) guidelines were used to evaluate the quality of reporting of exercise programs for those that had greater than five sentences of rehabilitation description. **Results**: One hundred and twenty five articles met the inclusion criteria for preliminary data extraction. Those that had a more detailed description for rehabilitation underwent a detailed extraction and evaluation with CERT guidelines. A mean of 2.5 sentences were used for rehabilitation descriptions for surgical procedures and 1.4 for non-surgical treatments for distal biceps ruptures. A total of 26 surgical and 10 non-surgical were further analysed. There was substantial heterogeneity across rehabilitation descriptions regardless of surgical technique and fixation methods used. The majority of studies had substandard reporting of rehabilitation exercise protocols as evaluated by the CERT (median score 26% (IQR=21-32) for operative studies, 11% (IQR=0-16) for non-operative interventions). **Conclusion**: Overall,

rehabilitation descriptions for distal biceps ruptures are sparse and of extremely poor quality for surgical and non-surgical outcomes. Despite the limited description, substantial variation in rehabilitation protocols were noted. This lack of adequate description of rehabilitation protocols undermines progress. The use of exercise/intervention reporting guidelines are needed.

Background

The distal biceps tendon is ruptured with an eccentric load applied to the elbow. This commonly occurs in the middle aged male populations with an estimated incidence of 1.2-2.55 per 100,000 (M. Kelly et al., 2015; Safran & Graham, 2002). Patients commonly report an "pop" with increased pain, ecchymosis in the medial forearm followed by weakness in elbow supination and flexion (Morrey et al., 1985; Safran & Graham, 2002). Surgical anatomical reinsertion is the most recommended treatment for this injury considering clinical and functional impairments are presented primarily with supination weakness (Legg et al., 2016; Schmidt et al., 2019). There are two main approaches used for surgical repair: a single anterior incision approach with suture anchors or endo-buttons to fixate the biceps tendon or a two-incision approach using a bone flap or burring out the bone (Watson et al., 2014). Their remains substantial variation between surgeons with respect to the need and timing for distal biceps repair (Ring et al., 2017a). Non-operative management for this condition has been reserved for those with low-demand and low-endurance type occupations (Beazley et al., 2017) that refuse surgery or where the delay in diagnosis has led to concerns about retraction compromising the potential for successful repair.

Regardless of the treatment choice, operative or non-operative, there remains significant variations for rehabilitation protocols such as type, timing or intensity (Berlet, Johnson, Milne, Patterson, & King, 1998; Bisson, Perio, Weber, Ehrensberger, & Buyea, n.d.; Kettler, Lunger, Kuhn, Mutschler, & Tingart, 2007; Wentzell, 2018). Positive outcomes after orthopaedic surgeries have shown to be highly dependent upon

compliance and participation with exercise/physical therapy protocols (DeFroda, Mehta, & Owens, 2018; Piva et al., 2015). Thus, a comprehensive review of the distal biceps literature is needed to advance knowledge in the following areas: length of immobilization (if any), active and passive exercise timelines, strengthening programs as well as medication use post-surgery for prevention of complications.

To date, no previous research has systematically summarized and appraised all relevant protocols for operative and non-operative management of distal biceps ruptures. Scoping reviews are a form of knowledge synthesis, which incorporate a range of study designs to comprehensively summarize and synthesize evidence with the aim of informing practice, programs and policy and providing a direction to future research policies (Arksey & O'Malley, 2005). The purposes for this scoping review are to describe the nature and extent of the literature addressing rehabilitation of distal biceps, including non-operative and post-operative management. The specific objectives are to describe:

1) The study designs used to evaluate bicep repair outcomes
2) The nature of the rehabilitation protocol: Description of immobilization type and length, exercise timelines with dosing parameters, medication protocols, timelines for return to sport and work as well as complications reported for aggressive vs. nonaggressive programs.
3) To summarize the amount of description and asses the quality of reporting for rehabilitation regimes in accordance with CERT (Consensus on exercise reporting template) guidelines.

Scoping Review Methodology

Although a systematic review focuses upon obtaining answers to well defined questions, a scoping review "maps" the relevant literature in a complete field of interest (Pouwels et al., 2016). Scoping reviews are of particular use when a body of literature has not been comprehensively reviewed or exhibits a complex heterogeneous nature not amenable to a more systematic review (Khalil et al., 2016). Hence, this work should be the first step to provide an overview of the literature regarding rehabilitation protocols for operative and non-operative distal biceps ruptures.

This scoping review is reported according to the PRISMA extension for scoping reviews (Appendix A). This guideline was developed as an extension for systematic reviews to apply reporting for this specific type of knowledge synthesis. This extension was also intended to apply to evidence maples which share similarities with scoping reviews and involve a systematic search of a body of literature to identify knowledge gaps, with a visual representation of results (Tricco et al., 2016).

This scoping review was informed by a framework developed by Arksey and O'Malley (Arksey & O'Malley, 2005) and those that advanced it forward (Daudt, Van Mossel, & Scott, 2013; Levac, Danielle; Colquhoun, Heather; O'Brien, 2010). This review employed the original five stages 1) Identifying the research question, 2) Identifying relevant studies, 3) Selecting the studies, 4) charting the data (data extraction), and 5) collating, summarising and reporting the results.

The CERT (Consensus of exercise reporting template) guideline was used to assess the quality of the rehabilitation interventions reported (S. C. Slade, Dionne,

Underwood, & Buchbinder, 2014). It's primary objective was to offer guidance for structured and detailed reporting of interventions to subsequently facilitate research replication and improve clinical uptake of effective exercise therapy (S. C. Slade, Dionne, Underwood, & Buchbinder, 2016). This guideline was developed as an extension of TIDieR (Hoffmann et al., 2014) and was based upon the EQUATOR network methodological framework for developing guidelines (S. Slade, Dionne, Underwood, & Buchbinder, 2017). The CERT is comprised of a maximum possible score of 19 points and allows for an explicit description of the key elements considered essential to reporting (Table 1) (Kent, O'Sullivan, Keating, & Slade, 2018). It was chosen for its applicability to any exercise intervention for both prevention and treatment studies across all evaluative study designs.

Identifying Relevant articles

In consultation with a librarian, a search strategy was created to identify publications related to distal biceps ruptures. A literature search was conducted using the databases PubMed, Embase, Medline Cochrane, CINAHL, ILC, LILACS and grey literature for relevant abstracts and articles related to distal biceps rupture. Literature search's for *rehabilitation*, *physiotherapy* and *exercise* in relation to distal biceps rupture were completed to identify all experimental studies. Independent and combined search terms included: "distal biceps repair", "distal biceps", "biceps brachii", "tendon rupture", "tendon repair", "elbow surgery", rehabilitation distal biceps", "exercise distal biceps", "physiotherapy distal biceps", "physical therapy distal biceps". A complete list of search terms and an example of a search strategy is provided (Appendix B). The search strategy

was customized to each data base. All searches were conducted from January 2018 to February 2019 with an update performed November 2019. Studies were screened at title and abstract by two investigators. Disagreements were discussed and decisions for inclusions were made after consensus.

Study Selection

Once the initial search was completed the two investigators screened title and abstracts for relevance. Inclusion criteria required the papers to involve 1) surgical or non-surgical procedures for distal biceps, 2) only to involve human subjects, 3) written in the English, 4) randomized control trials, cohort studies, cross sectional, case-control, case series and individual case studies. Exclusion criteria for studies were those papers reporting on 1) cadaveric specimens, 2) surgical descriptions papers, 3) overview papers, 4) anatomical studies, 5) clinical commentaries, 6) systematic reviews, 6) those pertaining to proximal biceps tendon ruptures.

Data Extraction and Analysis

Studies were further screened to ensure that they only focused on the distal biceps tendon by the primary author. Included full texts were organized and their data was extracted. Each article was categorized based upon study design (RCT, prospective, retrospective, case series/study) and type of repair (single incision, double incision, both single and double incision or non-anatomic repair). An inductive thematic analysis was used to identify patterns and summarize consistent findings across studies. The following information was extracted and analysed in summary format from each article: authorship, year of publication, title, subject number, full rehabilitation description as presented in

the article, medication use, immobilization length (weeks), strengthening exercise commencement (weeks post-surgery) and number of sentences dedicated to rehabilitation descriptions. Those with greater than 5 sentences were considered amenable to data extraction that was completed with a customized data extraction form. In addition, CERT guidelines were used to evaluate the quality of rehabilitation descriptions for each included study. Evaluation was done by two investigators with discrepancies resolved with discussion and consensus. Descriptive statistics were calculated to summarize the data as means and standard deviations for continuous variables. Counts and percentages were applied to categorical data. Further evaluation was done to identify a potential association of the intervention reporting quality with the publication year of each study.

Results

The initial literature search identified 494 titles. Of these, 344 were duplicates, 24 were overview papers, 3 were non-English, 24 were anatomy/biomechanical studies, 9 were surgical protocols, 8 were proximal biceps and 7 were systematic reviews (Figure 1). An additional 20 titles were added through screening references from full text articles for a total of 125 records to be included for preliminary data extraction. A total of 26 surgical and 10 non-surgical were and assessed by CERT guidelines.

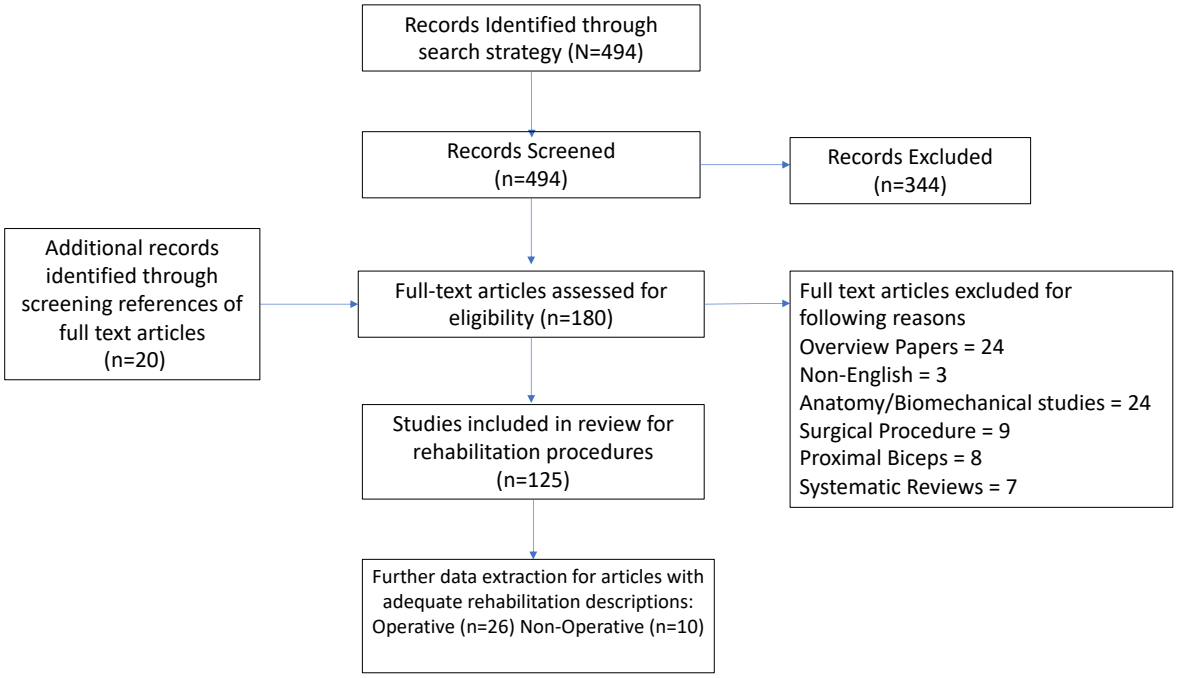


Figure 1. PRISMA flow diagram for literature search and study selection

Characteristics of Studies

One hundred and twenty-five studies were included for the initial review (Table 2). Only one randomized control trial and 4 prospective studies were identified. The remaining one hundred and twenty studies were either retrospective designs, case series or single case studies. Selected studies were conducted between the years 1983 to 2019, with n=26 published within the last 3 years. The sample sizes varied from 1 to 290 participants. One hundred and fifteen were identified as studies related to surgical repair. Ten were non-surgical papers. The most common method for surgical repair for all studies used a single incision (56%) followed by a double incision (26%), with 15% describing both single and double incisions.

Quality of Rehabilitation Reporting

For all included studies (n=125), a mean of 2.5 sentences were used for description of rehabilitation procedures that included post-operative immobilization, medication use, functional restrictions post-surgery, exercise therapy progression and timelines for return to work and sport activities (Table 2). Descriptions were extremely poor for the non-operative intervention, limited with a mean of 1.4 sentences per study excluding (Bandy, Lovelace-Chandler, & Holt, 1991) (Table 6).

Of the 36 studies that included more than 5 sentences of rehabilitation description, the vast majority of articles did not have adequate descriptions for rehabilitation according to CERT guidelines (median score 26% (IQR = 21-32) for operative studies, 11% (IQR = 0-16) for non-operative studies) (Table 3-4). The majority of operative papers failed to detail descriptions for adherence to exercise (item 5), motivation strategies (item 6), home programs (item 9), non-exercise components (e.g. education, massage, etc.) (Item 10) and how adherence and fidelity to exercise is assessed (item 16a). The majority of papers did address how exercises were progressed (Item 7b) and acknowledged most programs were "one size fits all" (Item 14a) without tailoring programs to each individual (Item 14b). Those that tailored their programs were individual case studies (Horschig et al., 2012; Hurov, 1996; Logan et al., 2019; Recordon, Misur, Isaksson, & Poon, 2015b; Wentzell, 2018). Three papers in this group were deemed to have a high overall CERT score (Horschig et al., 2012; Hurov, 1996; Logan et al., 2019)

For the non-operative interventions, the majority of studies had very low scores within all domains as assessed by CERT (Table 4). A similar trend to the operative papers was observed in that some papers did address how exercises were progressed (Item 7b). However, the majority of papers failed to detail any detailed descriptions for exercise interventions as indicated by poor scores in 14/19 items assessed.

Content of Rehabilitation Programs

Post-Operative Rehabilitation

The range of immobilization varied from 0-10 weeks across the described programs. Immobilization methods included casting, splinting, slinging and simple bandages post-surgical repair. Eight studies recommended the use of either Non-Steroid Anti-inflammatories or Indomethacin medication for prevention of heterotopic ossification. Four of these studies consisted of single incision procedures while the other four compared single and double incision surgeries. Strengthening exercises were given to patients between weeks 4-16 for all studies. The majority of papers (32) recommended strengthening at 12 weeks post repair while a substantial number (24) recommended it commence 6 weeks post reconstruction. There were no consistent differences noted between single and double incision techniques with regards to strengthening programs.

Results of the data extraction for the content of rehabilitation protocols in operative studies that provided greater than five sentences are displayed within Table 5. Ten of the twenty six articles were published within the last 3 years. Five articles provided detailed protocols for rehabilitation post-surgical reconstruction (Horschig et al., 2012; Hurov, 1996; Logan et al., 2019; Rollo et al., 2019; Wentzell, 2018). The average

length for immobilization was 4.1 weeks with the majority using a sling, splint or brace (21/25). Sixteen articles used single incision procedures, eight used a double incision technique and two studied both. All but 3 studies recommended the use of passive range of motion in all directions within the first two weeks from surgery. Active range of motion was prescribed 1-16 weeks post repair with the most common being within the first week with the use of a locked brace for extension (14/26). Strengthening usually began by isometrics within weeks 1-16 post-surgery. The most common strengthening exercise start times were within 6 weeks (8) and 12 weeks (8) post-surgical repair. Return to work, sport and regular activities varied significantly between 4 to 52 weeks. The most common time frame given was 12 weeks (8/26). The most aggressive rehabilitation protocol was a single incision technique with a 3-5 day immobilization period, immediate passive, active and strengthening exercises within the first week and return to normal activities at 4 weeks (Heinzelmann, Savoie, Randall Ramsey, Field, & Mazzocca, 2009). A double incision procedure had the most conservative rehabilitation program with an immobilization period lasting 11 weeks with return to normal activities at 52 weeks (Rollo et al., 2019).

Non-Operative Rehabilitation

Ten studies were identified for describing non-operative procedures for complete distal biceps rupture (Table 6). Two of the ten articles were published within the last 3 years. Sample sizes ranged from 1-18 with the largest being 18 subjects. There was quite a large variation with regards to immobilization as 6/10 did not report on immobilization post rupture. Those reported, ranged from above elbow casting for 4 weeks to sling

immobilization for 3 weeks. Some recommended immobilization for pain but did not describe duration (Morrey et al., 1985). Passive exercises were generally recommended immediately by 5/10 studies but 4/10 did not report on this. Active exercise was recommended between 1-4 weeks with (3/10) recommending it within the first week and (2/10) by week 4. Strengthening recommendations varied greatly. Studies recommended to start strengthening exercises between week 1 to week 16. There was no clear consensus for this exercise type. Return to normal activities/sport was much quicker when compared to the operative group. A case study described a wrestler returning to sport 3 weeks post rupture (Bandy et al., 1991). Further, another study recommended return back to regular duties within 1 week (Geaney et al., 2010b). However, the majority (6/10) did not report on returning to regular duties.

Discussion

This scoping review found a high volume of research with poor description of the rehabilitation programs that were used to rehabilitate patients following distal biceps rupture, whether the rupture is repaired or not. The state of the literature makes it extremely difficult to define optimal rehabilitation given limitations in both description and quality of research. Given the state of the literature, it is not surprising that there is substantial heterogeneity across rehabilitation programs. In particular, most studies lacked a consensus for length of immobilization, exercise prescriptions (passive, active and strengthening) or timelines for return to work and sports. The methods for formulating recommendations pre and post-surgery were often not described with a (lack of) links given to supporting evidence.

A recent overview paper for distal bicep tendon injuries did include a review of programs for post-operative physiotherapy (Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, 2018). However, this review had no systematic methodology or study selection criteria. In addition, there was a lack of depth in the overview for all distal biceps literature without an assessment of rehabilitation programs. This paper not only extracted rehabilitation descriptions for 125 articles but further evaluated 36 studies with adequate descriptions and assessed each by the CERT guidelines for reporting. Due to variations in surgical technique along with significant variations in protocols, a broad scoping review was required to identify knowledge the gaps and implications for all distal biceps studies.

Immobilization and Early Mobilization

It was difficult to establish consistent timelines for duration of elbow immobilization in patients after surgical anatomical reinsertion or reconstruction and the method of fixation. Newer studies have advocated little to no immobilization questioning whether lengthy immobilization can deter graft mobility and subsequently delay recovery for repairs. In this review, half (13/26) recommended 0-2 weeks immobilization and these most of these (9/13) were published within the last 3 years. This emerging trend is most likely based upon cadaveric studies that have demonstrated tensile strength of the grafts that allow little immobilization and early range of motion (Bisson et al., n.d.; Kettler et al., 2007). Further, newer studies have shown early mobilization has demonstrated earlier return to normal activities with minimal complications reported (Spencer et al., 2008a).

Eight of the studies reviewed allowed for early active and passive exercises within the first week post-surgical repair (Barret et al., 2019; Bosman et al., 2012; Caputo, Cusano, Stannard, & Hamer, 2016; Cil et al., 2009; Heinzelmann et al., 2009; Logan et al., 2019; Smith & Amirfeyz, 2016; Wentzell, 2018). These studies presented a low complication rate profiles however 4 studies did present cases of heterotic ossification (HO). Three of the four of these studies were double incision techniques which have been previously indicated to have a higher incidence of HO (Ford et al., 2018; Kelly, Edward; Morrey, Bernard; O'Driscoll, 2000). Therefore, it could be assumed that these complications can be due to the surgical technique rather that an early rehabilitation program.

Strengthening Exercises

There was significant heterogeneity with strengthening exercise recommendations post-surgical repair of the distal biceps. Again, those studies published within the last 3 years tended to have more aggressive strengthening recommendations as the trends have been to move towards earlier mobilization. The majority of included studies recommended strengthening within the first 6 weeks of repair with some even recommending it within the first four weeks (D'Arco et al., 1998; Heinzelmann et al., 2009; Lynch, SA; Beard, 1999; Rollo et al., 2019; Spencer et al., 2008a; Wentzell, 2018). This aggressive rehabilitation trend has been observed throughout many recent tendon repair surgeries. It has been hypothesized that patients who receive early progressive passive and active exercises will benefit more with respect to pain reduction, physical function and quality of life (Kjaer et al., 2018). A systematic review and meta-analysis

of early motion for rotator cuff repair suggested high level evidence for early motion and strength exercises for rehabilitation after surgery that resulted in superior postoperative range of motion up to 1 year (Saltzman et al., 2017). In addition, another prospective RCT reported that aggressive rehabilitation post Achilles tendon repair resulted in higher functional scores, lower verbal pain scores, lower pain medication consumption, early return to work and higher strength post repair (De la Fuente et al., 2018). Therefore, distal bicep tendon surgeries and their recent protocols have followed this trend for earlier mobilization with a goal of achieving optimal results with minimal risks for complications.

Non-Operative Ruptures

Descriptions for non-operative conservative treatment for distal biceps ruptures was extremely poor. Only three of the ten studies had mention for immobilization post injury. In addition, protocols for active, passive and strengthening exercises varied greatly. Interestingly, this patient population returned to normal activities much quicker than those surgically repaired.

All studies within this group did not adequately describe the reason for subjects declining surgical repair. One study reported that the risks and benefits for surgery were presented and 6 patients opted for conservative treatment (Geaney et al., 2010a). Another indicated 17 patients declined surgery without reason and one patient had a delayed presentation (Freeman et al., 2009). All others in this group presented no description or reasoning for non-surgical management.

The majority of studies found no functional deficit for non-operative management of distal biceps ruptures (Bandy et al., 1991; Freeman et al., 2009; Geaney et al., 2010b; Hetsroni et al., 2008; Lopez-Zabala et al., 2013a). Some studies found significant differences both in strength and functional scores comparing operative and non-operative patient populations (Chillemi et al., 2007; Legg et al., 2016; Morrey et al., 1985; Schmidt et al., 2019). However, the majority of these studies had minimal descriptions of the rehabilitation procedures used (if any) for their non-operative conservative treatment groups.

Limitations

The most obvious limitation to this review is that low quality research with poor description limits the ability to make conclusions. Although previous authors have conducted systematic reviews, this scoping review questions the value of doing systematic reviews when the quality of the literature is so poor. It should be noted that we excluded studies where the descriptions of rehabilitation were not present since that was the focus of our review. It is possible that there were high quality surgical trials, without adequate rehabilitation descriptions. However, considering the majority of the papers were either retrospective or case series reviews most had methodological limitations and it is unlikely we miss anything of high quality. The fact that we had to exclude many papers for data extraction because there were not even 5 lines further accentuates the low quality of reporting.

We did not differentiate articles based on surgical procedure or fixation methods in relation to their rehabilitation procedures. Of the 19 studies that described both single

incision and double incision techniques, only one study differentiated their rehabilitation programs based upon which procedure was used (Recordon, Misur, Isaksson, & Poon, 2015a). The heterogeneity between rehabilitation protocols did not seem to be related to the type of surgery or fixation method. Finally, since there is no clear standard for best practice, this review focused on the heterogeneity between described protocols and not a best practice comparison.

Future Implications

There are some important implications from our work. Firstly, at present there is no value to conducting systematic reviews in this area of research where the literature is so poor in quality and description. There needs to be substantive changes in future research to move the field forward. Given the wide variation in rehabilitation protocols and that many patients do well with these different protocols it may be important for experts in the field to get together to establish a clear research agenda. Given that this injury happens in fairly healthy individuals it may be either that persistent disability has not been accurately assessed, or that outcomes are generally good and that the opportunities for improvement are limited. Given that positive outcomes have been described with nonoperative and operative management of biceps ruptures, there may be a need to explore the presumption that surgical repair is the gold standard. Better imaging, strength assessment and long-term follow-up of operative and nonoperative cases to understand the implications of these choices are needed. Future clinical studies should consider multisite collaboration to conduct high quality randomized clinical trials once the important questions are established. Within surgical and rehabilitation trials

there is a great need for clearer description of the rehabilitation protocols, that can potentially be guided by CERT or TiDieR reporting guidelines.

Conclusion

Overall, rehabilitation descriptions for distal biceps ruptures are of extremely poor quality for surgical and non-surgical outcomes. Although reporting has somewhat improved within the last three years, poor rehabilitation descriptions remain common place for this condition. This deficiency represents ongoing issues that if uncorrected will continue to decrease clinical validity and reliability for all distal bicep's studies.

The authors have not received any financial payments or benefits from any funding source related to the subject of this article

References

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps

Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and Elbow Surgery*, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375. https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J. W. (2003). Distal biceps tendon repair: Comparison of surgical techniques.

Journal of Hand Surgery, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D.

(2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps

tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147. https://doi.org/10.1097/JSA.0b013e3181824e76

Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5

Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003

Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009

Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025

Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130

Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336

Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287

Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687

Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001

Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.

Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper

Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and Head), *608*(1 996).

Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382

Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005

Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035

Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.

Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030

Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214

Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009

Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.

Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896

Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1

Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562

Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017.

https://doi.org/10.1177/0363546515587738
Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405
Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690
Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144
Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049
Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5
Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003
Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358
Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa
Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694
Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003
Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008
Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T. (2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291. https://doi.org/10.2343/geochemj.2.0468

Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7

O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016

Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.

Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6

Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004

Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349

Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017

Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5

Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032

Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries: Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2), 103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the “Salento technique”, a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence,

demographics, and the effect of smoking. *Clinical Orthopaedics and Related Research*, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-

008-9129-8
Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014
Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098
Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041
Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.
Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276
Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.
Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030
Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003
Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4
Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9
Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029
Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0
Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002
von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J.

(2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bulletin of the World Health Organization*, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623

Table 1. Brief description of the Consensus on Exercise Reporting Template (CERT) items

Item#	Item	Description
1	WHAT: Materials	Detailed description of the type of exercise equipment (e.g. weights, exercise equipment such as machines, treadmill, bicycle ergometer etc.)
2	WHO: Provider	Detailed description of the qualifications, teaching/supervising expertise, and or trainings undertaken by the exercise instructor
3	HOW: Delivery	Describe whether exercises are performed individually or in a group
4		Describe whether exercises are supervised or unsupervised and how they are delivered
5		Detailed description on how adherence to exercise is measured and reported
6		Detailed description of motivation strategies
7a		Detailed description of the decision rule(s) for determining exercise progression
7b		Detailed description of how exercise program was progressed
8		Detailed description of each exercise to enable replication (e.g. photographs, illustrations, video, etc.)
9		Detailed description of home program components (e.g. other exercises stretching, etc.)
10		Describe whether there are any non-exercise components(e.g. education, cognitive behavioral therapy, massage etc.)
11		Describe the type and number of adverse events that occurred during exercise
12	WHERE: Location	Describe the setting in which exercises were performed
13	WHEN, HOW MUCH: Dosage	Detailed description of the exercise intervention including, but not limited to, number of exercise repetitions/sets/sessions, session duration, intervention/program duration etc.
14a	TAILORING: What, How	Describe where the exercises are generic (one size fits all) or tailored whether tailored to the individual
14b		Detailed description of how exercises are tailored to the individual
15		Describe the decision rule for determining the starting level at which people commence an exercise program (such as beginner, intermediate, advanced etc.)
16a	HOW WELL: Planned, Actual	Describe how adherence or fidelity to the exercise intervention is assessed/measured
16b		Describe the extent to which the intervention was delivered as planned

Table 2. Data extraction for included distal biceps studies

Author	Year	#	Title	Research Design	Type of Repair	Rehabilitation Description	Meds	Immob	Streng	#
Al-Taher	2014	7	"Fixation of acute distal biceps tendon ruptures using mitek anchors: A retrospective study	Retrospective	Single Incision	Postoperatively, the elbow was immobilized in a plaster in 90 degrees flexion and in a neutral position between supination and pronation for 5 weeks. Thereafter, active, low demand exercises were started. After 3 months, loading of the tendon bone complex was gradually increased and 6 months postoperatively full loading was permitted	None	5 Week plaster cast	3-6 months	2
Alemann	2015	25	Repair of biceps with 3 T MRI	Retrospective	NR	None	None	NR	NR	0
Anakwenze	2013	18	"An Analysis of Timing"	Retrospective	Single Incision	This protocol consisted of splint immobilization with elevation and icing for 1 week, followed by progressive elbow ROM, exercises for 2 weeks to achieve 30 degrees of extension to 130 flexion. During this time, the elbow is iced after exercise sessions to minimize swelling and promote wound healing. Motion is encouraged with a sling worn for comfort only. Over next 3 weeks, passive exercises are continued to achieve full elbow ROM. At week 6 active ROM is begun. At week 10, progressive strengthening is initiated with a goal of lifting 20lb (9kg) at 5 months independently. All patients were compliant with protocol.	None	Splint 1 week	10 weeks	6
Andritsos	2018	11	DBT repair anchor and tunnel	Retrospective	Single Incision	The upper extremity was immobilized at 90 of flexion in a sling overnight. When wound healing was ensured and controlled motion was permitted, the patient was encouraged to use the arm for basic activities of daily living followed by gentle, gravity-assisted elbow motion, depending on the level of patient comfort as well as the security of the fixation. No patients were left immobilized for more than 14days. For a period of 4 weeks, the patients were encouraged to mobilize within a flexion arc from 60 to 120. This was followed by assisted movement for another 2 weeks. In the next 6 weeks, the patient started moving the arm actively in full ROM and then gradual loading was applied to the arm until the 20th week from the time of surgical intervention. All athletes of our study returned to full sports activity schedule in a total time of 40 weeks postop.	None	0-2 weeks	6 weeks	6
Atanda	2013	123	Distal Biceps and Workers Comp	Retrospective	Single and Double	A standardized post-operative protocol was followed for all patients. All patients wore a splint post-operatively for 2 weeks. Patients were then switched to a hinged brace for 4-6 weeks. All patients worked on gradual strengthening during this time and returned to work without their brace	None	Splint 2 weeks	4-6 weeks	2
Bain	2000	12	Repair of DBT using endobutton	Retrospective	Single Incision	Plaster back slab 90 deg flexion and full supination. One week into a sling; no heavy lifting for 3 months	None	1 week	12 weeks	3
Baker	1985	13	Rupture of DBT	Retrospective	Double incision	Post op 4 weeks of Immobilization followed by 4 weeks of active and passive movements. Week 4 resistance exercises.	None	4 weeks	4 weeks	2
Balabaud	2004	8	Repair Suture Anchor Ant Approach	Retrospective	Single Incision	Post-operative rehabilitation consisted of 4 weeks immobilization in an above elbow plaster, after which a posterior splint which held the elbow flexed to 90 deg and the forearm in neutral rotation was worn for 2 weeks. At 6 weeks passive and active range of motion exercises were commenced. Progressive resistance exercises were allowed at 3 months. Each patient was allowed to gradually return to normal activities after 4 months.	None	Cast 4 weeks	12 weeks	3
Barnes	1993	4	Repair of Biceps Mitek Anchors	Retrospective	Single Incision	Physiotherapy	None	Cast 6 weeks	NR	1
Barret	2018	58	Immediate ROM post DB Repair	Retrospective	Double incision	A simple sling was used, and the patient was allowed to perform active motion immediately after surgery, avoiding any resistance. Self-rehabilitation instructions were provided before surgery. Four times a day, the patient performed a minimum of 20 rotations of the wrist at 90 degrees and 20 cycles of elbow extension and flexion, standing in front of a mirror and doing the exercises with both hands. No weightlifting was allowed, and strengthening was permitted after six weeks. In case of postoperative stiffness at 2 weeks follow-up, the patient was referred to physiotherapy.	None	0	6 weeks	3
Bell	2000	26	Repair of DBT	Retrospective	Double	A postoperative physical therapy regimen was encouraged, but only 17 of the 25 patients participated in formal rehabilitation. Of these, the duration of therapy varied from 1 to 26 weeks. The forma rehabilitation program was the following. The elbow was held at 90" of flexion in a posterior splint with the forearm in neutral rotation for 3 weeks. The extremity was then range of motion from full flexion to 45 deg. short of full extension; with each week 5" to 10" of extension was added. No resistive exercise was allowed for 8 weeks. At 2 months gentle resistive exercise was started and progressed to full resistive exercises at 4 to 5 months, with return to heavy labor and sports allowed. The variability of therapy may be considered one limitation of the study, and the effects of therapy on functional	None	3 weeks	8 weeks	4

						outcome could not be determined with any significance.				
Bosman	2012	6	Chronic DBT w/o graft	Case Series	Single Incision	The patient is placed in a simple broad arm polysling (Molnlycke Healthcare, Dunstable, Bedfordshire, UK) postoperatively for comfort at 90 of elbow flexion. Active range of movement is commenced at day 1m postoperatively. The patient is advised to do no resisted flexion exercises beyond 1 kg for 6 weeks. Active and passive extension is allowed as able, with the patient encouraged to use gravity-assisted extension of the elbow during the first 3 weeks. The sling is only worn for comfort. Physiotherapy to work on extension is commenced at 4 weeks. At 6 weeks, a return to normal activities is encouraged, although no specific biceps strengthening is allowed for 8 weeks.	None	NR	8 weeks	5
Caekebeke	2016	23	Bioabsorbable vs. Nonabsorbable	Retrospective	Single Incision	The elbow was immobilized in 90° of flexion and neutral rotation for 10 days, after which active and passive range of motion exercises were started. Muscle strengthening commenced at 2 months postoperatively. Controlled, unlimited lifting was allowed at 3 months. Sport activities were allowed at 5 months.	None	10 days	8 weeks	4
Caputo	2016	12	DBT repair using Lacertus fibrosus	Retrospective	Single incision	The postoperative care of these patients is identical to that which we use after a primary repair of the distal biceps tendon. The initial postoperative dressing immobilizes the elbow at 90°, allowing forearm rotation. At the first postoperative visit in <1 week, the patient begins mobilization from a removable 90° elbow splint that does not restrict forearm rotation. The patient is instructed to remove the splint to perform elbow flexion-extension exercises without resistance and to perform passive forearm rotation exercises with the elbow held at 90°. For the first 6 weeks, patients are encouraged not to extend the elbow beyond 90°. After 6 weeks, the removable splint is discontinued, and further elbow flexion and extension are encouraged. Progressive structured strengthening is initiated at 3 months, and all restrictions are removed at 6 months.	None	6 weeks	12 weeks	5
Cheung	2005	13	Immediate ROM post DB Repair	Retrospective	Double incision	Postoperatively, the elbow was placed into a hinged elbow brace locked at 90° of flexion and neutral forearm rotation. On postoperative day 1, the brace was unlocked to allow for self-passive range-of-motion exercise from 60° of flexion to full flexion. Full rotation was permitted. The elbow extension lock was decreased to 40° at 2 weeks postoperatively, to 20° at 4 weeks postoperatively, and to full extension at 6 weeks postoperatively. Strength training began after 8 weeks	None	Brace 4 weeks	8 weeks	3
Chillemi	2007	9	Conservative vs. DBT Repair	Retrospective	Double	Post op Immobilization 6 weeks Cast (90 flex slight sup). Referred to PT	None	6 weeks	NR	0
Cil	2009	21	Immediate ROM 2 incision	Retrospective	Double incision	Postoperatively, the elbow was placed in a sling for 1 to 2 days for comfort. Patients were seen in clinic at that time, sling use was discontinued, and they were encouraged to begin passive range of motion exercises in pronation and supination, as well as active range of motion with emphasis on gaining full flexion and extension and full rotation as soon as possible. For the first 6 weeks, the elbow was allowed to be used during activities of daily living as tolerated by the patient with a 1-lb weight-lifting restriction. Two-pound weightlifting was allowed after 6 weeks. Full activity was resumed after 3 months. No formal physical therapy was employed in any of the patients after the operation. No patients were given nonsteroidal anti-inflammatory drugs to prevent heterotopic ossification and/or proximal radioulnar synostosis	None	1-2 days	6 weeks	5
Citak	2011	54	Three Surgical Techniques	Retrospective	Single and Double	Post-operative care in all patients consisted of elbow immobilization in 90 degrees of flex and neutral rotation for 3 weeks, follow by early functional rehab protocol. Active range of motion began at 6 weeks followed by strengthening over the next 6 weeks. Sporting activities were forbidden for 3 months after surgery	None	Cast 3 Week	6 weeks	2
Cross	2014	7	Tibialis Anterior Graft	Retrospective	Single Incision	Post-operatively the arm is place in a posterior splint at approximately 70 deg of flex for one to two weeks and transitioned to a hinged elbow brace for six weeks. Passive range of motion from 60-100 deg in the hinged brace is initiated after splint removal and increased by 10-15 deg per week, with the goal of full ROM 6-8 weeks. Limitations during PT for the first six weeks include no flex or supination. At week 6 the patient can begin active and active-assisted elbow flexion without the hinged brace. Progressive strengthening is performed from 6-12 weeks. Return to sport and work at 6 months.	None	Hinge Brace 6 weeks	6-12 weeks	4
Cuski	2014	170	Corticol Button/Inference screw	Retrospective	Single Incision	Patients are immobilized in a splint for 1 week followed by 1-month application of a range of motion brace to prevent extension (locked from 30-130 deg). After 1-month patient begin ROM exercises as tolerated but are instructed to avoid lifting. Patients are permitted to light lifting after 3 months. Wound check visit at 7-10 days and follow	None	Splint 1-2 weeks	12 weeks	3

						up every 6 weeks, 3 months and 6 months and then as needed				
DaCambra	2013	1	Bilateral DBT w/Endobutton	Case Study	Single Incision	The same postoperative protocol was used for each elbow. In the operating room, a plaster splint was fashioned with the elbow at 90 degrees flexion, the forearm in neutral rotation and the wrist in neutral. All digits were free. One week after the operation, a removable splint with the extremity in the same position was made and physiotherapy started. This consisted of passive elbow flexion and active extension exercises with his forearm supinated. Elbow flexion was full while a 30-degree extension block was observed. Passive full supination, and active pronation limited to 50 degrees with the elbow at 90 degrees flexion was also performed. This was implemented for five weeks. At six weeks, the removable splint was stopped, and strengthening and stretching exercises were added to obtain full motion. Resistance was progressed to a maximum of 4.54kg (10 pounds). Three months after the operation, all restrictions were removed.	None	6 weeks	6 weeks	4
D'Alessandro	1993	10	DBT in Athletes	Case Series	Double Incision	The forearm is held in supination with the elbow brace in 90 deg of flex for 3 weeks. AROM is then begun followed by progressive resisted strengthening at 6 weeks	None	3 weeks	6 weeks	2
D'Arco	1998	13	DBT Boyd Anderson	Retrospective	Double incision	One week after surgery, the hinged brace was unlocked and range of motion (ROM) limits were set at the available motion for elbow extension and flexion. Active elbow joint extension was begun at 2 weeks after surgery, during which time the elbow was returned passively to a flexed position by the patient. Active and active-assisted elbow joint extension and flexion and forearm pronation and supination were allowed 2 weeks later. Passive elbow joint motion was administered in the rehabilitation program by a physical therapist 6 weeks after surgery when necessary. Submaximal isometric exercises were begun at 4 weeks after surgery. Patients were progressed at 6 weeks to submaximal isotonic exercises for elbow flexion and extension and forearm pronation and supination. Patients were allowed to progress their strengthening exercises as tolerated from a period of 8 weeks onward. Wrist and shoulder strength exercises were begun at 4 weeks after surgery, with care taken not to place stress across the repaired tissue.	None	4 weeks	6 weeks	7
Darlis	2006	7	Chronic DBT	Retrospective	Single Incision	A posterior, long arm splint with the elbow in 90° of flexion is applied for 2 weeks and then replaced with a hinged elbow brace with an extension block. Extension is gradually added, so that the patient reaches full extension in the brace by 8 weeks. The elbow brace is then discontinued. The patient begins progressive strengthening in physical therapy until full loading is permitted at 6 months.	None	8 weeks	8 weeks	1
Davison	1996	8	Long Term DBT Ruptures	Retrospective	Double incision	Forearm is immobilized in 90 deg of flexion with forearm neutral for 4-6 weeks. The AROM and AAROM done by OT. Strengthening beginning at 6 months	None	4-6 weeks	12 weeks	3
De Carli	2009	23	Non-Anatomic Repair	Retrospective	Single Incision	Cast for 3 weeks in 90 deg of flexion. Then progressive mobilization for further 3 weeks. Muscle strengthening only at 3 months	None	3 weeks	12 weeks	2
Ding	2016	1	Chronic DBT rupture w/Achilles	Case Study	Single Incision	The patient is placed in a posterior splint for 6 to 8 weeks. After 6 to 8 weeks, the splint is removed, and physical therapy is initiated for range of motion exercises. We encourage a longer period of immobilization because we feel this causes less stretching of the graft itself. In our case series, we have not had any instances of residual stiffness. However, if there is a concern for stiffness, the patient is moved from a splint to brace at 4 weeks and range of motion exercises can be initiated. We advise lifting no more than 5 pounds with the affected extremity until 3 months postoperatively. Between 3 and 6 months, progressively more weight is added until unlimited activity is permitted after 6 months.	None	4-8 weeks	12 weeks	3
Ding	2016	1	Acute DBT w/Weightlifting	Case Study	Single Incision	After closure, the arm was then placed in a t-scope brace locked at 90° with a gradual increase in extension over the course of 6 weeks. After 6 weeks, the brace was removed and the patient was advanced to full active elbow ROM as well as pronation and supination before strengthening at 3 months after surgery. The patient achieved a full recovery, with return to sports 6 months after surgery.	None	6 weeks	12 weeks	2
Dillon	2011	27	Acute and Chronic w/ Endobutton	Retrospective	Single Incision	A posterior mold spent in 90 flex is applied for 2 weeks. At 2 weeks patients are allowed to start AROM. At 4 weeks they are allowed to begin using the arm for activities of daily living but no lifting >5 pounds. At 8 weeks, patients begin to work on strengthening ex. Restoration of full forearm flex and supination strength up to 6 months post-op.	None	2 weeks	8 weeks	4
Eardley	2009	14	DBT Bioabsorbable Screw	Retrospective	Single Incision	All patients were discharged with the operated limb immobilized in an above-elbow plaster of paris (POP) back-slab with the elbow at 90 flexion and neutral	None	6 weeks	12 weeks	1

						forearm rotation for 2 weeks. Review was at 2 weeks,6 weeks,3 months and 6 months postoperatively. At 2 weeks a Mayo elbow brace was applied restricting the terminal 30 of extension and active range of motion (ROM) was encouraged. At 6 weeks postoperatively, the elbow brace was removed, and patients were advised not to lift anything heavy for a further 6 weeks (12 weeks from surgery).				
El-Hawary	2003	19	Comparison of 1 vs. 2 incision	Prospective	Single and Double	The postoperative routine was identical for both treatment groups. The elbow was immobilized in 90° of flexion and full supination. Motion was started on the third postoperative day. This included active elbow extension and passive flexion with the forearm fully supinated as well as active pronation and passive supination with the elbow maintained at 90°flexion. A resting splint at 90° with the forearm maintained in supination was worn between exercises for 6 weeks. Extension was permitted to 60° during week one and increased 10° per week until full extension was permitted at 6 weeks. Active motion was permitted after 6 weeks and strengthening was permitted after 3 months. Full activity was resumed after 6 months. Patients received prophylaxis against heterotopic ossification with indomethacin 25 mg 3 times a day and misoprostol 200 mcg twice a day for 6 weeks.	Indo-methcin 3x/day and miso-prostol 2x/day for 6weeks	6 weeks	12 weeks	4
Ennaciri	2015	1	Surgical Management DBT	Case Study	Single Incision	A splint has been used to immobilize the left upper limb and protect the tendon repair for 6 weeks. Passive and progressive rehabilitation, ranged from 30° to 90° of flexion extension, was encouraged during this period	None	6 Weeks	NR	1
Faict	2019	20	Chronic DBT tendinopathy	Retrospective	Single Incision	Immediate gentle active and passive range of motion was allowed, and no splints or casts were used. After 6 weeks, progressive biceps muscle toning exercises were initiated under supervision of a physiotherapist. Daily activities without restriction were initiated after 3 months, and sports activities could be resumed after 6 months.	None	None	6 weeks	3
Fenton	2009	14	DBT with Biotenodesis Screw	Retrospective	Single Incision	Post-operative rehabilitation consisted of 3 weeks of immobilization in an above-elbow plaster with forearm in neutral rotation and 90 elbow flexion. This was followed by 3 weeks within a poly sling and thereafter gentle active-assisted were begun with our physiotherapists. At 6 weeks post-operatively full active mobilization was commenced	None	3 weeks	NR	3
Frank	2019	19	Chronic DBT	Retrospective	Single and Double	It is our practice to prescribe indomethacin, 25 mg orally 3 times a day, for 3 weeks in both direct repairs and reconstructions for heterotopic ossification prophylaxis. Standardized physiotherapy regimen was prescribed with gradual return of full extension by 6 weeks and progressive strengthening beginning at 3 months.	Indo-methcin 3 weeks	NR	12 weeks	1
Gallinet	2011	28	Suture Anchor	Retrospective	Single Incision	Immobilization with removal cast/splint in 60 to 90 flex depending on preoperative findings and neutral rotation. Rehabilitation was passive with elbow flexion in the sector protected by the orthosis. Active work and recovery of elbow extension were initiated on removal of cast/splint between 30-45 days.	None	30-45 days	NR	2
Garcia	2012	18	Mini-Open 2 incision	Retrospective	Double incision	After the surgery, all the patients used a plaster-cast splint for one week, followed by use of a sling, and they were instructed to perform passive movement up to the pain threshold, for flexion-extension and pronation-supination. Two weeks after the surgery, the sling was removed and the patients were released to perform light activities such as lifting objects of the weight of a telephone, wallet, glass, etc. Physiotherapy was also started, in order to improve their passive range of motion, along with indirect isometric exercises (movements in which the biceps was the secondary motor). Four weeks after the operation, the patients started to perform isometric flexion-extension and pronation-supination work and, six weeks after the operation, isotonic work.	None	1 week	4 weeks	4
Gasparella	2011	14	Suture Anchors	Retrospective	Single Incision	We followed 7-day immobilization in posterior elbow splint with 90 flex and forearm supination. Then bag sling with gradual mobilization for 2-3 times/week with passive and active assisted extension of the elbow with therapist. Passive mobilizer also used 2x/day for 20 min each for about 20 sessions. Until 2 weeks post op elbow ext. limited to 30 deg. From 5th week, sling removed, and muscle reinforcement is started in flexion/sup with maximum weight of 2-2.5 kg, from 10th week, muscle reinforcement increased progressively to greater loads. Strengthening and full activities are permitted at 3 months after surgery.	None	1 week	5 weeks	6
Giacalone	2015	33	Treatment of DBT	Retrospective	Double incision	Splint in 90 deg flexion 3 weeks; Inc. Flex/Ext 9 weeks…3 months heavy lifting	None	9 weeks	12 weeks	2
Goljan	2016	14	Single Incision Hemi Krackow Suture	Retrospective	Single Incision	At the first postoperative visit (7-10 days), the cutaneous sutures are removed, and a long arm thermoplastic splint is made keeping the elbow in 90° of flexion and neutral rotation. A therapy	None	6 weeks	10-12 weeks	4

						program is also initiated at this time focusing on initial passive elbow flexion and supination and active elbow extension up to 60°. Active extension and pronation are advanced depending on the intraoperative tension on the repair. Full active and passive range of motion is usually achieved by the 6-week mark and splinting is discontinued. Strengthening begins 10 to 12 weeks postoperative.				
Gregory	2009	23	Suture Anchors	Retrospective	Single Incision	An above elbow cast in 90 flex and forearm supination is applied for 3 weeks. NSADIS were prescribed 5 days after. The rehab was progressively started at 3 weeks. Resistance exercises were started at 6 weeks. Return to normal activities at 3 months.	Diclfenac (100mg/d)	3 weeks	6 weeks	2
Grewal	2012	91	Single Vs. Double	Prospective	Single and Double	The postoperative protocol was identical for both groups. Unless contraindicated, indomethacin (25 mg three times daily for three weeks) was prescribed as prophylaxis against heterotopic ossification. The elbow was immobilized in 90 of flexion with the forearm in supination. Active elbow extension exercises, passive flexion exercises with the forearm in full supination, and active pronation and passive supination exercises were initiated within the first few days postoperatively. A resting splint at 90 with the forearm maintained in supination was worn between exercises for six weeks. Depending on the degree of intraoperative tension at the tendon repair, extension was limited initially, and increased by 10 per week until full extension was achieved. Active motion was permitted after six weeks, and strengthening was permitted after three months.	Indo-methcin 3 weeks	6 weeks	12 weeks	4
Guglielmino	2016	20	Clinical and Functional Outcomes after DBT	Retrospective	Single and Double	Immobilization 90 flex for 3-4 weeks. Patients began rehab program after first month of follow-up. Second follow up at 3 months and can return to full sports and work about 6 months after surgery.	None	3-4 weeks	NR	1
Habashy	2018	1	Chronic DBT Rupture	Case Study	Single Incision	His post-operative protocol included strict immobilization for 2 weeks, followed by gradual eccentric extension protocol. He began aggressive dynamic physical therapy at 6 weeks	None	2 weeks	NR	2
Hallam	2004	9	Chronic DBT Endobutton/Ham string	Prospective	Single Incision	Finally, the forearm was closed in layers and a plaster back slab applied in 90° of flexion and full supination for 1 week. One week after surgery, the back slab was removed, patients were provided with a sling, and the elbow was mobilized as tolerated. Patients were advised not to per for many heavy liftings or grasping for 3 months. Contact sports were avoided for 1 year	None	1 week	12 weeks	1
Hansen	2014	27	Anatomic Repair CANNOT be performed	Retrospective	Single Incision	None	None	None	None	0
Hartman	2007	33	Mini-Open 2 incision	Retrospective	Double incision	The extremity is placed into a sling with elbow at 90 deg flex. Immediate gentle AROM without resistance is allowed. No brace, splint or formal physical therapy program is initiated. Lifting and return to work are generally allowed after 3 months pos-operatively	None	Sling	12 weeks	0
Haverstock	2017	16	Chronic Delayed DBT rupture	Retrospective	Single and Double	None	25mg Indo-methcin 3x/day 3 weeks	NR	NR	0
Heinzelmann	2009	31	DBT with STM Button Biotenodesis screw	Retrospective	Single Incision	At 3 to 5 days postoperatively, the splint is removed, and a compressive sleeve is applied. Home therapy is initiated at 1 week to include gentle active pronation, supination, flexion, and extension. Pain-free strengthening with 1-lb weights is started 1 week postoperatively. By 2 to 3 weeks, patients are performing activities of daily living and active motion is allowed as tolerated. Patients are counseled to avoid excessive elbow flexion against resistance, like picking up an 80- to 100-lb weight with the injured arm for 2 to 3 months. Most patients are back doing normal activities by 4 weeks. A representation of normal activities includes using the injured arm to do the following: shoot a basketball, rake leaves, drive a car, mow the yard, and carry a gallon of milk. Workers' compensation patients go to physical therapy from weeks 4 to 8.	None	3-5 days	1 week	6
Hetsroni	2008	22	Nonoperative vs. Operative	Retrospective		Postoperatively, the elbow was held at 90 degrees of flexion in a posterior splint with the forearm in neutral rotation for 2—3 weeks. Formal physiotherapy was then encouraged, initially with passive motion. At 6 weeks, active movements through a complete range of motion were allowed, and strengthening was exercised by 10—12 weeks. In the non-operative group, passive motion was allowed after a few day's rest following the injury, followed by active movements at 4 weeks, and strengthening exercises by 8 weeks.	None	2-3 weeks Splint	10-12 weeks	2
Hinchey	2014	190	Re-Rupture Rate	Retrospective	Double Incision	In the earlier years patients were treated with casting for 4-6 weeks. Evolved to more aggressive rehab protocol almost immediately after surgery. Difficult to correlate postop rehab to complications. Only	None	4-6 weeks	NS	2

						consistent protocol was non-weight bearing 6-8 weeks post op				
Horschig	2012	1	Rehab for DBT repair	Case Study	Single Incision	Protocol Included	None	10 Weeks	10-12 weeks	10
Hrubina	2013	21	Results of primary repair of DBT	Retrospective	Single Incision	Sling for 4-5 weeks. Rehabilitation stated with passive then active exercises and patients were permitted application of heavier loads to the operated extremity 8-10 weeks after injury.	None	4-5 weeks	8-10 weeks	2
Hurov	1996	1	Rehab for DBT repair	Case Study	Single Incision	Protocol Included	None	9 weeks	9 Weeks	10
Jockel	2010	15	DBT in women	Retrospective	Double incision	Arm is flexed to 90 deg and forearm neutral. After 1-week splint is removed and changed to long arm case for 4 weeks. Then to hinged brace with extension stop. Strengthening started at 8 weeks with resisted exercises at 3 months and return to normal activities at 12-16 weeks	None	5 weeks	8-12 weeks	3
John	2007	53	Single Incision SA	Retrospective	Single Incision	All patients, except one, were discharged on the same day of surgery, and postoperative immobilization varied depending on the intraoperative assessment of tension on the repair. Extremities were immobilized for between 1 and 4 weeks in a long arm cast or splint. Gentle passive and progressive range-of-motion exercises were then allowed until 6 weeks postoperatively in all patients. After 6 weeks, patients were allowed to use the affected extremity for light activities, and progressive strengthening exercises were initiated. Three months after surgery, all patients were allowed to resume normal activities without restriction or limitation.	None	1-4 weeks	6 weeks	3
Johnson	2008	26	One Incision vs. Two Incision	Retrospective	Single and Double	Post-operative care for both groups consisted of elbow immobilization in 90 flex and neutral forearm for 7-10 days followed by passive flexion and extension to 45 deg. This was advance in order to obtain full extension and flex by 6 weeks. AROM at 6 weeks and then strengthening over next 6 weeks. A flexion-assisted brace was used in most cases for 6-8 weeks.	None	7-10 days	12 weeks	2
Kale	2018	1	Chronic DBT w/2 incision	Case Study	Double incision	The patient was placed into a long-arm fiberglass posterior splint with the elbow at 90° of flexion and neutral forearm rotation. A supervised physical therapy program was initiated that permitted passive and active-assisted ROM and which gradually advanced the patients elbow extension. Resisted motion and strengthening were initiated 3 months after surgery. At 5 months after surgery, the patient was returned to modified work duties consisting of a 5-pound weight restriction on the left arm. He continued to progress with strengthening and at 9 months after surgery was returned to his regular duties as a cabinetmaker	None	NR	12 weeks	2
Karunakar	1999	20	DBT repairs	Retrospective	Double Incision	Splint in 90 deg flex and neutral rotation. 3-4 weeks after posterior splint was applied in 60 deg ext., passive flex began. 4-6 weeks active flexion was started blocked at 30 ext. 6 weeks AROM full motion, 8 weeks strengthening	None	4-6 weeks	8 weeks	4
Kelly	2003	8	Single Posterior Approach	Case Series	Single Incision	Most recently, simple sling day 1 and instructed to begin gravity-assisted extension exercises with passive flexion immediately. The sling is worn for the first 6 weeks to prevent a constant gravitational pull on the tendon. The patients removed the sling frequently to permit full active and passive motion of the elbow and forearm, using gravity alone to assist with elbow extension. They were instructed to "use no more force than would be required to lift a glass of water or a telephone receiver" for 6 weeks, then to "use common sense" and avoid heavy force (lifting, getting a window unstuck, etc.) until 3 months after surgery. From 3 to 6 months postoperatively, progressively more weight is allowed. Unlimited activities are permitted after 6 months.	None	0-6 weeks	12 weeks	3
Khan	2008	17	DBT Suture anchors Single Incision	Retrospective	Single Incision	The arm was placed in a well-padded posterior plaster splint that kept the elbow flexed at 90 deg and forearm between neutral and full supination for 2 weeks. The arm was then placed in a hinged brace so that the patient could start passive flexion and active extension motion with an ext. block at 90 deg and the arm supinated. The brace was adjusted weekly for more ext. (30 deg. Every two weeks). After 6-8 weeks AROM was initiated. Resisted supination began at 3 months	None	2 weeks	12 weeks	2
Klonz	2003	14	Anatomic vs. Non-Anatomic Repair	Retrospective	Single incision	None	None	None	None	0
Kodde	2013	22	DBT with Cortical Button		Single incision	Post-operatively, a long-term cast was applied for 1 week. An oral NSADI (Meloxicam) was routinely prescribed for 1 week. After 1 week, PT was started. Both passive and active ROM exercises were allowed. Patients were advised to prevent flex against resistance for the first 3 months. After 3 months, patients were allowed to resume normal activities as prior to the biceps tendon injury.	Melxcam 1 week	6 weeks	12 weeks	3
Kobayshi	2003	15	DBT with Single Incision	Retrospective	Single Incision	Forearm 90 deg flex and full supination. Immobilization splint for 2 weeks followed by brace				

						to start passive range of motion with 90 deg ext. block. AROM at 6 weeks. 3 months for strengthening.	None	2 weeks	12 weeks	3
Kumar	2017	2	DBT Functional Outcome	Case Series	Single incision	110 deg of flexion and supination was given. Patient was discharged on second post op day and at one month follow up slab and sutures were removed, elbow mobilization started. Wound was healed well and at 2 months post of he had near normal range of movement and without any pain and quick DASH score improved to 11 at 2 months post op and it is improving further.	None	4 weeks	NR	1
Lang	2018	47	DBT w/ cortical button, transosseus fixation or SA	Retrospective	Single Incision and Double	All patients underwent a similar rehabilitation protocol, under the observation of a skilled physical therapist. Passive and active range of motion therapy was started at 10–14 days following surgery. Lifting light weights (with a maximum of 5 kilograms) was allowed at 6 weeks after surgery. At 12 weeks after surgery, an increase in weight load was permitted.	None	NR	6 weeks	3
Legg	2016	47	Non-Op vs. Endobutton	Retrospective	Single Incision	Progressive early active range of motion exercises are started 7 to 10 days postoperatively, after removal of the backslap. At 6 weeks postoperatively, they are then reviewed in outpatients to ensure that full range of motion has been achieved and to assess for any complications. Anterior posterior and lateral radiographs are performed to ensure that the position of the Endobutton is unchanged from the intra operative image and that there have not been any radiologic complications. Light lifting is allowed at 3 months, progressing to unrestricted weights at 6 months. The nonoperative cohort received the same early range of motion physiotherapy, which started as soon as pain allowed.	None	7-10 days	12-24 weeks	4
Leighton	1995	9	DBT repairs	Retrospective	Double incision	The forearm is held in supination and 90 deg flex for two weeks. AROM started at 4 weeks. Strengthening at 4-6 weeks	None	2 weeks	4-6 weeks	2
Levy	2000	5	Chronic DBT using FCR graft	Case Series	Single Incision	The elbow is placed in a splint at 90° of flexion and 45° of supination. Sutures are removed 10 days after surgery. A hinged elbow brace is worn that allows the maximum extension obtained without tension in the operating room. Full extension is allowed at 8 weeks and resistive exercises are started at 3 months. Full activities are allowed at 4 months	None	8 weeks	12 weeks	2
Lintner	1996	5	DBT w/Suture anchors Ant Approach	Retrospective	Single incision	Posterior splint which held elbow flexed to 90 deg w full arm supination	None	8 weeks	12 weeks	6
Logan	2019	1	Rehab for DBT repair	Case Study	Single and Double	Protocol Included	None	6 weeks	12	10
Lynch	1999	6	Repair of Distal Biceps w/SA	Case Series	Double Incision	Operative patients were initially immobilized until the incision healed and staples were removed at about 7–10 days, at which time the patients began physical therapy. Physical therapy consisted of initial protected range of motion with extension limited to 40°. Unlimited passive and active assisted full flexion were allowed within this range. Range of motion limits were progressively reduced up to 4 weeks, at which time unlimited motion was allowed. Pronation and supination progressed along the same course with initial restrictions limited by pain. Exercises in flexion and supination with 2 lb. resistance were also begun at 4 weeks and this gradually increased up to 10–15 lb. by week 10. Patients returned to work when the arm was no longer tender, and they had a painless, nearly normal range of motion of the elbow and forearm.	None	7-10 days	4 weeks	6
McKee	2005	53	DBT with Single Incision and SA	Retrospective	Single incision	Postoperative radiographs confirm proper placement of the suture anchors and tendon. Patients are splinted at 90° of flexion for 2 weeks. At this point, the splint is removed and range-of-motion exercises under the guidance of a physiotherapist are initiated. Full extension and rotation are typically achieved at 4 weeks, and gradual strengthening of flexion is instituted at 6 weeks postoperatively. Unrestricted activity and return to sports are allowed at 8 to 12 weeks postoperatively. It should be noted that compliance with the postoperative regimen was highly variable, and many patients returned to aggressive activities earlier than was recommended.	None	2 weeks	6 weeks	3
Moosemayer	2000	9	DBT with Boyd Anderson	Retrospective	Double incision	Immobilization for 6 weeks 90-110 Flexion, slight supination	None	6 weeks	NR	0
Morrell	2012	12	DBT with TFL graft w/SA	Retrospective	Single Incision	Postoperatively, all patients are immobilized with the elbow in 50 degrees of flexion for 6 weeks. Sutures are removed at the 2-week visit. At the 6-week visit, a standard physical therapy program is begun to work on range of motion, particularly active-assisted flexion-extension and pronation-supination. At 12 weeks, gradual strengthening exercises are commenced.	None	6 weeks	12 weeks	2
Morrey	2014	23	DBT in extreme flexion	Retrospective	Double incision	Postoperatively, the elbow is immobilized in a posterior plaster splint or in a locked brace in 90 of flexion with neutral pronation supination for the first 2 weeks, depending on the degree of swelling. At week 2, patients are allowed to increase elbow extension in the brace each week in 10 increments	None	6-8 weeks	12 weeks	4

						starting from the initial flexion position. Patients are encouraged to work on active extension and passive flexion ex's, pronation and supination in 90 deg of flexion. Brace protection discontinued once extension at 20 deg (6-8 weeks), Strengthen 3 months, normal activities at 6 months				
Nayyar	2011	1	DBT and Supinator Muscle Rupture	Case Study	Single Incision	After surgery, the patient was placed in a well-padded posterior long arm splint for 10 days, with the elbow at 90 degrees of flexion and the forearm in neutral position. At postoperative day 10, the patient was placed in a Bledsoe brace, and the ROM gradually increased. At four weeks, active ROM exercises were begun under the guidance of a physical therapist and at ten weeks, a program of progressive resistive exercise program initiated for flexion and supination/ pronation at the elbow.	None	NR	10 weeks	3
Niemeyer	2007	18	DBT with Transcortical Refixation	Retrospective	Single Incision	All patients were treated with ibuprofen for at least 14 days after surgery, to prevent HO. Immobilization for 4 weeks in 90 deg flexion and supination	NSAID 2 weeks	4 weeks	NR	0
Nimrod	2013	20	Chronic DBT with allografts	Retrospective	Single and Double	Patients were immobilized in a posterior splint for 2 weeks. At that point, passive and gravity-assisted range of motion exercises were initiated. Slings were discontinued at 6 weeks, and patients began progressive strengthening and physical therapy until reaching full weightbearing status	None	2-6 weeks	6 weeks	2
Norman	1983	16	DBT with Henry Approach	Retrospective	Single incision	Immobilized 90 deg flex and mid rotation of forearm for 6 weeks. Then sling for week 7-10 sling. Active finger and circumduction exercises for shoulder during immobilization. Formal PT	None	6-8 weeks	NR	2
Olsen	2014	37	DBT: Cortical Button vs. Inf Screw	Retrospective	Single incision	Patients began active range of motion (ROM)at 5 to 7 days postoperatively as long as there were no signs of wound dehiscence. Beginning at 6 weeks, patients were advanced to a 10-pound lifting restriction, and at 12 weeks they were allowed to resume activity as tolerated. No bracing was used, and all patients attended formal physical therapy sessions.	None	None	6 weeks	3
Pangallo	2016	20	Mini-Open One-Incision	Retrospective	Single Incision	The arm was splinted at 90 of flexion with neutral rotation for 2 weeks. The wrist is unlocked. A hinged brace was applied for two more weeks allowing total passive flexion movement and limited extension movement from 90 to 60 for 7 days, 60 to 30 for 5 days and 30 to complete extension during last days. The brace was removed at 4 weeks, and a rehabilitation program was started. Weight exercises were not allowed for 2 months. Strength training exercises started at 3 months, with no restrictions from the fourth month forward.	None	4 weeks	12 weeks	2
Pascarelli	2013	9	Two Anterior Mini Incisions	Retrospective	Double incision	After fixation, the limb was immobilized with a plaster cast at 90 degrees of flexion and maintained for three weeks when physiotherapy was initiated	None	3 weeks	NR	0
Peeters	2009	26	DBT and EB	Retrospective	Single incision	Our standard postoperative protocol included immediate mobilization in patients who were treated acutely. In the subacute presentations (>6 weeks), a cast was applied for 2 weeks. After 6 weeks, biceps strengthening was started. All patients were allowed to resume normal activity without restriction or limitation 3 months after surgery.	None	0-2 weeks	6 weeks	2
Phadnis	2016	21	DBT EB and Pulver Weave	Retrospective	Double Incision	Postoperatively, the arm is placed in a sling for 2 weeks. From 2 to 6 weeks, the patient removes the arm from the sling only to perform active range-of-movement exercises in a safe zone from 45° to full flexion. From 6 to 12 weeks, full active range of movement is permitted with a graduated loading program from 12 to 24 weeks. Sports-specific rehabilitation program is commenced once 90% strength compared with the contralateral side is achieved.	None	2-6 weeks	12-24 weeks	2
Rantanen	1999	19	DBT repairs	Retrospective	Single and Double	After surgery, the arm was placed in a dorsal plaster cast splint with the elbow joint in 90° to 100° flexion for 3 to 5 weeks. Passive unresisted mobilization was initiated thereafter. Gradual weight training was allowed after reaching a near normal elbow range of motion. The rehabilitation was supervised by a physical therapist in most cases. The patients were told to avoid strenuous exercise, such as competitive sports, and heavy lifting for 4 to 6 months.	None	3-5 weeks	When ROM full	3
Rashid	2016	5	Failure of DBT by gapping	Retrospective	Single Incision	None	None	NR	NR	0
Recordon	2015	43	EB vs. TS Repair using 2 incision	Retrospective	Double Incision	The postoperative management of the 2 groups of patients was different. The elbows that had transosseous repair were placed into an above-elbow plaster of Paris cast with the elbow at a right angle. This treatment was designed to avoid any excessive premature load, which may fracture the bone bridges created in the radius. The elbow wounds were checked in clinic at 2 weeks, and the elbow was again splinted in an elbow cast, giving a total immobilization period of 6 weeks. At 6 weeks after surgery, patients were allowed gentle protected mobilization of the elbow and use of the arm for driving and light activities of daily living. Three months after surgery, they were allowed	None	0-6 weeks	12 weeks	5

						strengthening and unprotected use of the elbow. Elbows that had endobutton fixation had a pressure dressing to minimize postoperative bleeding. The elbow was placed into a sling, and the patients were allowed immediate assisted active gentle mobilization of the elbow. The wounds were checked at 2 weeks. One month after surgery, patients were allowed to use the arm for driving and light activities of daily living. Three months after surgery, they were allowed to commence strengthening activities with unrestricted use of the elbow.				
Redmond	2016	23	DBT functional Outcome	Case Series	Single Incision	Unknown	None	NR	NR	0
Reichert	2018	28	DBT: Cortical Button vs. SA	Retrospective	Single Incision	Day of discharge, patients provided a sling and told to wear for 4 weeks. Then the elbow can me mobilized as tolerated. Then directed to outpatient clinic to conduct formal physiotherapy. This management focused on reducing pain, inflammation and edema. In the period of limb immobilization, passive exercises on the elbow joint of the surgical limb were carried out in the range of motion that did not cause pain. Isometric exercise of the extensor muscles and flexors of the forearm and muscles rotating the forearm were also performed. Consecutively, after sling removal the patients were advised to introduce active elbow joint movement with an unrestricted range of motion band, they were permitted to use the surgical limb in daily activities. Such as bathing, lifting a cup of coffee or lifting items with a weight of not more than 1kg. Then, active exercises of the elbow joint of the surgical limb were introduced. The patients were allowed to return to non-contact sports after the 12th week and contact after the 24th week post-operatively,	None	4 weeks	4-6 weeks	5
Reichert	2018	7	DBT PIN Nerve Palsy	Retrospective	Single Incision and Double	Postoperatively, splinting the extremity in an appropriate position for 2–3 weeks to take off the tension was recommended. The postoperative procedure was based on physical, occupational, and hand therapy, with the aim of minimizing disability and preparing the patient to return to his previous work environment and recreational activities.	None	2-3 weeks	NR	1
Ribeiro	2018	4	DBT repair using Semitendinosus graft	Case Series	Double incision	The above-elbow splint was removed after two weeks, and a simple sling was maintained until the sixth postoperative week. Physical therapy was initiated six weeks after surgery, was maintained for approximately two months. No restriction on the final range of motion of the elbow was observed.	None	2 weeks	NR	1
Rollo	2019	37	DBT with Salento Technique	Retrospective	Double Incision	We created a specific rehabilitation protocol to provide the clinicians and the physiotherapists with precise indications on the postoperative course of rehabilitation, and to rationalize and to have the entire patient population conform to a single program in order to reduce the bias.	None	6 weeks	2 weeks	Protocol
Ryhanen	2006	16	DBT: Chronic	Retrospective	Bone Anchors	All of the operated arms were immobilized postoperative timely in long arm casts in supination and 90 degrees of flexion of the elbow for four weeks, after which mobilization was usually encouraged and facilitated by physio therapy. Passive motion was started immediately, active motion within one week and strengthening exercises after two weeks.	None	4 weeks	6 weeks	2
Sarda	2013	13	DBT repairs	Retrospective	Unknown	None	None	NR	NR	0
Savvidou	2004	1	DBT Rupture	Case Study	Double incision	Brachial cast 110 elbow flexion and medium pronation 6 weeks.	Idomethacin	6 Weeks	NR	1
Schmidt	2012	19	DBT: Repair compared w/imaging	Retrospective	Single Incision: Endobutton	Prophylaxis for heterotopic bone was not prescribed. Patients were placed in a 90 degrees posterior sling in neutral forearm rotation after the operation. Active and passive elbow and passive forearm range of motion were initiated at 2 weeks. Unrestricted forearm rotation was permitted at 6 weeks, and strengthening was initiated at 10 weeks.	None	6 Weeks	10 weeks	2
Sharma	2004	3	Chronic DBT modified Ant Approach	Case Series	Single Incision	In all three cases, the elbow was immobilized for 6 weeks in an above elbow plaster, following which an extensive course of physiotherapy was started, initially with passive stretches followed by active assisted exercise to gain full range of motion. A progressive strengthening programmed using resisted exercises, supervised weights lifting and closed chain exercise following this.	None	6 weeks	6 weeks	2
Sheilds	2015	41	DBT: Single vs. Double	Retrospective	Single and Double	All patients underwent a similar rehabilitation protocol at our institution. Patients were placed into a splint after surgery, which was removed to begin active ROM at 5 to 7 days postoperatively. After 6 weeks of no weightbearing, patients were advanced to a 10-lb lifting restriction, and at 12 weeks they begin progressive resistance exercises as tolerated. No bracing was used, and all patients attended formal physical therapy.	None	6 weeks	6 weeks	2
Siebenlist	2014	49	DBT: Func.Outcomes post DBT	Retrospective	Single Incision	For postoperative management, the elbow was immobilized in a plaster cast in 90° of flexion for one to two weeks. Passive motion exercises started two days postoperatively. Six weeks after surgery, gradual biceps strengthening was applied. In a delayed surgical intervention, a cast was applied for	None	1-2 weeks	6 weeks	3

						two to three weeks and no active exercises were allowed to secure tendon repair within this time period. All patients were allowed to resume normal activity without restriction or limitation for three months postoperatively following distal biceps repair.				
Siebenlist	2018	28	Cortical Button for DBT Repair	Retrospective	Single incision	For postoperative management, the elbow was initially fixed in a posterior orthosis in 90 flexion Two days after surgery, the orthosis was replaced by a mobile, hinged brace limiting the last 20 of extension to protect the tendon repair from maximum extension. At the same time, the patients began passive and active (gravity-assisted) mobilization under a physiotherapist's supervision. Forearm rotation was not restricted; however, the patients were encouraged not to supinate the forearm actively. After 4 weeks, the brace was removed, and full extension and active supination exercises were initiated. Six weeks after surgery, unrestricted daily activities were allowed and gradual biceps strengthening was applied and increased over the next 6 weeks. Sporting activities were allowed after 12 weeks. To prevent heterotopic ossification (HO), indomethacin 50 mg was routinely given twice a day along with a proton pump inhibitor for 3 weeks following surgery.	Indo-methacin (3 weeks)	4 weeks	6 weeks	5
Shane	2010	17	DBT Partial Tears	Retrospective	Single and Double	Postoperatively, all elbows were placed in a posterior splint and immobilized until the initial dressing and sutures were removed (10–14 d). They were then placed in a splint that was removed for daily active motion. At 6 weeks, biceps strengthening was started, with unrestricted activity allowed at 3 months.	None	6 weeks	6 weeks	1
Sheilds	2015		1 incision CB vs. 2 incision Bone Tunnels	Retrospective	Single Incision and Double	All patients underwent a similar rehabilitation protocol at our institution. Patients were placed into a splint after surgery, which was removed to begin active ROM at 5 to 7 days postoperatively. After 6 weeks of no weightbearing, patients were advanced to a 10-lb lifting restriction, and at 12 weeks they begin progressive resistance exercises as tolerated. No bracing was used, and all patients attended formal physical therapy.	None	1 week	12 weeks	2
Silva	2010	29	DBT: Single Incision w/Bio-Ten Screw	Retrospective	Single Incision	The operative arm was placed in a splint at 90 with neutral forearm rotation. One week postoperatively, the splint was removed, and patients were allowed. to start full range of motion (ROM). No lifting 1 lb. was allowed for 8 to 12 weeks. Physical therapy was initiated 4 to 6 weeks postoperatively if patients were not approaching full ROM at that time. Patients were transitioned back to all activities of daily living over 3 to 6 months postoperatively.	None	1 week	8-12 weeks	3
Smith	2016	22	Immediate ROM post DB Repair	Retrospective	Single Incision	The single incision is covered with a water-resistant adhesive dressing with an absorbent pad and completed with wool and crepe bandage. No brace is used. The patient is encouraged to engage in active flexion/extension and pron/supination of the elbow from the day of the operation. A wound check is performed at 2 weeks, at which point the patient is referred to physiotherapy for assistance with mobilization. This initially involves active and passive ROM exercises of the shoulder, elbow, and wrist, progressing to a resisted exercise program from 6 weeks, assuming that full ROM has been restored by this time. A 1-kg weight restriction is imposed for the first 6 weeks. Patients are reviewed routinely by a clinician at 8 weeks. Full activity and return to sports are permitted from 12 weeks.	None	0	6 weeks	4
Sotereanos	2000	16	Single Anterior Approach	Retrospective	Single Incision	After wound closure, the arm was placed in a well-padded posterior plaster splint that kept the elbow flexed at 90" and the forearm between neutral and full supination. If the test done at surgery showed that the repair was very secure, the elbow could be splinted in extension beyond 90". This could usually be done in the acute cases in which fixation of the tendon on the radial tuberosity was carried out with less difficulty. The plaster splint and sutures were removed 10-12 days after surgery. Passive range of motion was begun with the arm in full supination with limits of 90" of extension. A hinged elbow brace was applied and set to prevent extension past 90". Active triceps isometric exercises were begun at this time. The brace was adjusted week to allow more extension. At 6 weeks, the brace was discontinued, and full active range of motion was allowed. Resisted supination and flexion were not allowed for 12 weeks after the procedure. Strengthening exercises were begun at 4 months.	None	6 weeks	16 weeks	4
Spencer	2008	15	Therapy vs. No Therapy	Retrospective	Single Incision	In both groups, a posterior splint at 90° was worn for the first 2 weeks. In the supervised therapy group, a hinged brace was worn for the next 4 weeks. Passive ROM was initiated at 2 weeks, but extension was limited to 40° and increased by 10°/week as tolerated with full extension allowed at 6 weeks	None	2-6 weeks	6 weeks	3

						postoperative. The non-supervised therapy group had the postoperative splint removed at 2 weeks and were allowed to use the arm for simple daily activities such as bathing, lifting a coffee cup, and simple lifting of no greater than 2 lbs.				
Tanner	2013	27	DBT: Single Incision	Retrospective	Single incision	Range of motion (ROM) is initiated when the patient is comfortable. Gradual progressive strengthening is allowed at 12 weeks. Patients are allowed to use the arm as tolerated at 6 months	None	NR	12 weeks	3
Tarallo	2014	47	DBT: Double Incision Muscle Split	Retrospective	Double incision	The elbow is then splinted for 4 wk. Early active-assistive and ROM activities into elbow flexion and extension are advised 3-4 times per day. All patients were treated with indomethacin 75 mg for 3 wk. as a standard protocol to prevent heterotopic ossifications	Indomethacin (3 weeks)	4 weeks	Unknown	1
Tarallo	2018	63	Modified Double Incision DBT	Retrospective	Double incision	None	None	NR	NR	0
Thompson	1998	1	Rupture of DBT College football	Case Study	Double incision	The athlete was placed in cast postoperatively for 6 weeks and then placed in brace with limited elbow extension. During this time, wrist and isometric exercises of the forearm and shoulder done. The athlete had minimal pain which managed with and electrical stimulation. At 12 weeks, the patient removed from the brace was but instructed not to stretch into extension Manual resistive exercises for the shoulder rotation, abduction, internal/external performed, adduction well wrist flexion, extension, radial deviation. At 16 weeks the athlete could do biceps curls. Wrist curls were done using free weights slowly increasing resistance. 6 months back to play.	None	12 weeks	16 weeks	6
Van Der Vis	2018	37	Functional outcome DBT	Retrospective	Single Incision	Post-operative rehabilitation varied substantially and depended on the surgeon. In general, a cast was used for 2-8 weeks or immobilization in a sling for 6 weeks. This was followed by a brace, 2-3 months of non-weight bearing or no active flexion for 6 weeks. All patients were advised physiotherapy, 7 patients decline physiotherapy. Median physiotherapy sessions were 10	None	2-8 weeks	NR	4
Ware	1992	4	Repair of DBT	Retrospective	Double	After the operation, an above-elbow plaster splint was applied to keep the elbow flexed to a right angle and the forearm in full supination. After six weeks, graduated exercises were encouraged from a split cast for a further two to three weeks. Prompt rehabilitation was achieved in all four cases.	None	6 weeks	6 Weeks	1
Waterman	2016	290	Single vs. Double in Military	Retrospective	Single and Double	None	None	NR	NR	0
Weinstein	2008	32	Double Incision DBT	Retrospective	Double	The extremity was placed in a posterior splint in 90of flexion. Patients wore a splint for 4 weeks postoperatively. The elbow was immobilized for 1 week, followed by a passive motion protocol to increase range of motion until 4 weeks. Active range of motion with progressive strengthening was allowed from 4 to 8weeks postoperatively. Patients were allowed to return to normal activities at 4 months	None	4 weeks	4-8 weeks	2
Wentzell	2018	1	Rehab for DBT repair	Case	Single Incision	Protocol Provided	Advil 200mg, Tylenol 3	NR	4 weeks	10
Witkowksi	2017	18	Retrospective Evaluation of DBT using Suture Anchors	Retrospective	Single Incision	On the day when patients were discharged from the hospital, they were provided with a sling and advised that it can be removed after 4 weeks, and the elbow mobilized as tolerated. The patients were also directed to out-patient clinics to undergo physiotherapy. Based on the information gained from patient histories, the time of postoperative supervised physiotherapeutic procedure lasted 3.55±3.98 weeks, including physical treatments like local cryotherapy, low-level laser therapy, and magnetic therapy, and exercise of the operated elbow joint.	None	4 weeks	NR	2
Yao	2019	3	Unknown	Retrospective	Single	Unknown	None	NR	NR	0

NR-Not Reported
PROM-Passive Range of motion
AROM-Active Range of Motion
AAROM- Active Assistive Range of Motion
Ext.- Extension
Deg.-Degree
Strength: Start of strengthening program
Immob: Immobilization Period
Sub #: Subject number
#: Number of sentences given for rehabilitation
DBT: Distal biceps tendon
ROM: Range of Motion

Table 3. CERT Guideline Scores for studies describing operative interventions

Author	1	2	3	4	5	6	7a	7b	8	9	10	11	12	13	14a	14b	15	16a	16b	Total # (%) of items fulfilling criteria
Anakwenze	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	4 (21)
Andritsos	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	4 (21)
Barrett	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	5 (26)
Bosman	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	5 (26)
Caputo	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	3 (16)
Cheung	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	4 (21)
Cil	0	0	1	1	0	0	0	1	0	0	0	0	1	0	1	0	1	0	0	6 (32)
DaCambra	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	4 (21)
D'Arco	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	5 (26)
El-Hawary	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	3 (16)
Gasparella	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	5 (26)
Heinzelmann	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	6 (32)
Horschig	1	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	0	1	14 (74)
Hurov	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	1	0	1	12 (63)
Lintner	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	4 (21)
Logan	1	1	1	1	0	0	1	1	1	0	1	0	1	1	1	1	1	0	0	13 (68)
Lynch	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	5 (26)
Recordon	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	1	1	0	0	7 (37)
Reichert	0	1	1	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	7 (37)
Rollo	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	6 (32)
Siebenlist	0	1	0	1	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	6 (32)
Smith	0	1	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	5 (26)
Soteranos	0	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	0	4 (21)
Spencer	0	0	0	1	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	4 (21)
Thompson	0	0	1	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	5 (26)
Wentzell	1	1	1	1	0	0	1	1	0	0	0	0	1	1	1	1	1	0	1	12 (63)

MED 26% (IRQ=21-32)

Table 4. Cert Guideline scores for studies describing non-operative rehab interventions

Author	1	2	3	4	5	6	7a	7b	8	9	10	11	12	13	14a	14b	15	16a	16b	Total # (% of items fulfilling criteria
Baker	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2 (11)
Bandy	1	1	1	1	0	0	1	1	1	1	0	1	1	1	1	1	1	0	1	15 (79)
Chillemi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 (0)
Freeman	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 (0)
Geaney	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2 (11)
Hetsroni	0	1	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	4 (21)
Legg	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 (0)
Morrey	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	3 (16)
Schmidt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0 (0)
Zabala	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	3 (16)

MED 11% (IQR=0-16)

Table 5. Rehabilitative procedures post-surgical distal biceps repair

Author	Year	#	Immob. Period/ Type	Surg. Type	Passive Ex's	Active Ex's	Strength	Return to Normal Activities/ Sport	Complication Reported
Anakwenz	2013	18	1 week/Splint	Single Incision	Week 2	Week 6	Week 10	NR	NR
Andritsos	2018	11	0-2 Weeks/Sling	Single Incision	Week 0-4	Week 6	Week 6	40 Weeks	NR
Barrett	2019	58	0 weeks/Sling	Double Incision	Week 1	Week 1	Week 6	NR	1 HO, 1 Radioulnar Synostosis
Bosman	2012	6	0 weeks/Sling	Single Incision	Week 1	Week 1	Week 8	NR	No major complications (wound/light transient numbness)
Caputo	2016	12	6 weeks/Splint	Single Incision	Week 1	Week 1	Week 12	NR	NR
Cheung	2005	13	6 weeks/Hinge Brace Locked	Double Incision	Week 1	NR	Week 8	NR	1 rerutpure, 1 LAC neuritis (Both not included in study post)
Cil	2009	21	0 weeks/Sling	Double Incision	Week 1	Week 1	Week 6	12 Weeks	1 Wound infection, 1 Stich abscess, 2 HO
DaCambra	2013	1	6 weeks/ Cast & Splint	Single Incision	Week 2	Week 2(only elbow ext)	Week 6	12 Weeks	Minor paresthesia
D'Arco	1998	13	4 weeks/Hinged Brace Locked	Double Incision	Week 2	Week 2(only elbow ext) / Week 4 flex	Week 4-6	NR	None observed
El-Hawary	2003	19	6 weeks/Splint	Both	Week 1	Week 1(only elbow ext) / Full active 6 weeks	12 weeks	NR	Both transient paresthesia; 20% Single, 0% double
Gasparella	2015	14	1-week Brace/Sling	Single Incision	Week 1	Week 1 (only elbow ext) / Week 5 Flex	12 weeks	12 Weeks	14% long term paresthesia
Heinzelman	2009	31	3-5 days Splint/Sleeve	Single Incision	Week 1	Week 1	Week 1-3	4 Weeks	1 HO
Horschig	2012	1	10 weeks total (1-2-week splint, 3-10 week brace)	Single Incision	Week 2	Week 3-6 (Brace ext locked)	Week 10-12	26 Weeks	NR
Hurov	1996	1	9 weeks/Cast 5 weeks 4 weeks Splint	Single Incision	Week 5	Week 5	Week 9	17 Weeks	NR
Lintner	1996	5	8 weeks/Splint	Single Incision	Week 1	Week 6-8 (Splint locked)	Week 12	20 Weeks	None Observed
Logan	2019	1	6 weeks/Brace	Both	Week 1	Week 1	Week 12-16	16 Weeks	NR
Lynch	1999	6	7-10 days/NR	Double Incision	Week 1	Week 1 (ext limited)/Week 5 full	Week 4	No longer tender, painless ROM	Minor calcifications
Recordon	2015	43	0 weeks/Sling Endo; 6 weeks TS	Double Incision	Week 1-6	Week 1-6	Week 12	12 weeks	1 HO; 30% Paresthesia
Reichert	2018	28	4 weeks/Sling	Single Incision	Week 1	Week 1	Week 4-6	12 weeks non contact; 24 weeks contact	Minor Complications

Rollo	2019	37	7-11 weeks/Cast 1 week, Hinged brace	Double Incision	Week 1	Week 1 (ext limited)/Week 4-6 full	Week 2-6	52 weeks	None observed
Siebenlist	2018	49	1-2 weeks/Cast 2-4 weeks for delayed repair	Single Incision	Week 1	NR	Week 6	12 weeks	10.2%, 3 LACN Paresthesia, 2 PIN Paresthesia
Smith	2016	22	None	Single Incision	Week 1	Week 1	Week 6	12 weeks	2/3 Transient Nerve Paresthesia
Soteranos	2000	16	6 weeks (10-12 days/Splint, Brace)	Single Incision	Week 2	Week 6	Week 12-16	NR	Minor Complications
Spencer	2008	15	2 weeks/Splint	Single Incision	Week 2-6	Week 2-6	NR	NR	2 LABCN Transient
Thompson	1998	1	12 weeks/6 weeks cast 6 weeks brace	Double Incision	Week 16	Week 16	Week 16	24 weeks	NR
Wentzell	2018	1	NR	Single Incision	Week 1	Week 1	Week 4- 6	NR	NR

Legend: NR-Not reported; Ext – Extension; LABCN- Lateral Antebrachial Cutaneous Nerve; HO-Heterotopic Ossification

Table 6. Rehabilitative Procedures for Non-Operate Distal Biceps Ruptures

Author	Year	Subjects	Immobilization Period	Passive Exercise	Active Exercise	Strengthening	Return to normal activities/ Sports
Baker	1985	3	3weeks (Sling)	Week 4	Week 4	Week 16	NR
Bandy	1991	1	None	Week 1	Week 1	Week 1	3 weeks
Chillemi	2007	4	4weeks (above elbow cast)	NR	NR	NR	NR
Freeman	2009	18	NR	NR	NR	NR	12 weeks
Geaney	2010	5	NR	Week 1	Week 1	Week 1	1-week RTW
Hetsroni	2008	10	NR	Week 1	Week 4	Week 8	NR
Legg	2016	10	None	Week 1	Week 1	Week 12-24	24 Weeks
Morrey	1985	3	? Duration only for pain	NR	NR	Post Immobilization	NR
Schmidt	2018	14	NR	NR	NR	NR	NR
Zabala	2013	1	3 weeks(sling)	Week 1	NR	NR	NR

Legend: NR-Not reported; Ext – Extension; LABCN- Lateral Antebrachial Cutaneous Nerve; HO-Heterotopic Ossification; RTW-R

APPENDIX A

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (Prisma-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	Title Page#1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	Page 2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	Page 4-5
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	Page 5
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	N/A
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	Page6-7
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	Page 6
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	Appendix A
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	Page 7-8
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	Page 8
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	Page 8

Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	Page 6
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	Page 8
SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	Page 9
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	Page 9
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	Table 3-4
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table 2, 5, 6
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Page 9-16
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	Page 13-14
Limitations	20	Discuss the limitations of the scoping review process.	Page 17
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	Page 19
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	Page 19

Appendix B

Search terms used within PubMed for all areas of clinical studies across different clinical areas for the management of distal biceps tendon rupture

1. Distal biceps repair
2. Distal biceps
3. Biceps brachii
4. Biceps
5. Tendon rupture
6. Tendon repair
7. Elbow surgery
8. Surgery distal biceps
9. Technique distal biceps
10. Rehabilitation distal biceps
11. Exercise distal biceps
12. Physiotherapy distal biceps
13. Physical therapy disal biceps
14. 4 or 5
15. 10 or 11
16. 7 and 5
17. Biceps management
18. Biceps strain
19. Partial tear distal biceps
20. Exercise biceps
21. Bicipital tendonitis
22. Biceps Tendonitis
23. Lacertus Fibrosus
24. Lacertus Biceps
25. Outcomes distal biceps
26. Outcomes Biceps
27. Pain distal biceps
28. Partial rupture distal biceps
29. Rehab distal biceps
30. Rehab biceps
31. Range of motion distal biceps
32. Range of motion elbow
33. Elbow distal biceps
34. Single incision repair distal biceps
35. Double incision repair distal biceps
36. Single incision
37. Double incision
38. Diagnosis distal biceps

39. Imaging distal biceps
40. Magnetic resonance distal biceps
41. Diagnostic distal biceps
42. Ultrasound distal biceps
43. Chronic distal biceps
44. Acute distal biceps
45. Non-operative distal biceps
46. Operative distal biceps
47. Injury distal biceps
48. Injury elbow
49. Traumatic injury elbow
50. Fixation distal biceps
51. Endobutton biceps
52. Endobutton
53. Screw repair distal biceps
54. Suture distal biceps

CHAPTER 3: FACTORS ASSOCIATED WITH POOR OUTCOMES FOLLOWING DISTAL BICEPS RECONSTRUCTION

Target Journal: Journal of Hand Surgery (To be submitted)

Authors
Pulak Parikh[1], Joy C. MacDermid[2], Vikas Tuli[3], Luciana Macedo[4], Julie Richardson[5], Michelle Manley[6]

[1]School of Rehabilitation Science, McMaster University
parikhp@mcmaster.ca

[2]Hand and Upper Limb Centre, St. Joseph's Health Centre, London, ON
jmacderm@uwo.ca

[3]Full Radius Orthopaedics, Newmarket, ON
tulivik@yahoo.ca

[4]School of Rehabilitation Science, McMaster University
jrichard@mcmaster.ca

[5]School of Rehabilitation Science, McMaster University
macedol@mcmaster.ca

[6]Spectrum Institute for Health and Rehabilitation, Newmarket, ON
michellemanley7@gmail.com

Corresponding Author
Pulak Parikh
School of Rehabilitation Science, McMaster University
1400 Main Street West
Hamilton, Ontario L8S 1C7
Email: parikhp@mcmaster.ca
Email 2: pulakpar@yahoo.com

Declaration of Interest: No conflicts of interest are declared by each of the authors, Pulak Parikh, Joy C. MacDermid, Vikas Tuli, Michelle Manley, Luciana Macedo and Julie Richardson

Acknowledgements: Joy MacDermid was supported by a Canadian Institutes of Health Research Chair in Gender, Work and Health and the Dr James Roth Chair in Musculoskeletal Measurement and Knowledge Translation.

Abstract

Introduction/Background: Distal bicep tears are relatively rare but more common within the middle-aged male population. The purpose of this study was to identify factors associated with less favorable outcomes (as measured by pain, function and disability) following surgical repair. **Methods:** This is a cross sectional study of 60 participants at 1-15 years post distal biceps reconstruction. Two outcome measures were administered included the Patient Rated Elbow Evaluation (PREE) and the Disability of the Arm, Shoulder and Hand (DASH). Elbow flexion, supination and grip strength were tested using a hand-held dynamometer for both surgical and non-surgical arms. The clinical predictors evaluated were smoking history, strength differential (surgical vs. non-surgical arm), duration of time to surgery and physiotherapy attendance and completion. A stepwise regression model was used to evaluate the relationship between the clinical predictor variables and functional outcome measures. **Results**: The stepwise regression analysis demonstrated that having a smoking history and weaker bicep flexion strength indicated poor prognosis post distal biceps repair that accounted for 50.4% of variability in DASH scores. **Discussion:** Smoking has been identified as a negative predictor of outcomes for other many other orthopaedic conditions. Our study indicated a smoking history is associated with less favorable pain, function and disability outcomes following distal biceps repair. Clinical implications for patients undergoing this surgical procedure can include smoking as potential predictor for poor prognosis if repair is indicated.

Background

Distal bicep injuries are quite rare, occurring mostly in middle aged males with an incidence of 2.55-5.35 per 100,000 patient-years (M. Kelly et al., 2015). A significant amount of controversy exists about many factors associated with this condition including the efficacy of diagnosis (Alentorn-Geli et al., 2016), prognosis (Hinchey, Aronowitz, Sanchez-Sotelo, & Morrey, 2014), surgical technique (Citak et al., 2011; Watson et al., 2014), complication rates (Amin et al., 2016; Cohen & Katolic, 2003), rehabilitation (Cheung, Lazarus, Cheung, Lazarus, & Taranta, 2005; Spencer, Tisdale, Kostka, & Ivy, 2008b) and whether or not surgical repair is indicated (Geaney et al., 2010b; Ring, Lubahn, & Beredjiklian, 2017b; Schmidt, Savoie, et al., 2016). This uncommon injury usually occurs with an eccentric load to the biceps often associated with a "pop" at the time of injury (Safran & Graham, 2002). Following this injury, patients usually persist with pain and weakness most predominantly in supination as the brachialis and brachioradialis remain competent to provide elbow flexion strength (Sleeboom & Regoort, 1991).

Risk factors for the rupture of the distal biceps include manual labor populations (Morrey et al., 1985), weight training (Wentzell, 2018), anabolic steroid use (Visuri & Lindholm, 1994) and smoking (M. Kelly et al., 2015; Safran & Graham, 2002; Waterman et al., 2017). However, to date there has been limited research evaluating prognostic factors post-surgical reconstruction of the distal biceps. Many factors have been hypothesized to determine outcomes, such as time factors (days) to surgery, the use of a standardized rehabilitation protocol physiotherapy, smoking history, steroid use, flexion

or supination strength as well as demographic factors such as work history, age and recreational activities. The purpose of this study is to identify factors associated with less favorable outcomes following surgical repair of a torn biceps tendon.

Methods

This is a cross sectional study of patients at 1-15 years post distal biceps tendon reconstruction. Patients were eligible for the study if they were between 18 and 65 years of age and have had received a distal bicep repair in the last 15 years (minimum of 1-year post-operative) in a hospital setting in Ontario between the years 1999-2014. Patients were assessed by an orthopaedic surgeon in one visit for eligibility, provided informed consent and then completed study outcome measures and strength testing. Patients were excluded if they had bilateral symptoms, diagnoses of any other elbow or shoulder pathology, any concurrent injury to the upper extremity including recent trauma, any upper extremity surgery within the past 3 years or if they are unable to speak, read and write or understand English. All patients were evaluated at a local outpatient physiotherapy clinic in Newmarket, Ontario. All evaluations were conducted by an upper extremity fellowship trained orthopaedic surgeon and 2 trained physiotherapists, each with greater than 15 years of clinical experience.

All demographic and surgical data was extracted by the physiotherapists from patient clinical charts prior to participants visit to the clinic and then confirmed by intake history forms. Functional outcome measures and strength testing were completed in person during a s ingle clinical visit.

Outcome Measures

1) The DASH (Disabilities of Arm, Shoulder and Hand) outcome measure is a 30 item, self-report questionnaire designed to measure physical function, pain and disability in patients with disorders of the upper limb (Hudak et al., 1996). 2) The PREE (Patient Rated Elbow Evaluation) is a 20 item patient-reported outcome questionnaire that measures elbow-related pain and disability of the affected upper extremity (J. Vincent & MacDermid, 2012) (Table 1. Descriptions for outcome measures). Both the DASH and PREE have demonstrated good validity and sensitivity for individuals after distal biceps reconstruction (J. I. Vincent, Macdermid, King, & Grewal, 2013).

Potential factors

Baseline Variables: Age (years), hand dominance (right or left), mechanism of injury (trauma, sport, eccentric load), smoking history (yes/no), steroid use (yes/no), activity level (minimal, moderate, high) occupation (desk work, labor profession)

Surgical Parameters: Days to surgery (number of days), complications (mild, moderate, severe), physiotherapy adherence (yes/no)

Range of Motion and Strength at Follow-up: Dynamometer strength for flexion and supination, grip strength, wrist/hand motion (Table 2. Descriptions for clinical factors).

These factors were hypothesized to have had negative effects upon pain, function and disability for other tendon injuries such as rotator cuff repair (Santiago-Torres, Flanigan, Butler, & Bishop, 2015) and other orthopaedic surgery outcomes (Bedard, Dowdle, Owens, et al., 2018; Bulut et al., 2016; Delancey et al., 2018).

Isometric strength was measured for supination and flexion using a Layfayette handheld dynamometer (Model 01163). We conducted three trials for each test using a "break test" methodology as described by Stratford (Paul W Stratford & Balsor, 1994) and reported the average. The starting position for testing had patients in sitting, right elbow flexed to 90 degrees and the forearm fully supinated. The right shoulder was stabilized, and the subject maintained this position until complete. Following a warm-up of submaximal and one maximal contraction for supination and flexion, the subjects performed 3 maximal elbow flexion and then 3 supination efforts with 30 second rest intervals with 2 minute rest intervals between flexion and supination tests. Resistance for the dynamometer was 1cm proximal to the wrist. Instructions for the break test were "Pull as hard as you can; now don't let me move your arm". Consistent verbal encouragement was given at the time. Values for the tests were recorded as kg of force.

The STROBE (Strengthening the Reporting of observational studies in Epidemiology) checklist for all types of observational studies was used as a guide for reporting (Appendix A) (von Elm et al., 2007). This scale contains a list of 35 items that evaluate the degree, rigor and amount of information provided in each article section. Each item is scored by "yes", "no" or "unclear".

Ethical Considerations

All participants provided voluntary written informed consent after discussion of potential risks and benefits for their participation within the study. Informed consent was obtained by the surgeon and treating physiotherapist prior to the initial assessment. Ethics

approval was obtained from Southlake Hospital Institutional Review Board (Study Number: 0043-1415).

Surgical Technique

All patients were repaired by a single upper extremity fellowship trained orthopaedic surgeon. During surgery, patients were placed supine with an Esmarch utilized and tourniquet set 250 mm Hg. A transverse incision was made at the flexor crease of elbow. Subsequently, identification and protection of the lateral antebrachial cutaneous nerve (LABCN) was completed. The distal biceps tendon was identified and tagged with 2 locking Krackow stiches (Ethibond or Hi-Fi). Before tagging, the last bit was trimmed (usually 2-3 mm) until a good quality tendon was fabricated. Next, a digital tunnel was recreated into the radial tuberosity. For the anterior incision, the arm was kept supinated.

Additionally, a lateral incision was made 2 fingerbreadths distal to the radio-capitellar joint. The incision was made through EDC with arm pronated. The radial tuberosity was identified along with a footprint of the distal biceps tendon. Once complete, a trough was made with a high-speed burr usually 10 mm long and 4 mm wide. Two transosseus holes were made anterior to the trough with wide enough bone bridges so a fracture was avoided. Irrigation with saline was done in order to not leave any bone dust behind. Two, 28 G wires were passed from transosseus holes into the trough.

Once complete, the tendon was passed through the anterior incision with its four arms of suture. Sutures were colour coded to be identified easily. The distal biceps were then passed deep to radial tuberosity with a snap. The LABCN was visualized to ensure it

was not trapped/irritated by distal biceps tendon. It was retrieved in the lateral incision. Multiple attempts were avoided for fear of injury the LABCN. Each strand of the suture was then passed separately through the tranosseous holes and tied to each other. The EDC fascia was closed with Vicryl and both incisions were closed with nylon. Hemostasis was ensured prior closure. Finally, plaster of paris was applied to the arm with 80 degrees flexion of the elbow for one week.

Rehabilitation

Immediately after tendon repair, patients are casted with a back-slab cast for one week. During their first clinical visit the cast is removed, and passive movement exercises are demonstrated. A custom removal splint is fitted with the elbow in 90 degrees of flexion and neutral supination/pronation. This is worn for six weeks from surgery, with strict restrictions given for movement involving for the shoulder or elbow other than passive exercises. Strengthening exercises including the elbow are restricted for 12 weeks with no heavy manual work for 6 months post repair. Patients are seen for four total clinical visits (week 1, week 6, week 12 and week 24).

Statistical Analysis

Descriptive statistics were calculated as means and standard deviations for continuous variables with normal distributions. Medians and Inter-quartile ranges were given for variables with a skewed distribution. Counts and percentages were applied to categorical data. All statistical analysis was done using STATA version 13.1. Initial analysis began with a graph matrix scatterplot of potential independent variables (strength difference, mechanism of injury, smoking, steroid use, duration of time from injury to

surgery, physiotherapy attendance(yes/no)) with the primary outcome measure DASH and the secondary outcome measure PREE to evaluate if the associations were linear. A stepwise linear regression was modeled to include all the factor (independent) variables added to predict DASH scores (dependent variable). Assumptions for regression were tested however not met secondary to skewed data for the dependent variable. A log transformation (natural log) for the both dependent variables was conducted prior to regression analysis. This transformation is the most widely used method to address skewed data in biomedical and psychological research (Feng et al., 2014). Distributions were checked pre and post transformations with a Shapiro-Wilk tests as well as histograms and kernel density graphs with normality curves. Assumptions for multicollinearity and singularity were checked with visual inspection. Outliers were examined visually and were reviewed for clinical relevance.

All other assumptions for regression, (normality of residuals, linearity and homoscedasticity) were checked and met following transformation. Fit for the model was examined visually. All tests were two tailed and considered significant at $p<.05$. The model was cross validated using a bootstrapping method with 200 repetitions within an add-on component from STATA version 13.1 using the "regvalidate" command. A robust regression analysis was also conducted secondary to the skewness of the dependent variable. This would not require the assumption of normality and results would be compared using both methods.

Results

A total of 152 patients were contacted to participate within the study. Eighty-four (55%) patients agreed to participate by confirming attendance for one clinical visit however some (14%) did not attend for unknown reasons. A convenience sample of 60 male individuals (39%) were included in the study for analysis. The median age of the participants was 47 IQR3 (52)-IQR1 (42). All descriptive statistics for the included variables are detailed within Table 3 and Table 4. There was no missing data as all values were obtain during one visit. Median scores for the DASH were 0, IQR3 (6.25)-IQR1 (0) and the PREE 0, IQR3 (7.65)-IQR1 (0). Mean difference in strength from the surgical to non-surgical side was -.03 kg, SD (2.28), CI (-.62-.56). Twenty percent of the participants (12/60) had a history of smoking. Seventy two percent (47/60) of participants underwent physiotherapy after surgery and were compliant with their protocols and home exercises according to chart reviews and discharge summaries. The mean amount of days from the time of injury to surgery was 15.5, SD (22.6), CI (9.66-21.34). The stepwise regression provided evidence that having a history of smoking and weaker flexion strength is associated with higher pain and disability scores as measured by the DASH, F (2, 26) =15.23, P=<.000, R^2=.590, Adj R^2= .574. Therefore, both smoking and difference in strength accounted for 57.4% of the variability in DASH scores. Variables included with coefficients, t-values and p-values (Confidence intervals) are presented in Figure 1. A stepwise regression for the secondary outcome (PREE) did not provide any evidence of an association to the factors included. Robust regression yielded similar variance values however had a larger coefficient and error therefore was not reported. Model fit was

determined from visual inspection of the prediction plots. Regression diagnostics were performed, and the assumptions were met. Bootstrapping methodology proved to have a large shrinkage (22.6%) with 200 repetitions done with an additional program added to STATA version 13.1.

Figure 1. Regression model predictors for DASH

Source	SS	df	MS	Number of obs =	29
				F(2, 26) =	15.23
Model	19.6419876	2	9.82099378	Prob > F =	0.0000
Residual	16.7700239	26	.64500092	R-squared =	0.5394
				Adj R-squared =	0.5040
Total	36.4120115	28	1.30042898	Root MSE =	.80312

logdash	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
FlexDiff	-.1254836	.0478177	-2.62	0.014	-.2237743	-.0271928
Smoking	1.181423	.3293687	3.59	0.001	.504396	1.85845
_cons	.9865083	.1929263	5.11	0.000	.5899427	1.383074

Discussion

This cross-sectional analysis was the first ever study to identify poor prognostic factors associated with distal biceps repair. The results of this study demonstrated that smoking and strength differential between the injured versus the non-injured side explained 50.4% of the variation in DASH scores. This means that individuals who smoked had higher scores on the DASH compared to those that do not smoke while controlling for strength differential. Further, after controlling for smoking, those having weaker flexion strength reported higher DASH scores. Regression results are presented

in log values as the transformed data set shares little in common with the original data set, therefore possibly biasing predictions (Feng et al., 2014).

With the majority of trials for distal biceps being retrospective this trial was not unique; however, this is the largest trial (60 participants) to date that had a (greater than 10 year) follow up for subjects that included strength testing and functional outcome assessment. Our results agree with previous studies that smoking is associated with poorer pain, function and disability post orthopedic surgical procedures especially those involving muscle tendon repairs (Bedard, Dowdle, Owens, et al., 2018; Chalmers, Granger, Nelson, Yoo, & Tashjian, 2018; Santiago-Torres et al., 2015). Differential values in strength were an unexcepted outcome post-surgery and the those with persistent strength deficits had higher disability after surgical repair. It was interesting to observe that those with weaker elbow flexion values were predicted to have higher disability. In comparison, the biceps has been known to generate a larger torque for elbow supination rather than flexion (Schmidt, Jarrett, & Brown, 2013) , therefore this observation was incongruous to its overall function. This can possibly be indicative of measurement error or subjects compensation with other muscles during testing.

Smoking History

Patients with a smoking history have been reported to be have a greater risk for distal biceps rupture. Individuals who smoked were 7.5 times more likely to be at risk for distal biceps ruptures compared to those who did not smoke (Safran & Graham, 2002). In addition, smoking has been known to cause vascular insufficiency and decreased oxygenation of tissues that has had a negative effect on numerous orthopedic surgeries

(Bedard, Dowdle, Wilkinson, et al., 2018; Chalmers et al., 2018; Santiago-Torres et al., 2015). Therefore, our findings are consistent with studies for the negative impact of smoking in orthopaedic conditions. Furthermore, although both single incision and double incision have shown similar complication profiles, adverse outcomes (re-rupture) have been reported to be more likely among patients that used tobacco (Waterman et al., 2017).

Days to Surgery

There remains conflicting evidence for chronic repair of distal biceps rupture. Poor prognosis of outcomes have been observed when repairing grafts greater than 21 days post rupture (Ruch et al., 2014). The significant risk of complications post-surgery has also been shown to increase with delayed repairs in comparison to those repaired acutely (Haverstock et al., 2017; Kelly, Edward; Morrey, Bernard; O'Driscoll, 2000). Surgeons are faced with many challenges when the ruptured tendon has been present for weeks or even months. With the tendon retracted, the path to the tuberosity is closed, and the antecubital tissues are obscured by scar tissue, making the reattachment of the tendon nearly impossible without limiting extension of the elbow (E. W. Kelly, Sanchez-Sotello, Morrey, & O'Driscoll, 2003). There has been no consensus defining a delayed presentation however the use of (cadaver) allografts have been advocated (Ding et al., 2016; Kale et al., 2018; Phadnis, Flannery, & Watts, 2016). The results of our study had 13 patients repaired over 20 days post rupture with excellent results. Several delayed reconstructions of the bicep tendon with both allografts and primary repairs have had good to excellent results with regards to strength, range of motion, complication rates and

functional outcomes (Anakwenze et al., 2013; Frank, Seltser, Grewal, King, & Athwal, 2019).

Therefore, although there remains little consensus on what timeframe constitutes a chronic rupture, positive results can be obtained depending on skill of the surgeon to repair the original tendon or the ability for the use of a graft for an anatomic repair (Bosman et al., 2012).

Rehabilitation

A standardized protocol for physiotherapy was given to all patient's post-surgical repair. No standardized clinical practice guideline exists for rehabilitation of biceps repairs. Further the protocols reported in the literature vary greatly. A current review of the literature has determined it difficult to establish any relationship between functional outcomes and use of postoperative physiotherapy (Królikowska et al., 2018). Our results indicate that 72% (47/60) of the patients attended physiotherapy at the institution and followed a protocol postoperatively. The 28% that did not comply did not have significantly different pain scores or functional outcomes. Many have questioned the need for a supervised physiotherapy protocol post distal biceps reconstruction. Interestingly, it was found that an unsupervised group (post 2 weeks surgical repair) regained their motion quicker, had no re-ruptures and had similar disability scores to those supervised with a two incision endo-button technique (Spencer et al., 2008a). Considering our findings in light of previous studies, it is clear that the role and appropriate protocol for biceps postoperative rehabilitation has not been defined. Research studies are needed to identify the need for supervised therapy and should

consider stratification of the findings to those with/without negative prognostic profiles. Potentially a video based or gradual return to activity protocol could be more efficient yet effect for rehabilitation services post distal biceps reconstruction.

Limitations

There are many limitations with our study. First, this is a cross sectional study. Therefore, it is exposed to the risk of error (random, sampling), bias, confounding factors, etc. In addition, only 12 smokers were recorded within the trial. Although statistical significance was achieved the results must be taken with caution secondary to the small number of observations. In addition, the overall sample size was small; although given the lower incidence of biceps ruptures this is a relatively large cohort from a single centre. Sample sizes for other studies in the literature that measure both strength and functional outcomes range from 1-49 (Siebenlist et al., 2014). In the Canadian context, geography can be a factor since many patients attend specialty units from a distance which can limit their ability to return for nonessential follow-up visits. Since the majority of the patients were experiencing excellent outcomes, they may not have been motivated to return for follow-up visits. This was also the reason for the skewed data set as most scores for the PREE and DASH were close to or at 0. In contrast, patients that did follow-up may have had lingering symptoms that could have introduced selection bias. Further, another possible limitation was that we did not adjust scores for hand dominance. Hand dominance has been known to cause variations in strengths between individuals (as much as 10-20% between arms) (Güleçyüz et al., 2017). However, since differences pertain to groups more than individuals, we could not be confident that adjustment for individuals

would be appropriate. Bootstrapping the model was arduous as the sample size was small and the shrinkage was quite high. Future studies would be needed to further validate the model.

Measurements were also taken by therapists after review of the chart and patient history which could have introduced measurement bias in data collection. In addition, patients had consistently good outcomes and had their surgery up to 10 years prior which also introduced significant recall bias when completing functional measures.

Conclusion

This is the first study to associate that having a smoking history and weaker flexor strength post-operatively indicates a negative effect on pain, function and disability post orthopedic surgical procedures especially those involving the distal biceps tendon.

The authors have not received any financial payments or benefits from any funding source related to the subject of this article

1

References

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps

Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and Elbow Surgery*, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375. https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J. W. (2003). Distal biceps tendon repair: Comparison of surgical techniques. *Journal*

of Hand Surgery, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D.

(2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147.

https://doi.org/10.1097/JSA.0b013e3181824e76
Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5
Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003
Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009
Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025
Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130
Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336
Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287
Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006
Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687
Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001
Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.
Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and

Head), *608*(1 996).
Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382
Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005
Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035
Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.
Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030
Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214
Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009
Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.
Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896
Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1
Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562
Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017. https://doi.org/10.1177/0363546515587738

Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405

Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690

Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144

Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049

Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5

Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003

Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358

Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa

Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694

Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003

Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008

Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T.

(2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291.

https://doi.org/10.2343/geochemj.2.0468
Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7
O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016
Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.
Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6
Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004
Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349
Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017
Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5
Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032
Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries: Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2),

103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the "Salento technique", a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. *Clinical Orthopaedics and Related Research*, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First

Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair

and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014

Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098

Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041

Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.

Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276

Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.

Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030

Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4

Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9

Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029

Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0

Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002

von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bulletin of the*

World Health Organization, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623

Table 1. Patient rated outcome measure descriptions

Construct	Measure	Scale Range	Details	Validity	Reliability	Responsiveness	Minimal Clinically Important Difference
Primary Outcome							
Function and Disability	Disabilities of the Arm, Shoulder and Hand (DASH)(Wylie, Beckmann, Granger, & Tashjian, 2014)	0-100 Lower Better	30 items Physical activities in arm, shoulder, hand (21); Symptoms of pain, tingling, weakness (5); Impact of social activities (4) **Must answer 27 questions to be scored	**Criterion Validity:** Correlated with other scores over different regions of the upper extremity and general outcome measures including SF-36 **Construct Validity:** Difference between working/not able to work; disease and health state, ability to do what they want versus not able	Excellent ICC: .77-.98 SEM: 2.8-5.2	Excellent Effect size (all studies) .4-1.4	10 for shoulder complaints, 17 for elbow wrist and hand
Secondary Outcomes							
Pain, Function and Disability	Patient Rated Elbow Evaluation (PREE)(MacDermid, 2010; J. Vincent & MacDermid, 2012)	0-100 Lower Better	Rate the average amount of pain over the past week of the elbow and rate the amount of difficult you experienced performing each of the items listed from 0 (no difficulty) to 10 (most difficult)	**Construct validity**: Moderate to high correlations to ASES, DASH, SF-36	Excellent ICC: .89 SEM: .27-3.28	Excellent Effect size (all studies) .8-1.6	7-11 depending on baseline scores

Table 2. Description of Potential Predictors

Potential Predictor	Measure	Details
Days to Surgery	Number of days from rupture to surgical repair	Measured by retrospective chart review
Smoking History	Past/present smoking history (Y/N)	Measured by health questionnaire administered during first visit
Steroid Use/History	Past/present steroid use (including cortico-steroids) (Y/N)	Measured by health questionnaire administered during first visit
Dynamometer Strength (Flexion and Supination)	Isometric strength was measured for supination and flexion using a Layfayette handheld dynamometer (Model 01163).	Three trials for each test were conducted using a "break test" methodology as described by Stratford(Paul W Stratford & Balsor, 1994) with the average reported
Pain free grip strength	Isometric grip strength measured by Jamar hydraulic hand dynamometer	Three trials conducted as described by Stratford(P. W. Stratford, Norman, & McIntosh, 1989) with average reported
Hand Dominance	Right or Left hand dominance	Measured by health questionnaire administered during first visit
Physiotherapy Adherence	Patient attendance for physiotherapy appointments and protocol completion	Measured by retrospective chart review and physiotherapy discharge summary
Surgical Complications	Mild complications (temporary <2 weeks) Moderate Complications (2-4 weeks) Serious Complications (>1 month)	Assessed by the surgeon at follow up visits for 6 month period
Activity level	Minimal (exercise <1 x / week) Moderate (exercise 1-3x/week) High (exercise >3x/week)	Measured with health questionnaire administered during first visit
Education	Less than high school education High school diploma College or University diploma or degree	Measured with health questionnaire administered during first visit
Age	At the time of surgical repair	Measured by retrospective chart review
Occupation	Laborious profession Desk work	Measured by health questionnaire administered during first visit

Table 3. Demographic and Surgical Information

Age	Hand Dominance	SS	Occupation	Year of Surgery	Physio	Imaging	Smoking	Steroid Use	Mechanism of Injury	Days to Surgery
46	R	R	Lineman	2013	1	None	N	N	Accident	19
48	R	L	Engineer	2010	1	US	N	N	Lifting	12
42	R	L	Paramedic	2009	1	US	N	N	Lifting	13
52	R	L	Soldier	2014	1	US, MRI	Y	N	Lifting	29
47	R	L	Technician	2012	1	US	N	N	Sports (hockey)	5
46	R	R	Desk	2011	1	US	N	Y	Sports (hockey)	21
54	L	L	Service Manager	2015	1	U/S	N	N	Sports (hockey)	34
47	R	R	Sales	2013	1	US	N	N	Lifting	6
36	R	R	Nurse	2014	1	US	N	N	Sports pitching	5
59	R	R	Carpenter	2014	1	U/S	Y	N	Lifting	35
48	L	R	Soldier/Contractor	2008	0	None	N	N	Rep. Use	5
35	R	R	Sales	2015	0	US	N	N	Lifting	43
46	R	R	Contractor	2015	1	None	N	N	Hyperextension	7
29	R	L	Construction	2013	0	US	Y	N	Lifting	5
47	L	R	Teacher	2012	1	None	N	N	Lifting	4
41	R	R	Desk Job	2012	0	None	N	N	Sports	9
39	R	L	Truck Driver	2010	0	US	N	N	Hyperextension	8
19	R	L	Lineman	2012	1	US	N	N	Lifting	4
42	R	L	Technician	2010	0	US	N	N	Sports (hockey)	8
47	L	R	LCBO Manager	2012	1	None	N	N	Lifting	20
49	R	R	Manufacturing	2016	1	MRI	Y	N	Lifting	26
58	R	R	Manager	2015	1	None	N	Y	Sports (hockey)	9
46	R	R	Construction	2013	1	None	N	N	Lifting	26
54	R	R	Manager	2010	1	US	N	N	Sports (hockey)	4
55	R	L	Paramedic	2012	1	None	N	N	Sports (wrestling)	16
49	R	L	Quality Manager	2011	1	US, MRI	N	N	Lifting	24
54	R	R	Technician	2011	1	US	N	N	Hyperextension	16
51	R	l	Firefighter	2016	1	U/S	N	N	Hyperextension	13
46	R	L	Mechanic	2007	0	None	N	Y	Lifting	2
44	R	L	Technician	2012	1	None	N	N	Sports (hockey)	20
43	R	R	Firefighter	2002	1	None	N	N	Lifting	17
54	L	L	Contractor	2013	1	None	N	N	Accident	10
42	R	R	Carpenter	2010	1	None	Y	N	Lifting	4
52	R	L	Technician	2010	1	None	N	N	Lifting	11
54	R	R	Service	2003	1	None	N	Y	Sports (hockey)	5
39	R	R	IT	2009	1	None	N	N	Dog	8
36	R	R	Mechanic	2015	1	US	N	N	Sports (football)	8
45	L	R	Maintenance	2012	1	MRI	N	N	Lifting	13
49	R	R	Construction Manager	2006	0	None	Y	N	Lifting	14
46	R	R	Electrician	2009	1	US	Y	N	Accident	3
48	L	L	Millwright	2007	1	None	N	N	Lifting	1
45	R	R	Electrician	2012	1	None	N	N	Catching	4
53	R	R	Retired	2008	1	U/S, MRI	N	N	Lifting	12
44	R	R	Consultant	2010	0	None	N	N	Lifting	6
34	R	R	Millwright	2011	1	None	N	N	None	34
30	R	R	Landscaping	2011	1	None	Y	Y	Pulling	14
48	R	R	Mechanic	2009	1	US	N	N	Sports (hockey)	5
60	L	R	Self-employed	2011	1	MRI	N	N	Sports (Karate)	15
49	R	L	Project Manager	2010	1	US	N	N	Sports (sailing)	3
48	R	R	Manager	2008	1	None	N	N	Lifting	9
41	L	L	Technician	2006	1	None	N	N	Accident	10
42	R	R	Lawyer	2009	1	US, MRI	N	N	Lifting	32
67	R	R	Mechanic	2017	1	MRI	N	N	Hyperextension	
57	L	R	Construction site supervisor	2011	1	U/S	N	N	Lifting	7
57	R	R	Equipment Operator	2014	1	US	N	Y	Lifting	9
44	R	L	Service Tech	2009	1	None	N	N	Hyperextension	14
55	R	L	Clothier	2017	0	None	N	N	Hyperextension	12
45	R	R	Shipper	2016	1	None	Y	N	Lifting	6
52	R	R	IT	2016	1	U/S, MRI	N	N	Sports (hockey)	170
32	R	L	Truck Driver	2006	1	None	N	N	Hyperextension	8
46	R	L	Retired	2007	1	U/S	y	N	Lifting	14
42/47	R	L/R	Door installation	2012/2017	1	None	N	N	Lifting in hyperextension	14 for L, 20 for R

44	R	L	Lawyer	2007	1	U/S	N	N	Hockey (Catching in glove)	9
65	R	L	Prof engineer	2009	1	None	Y	Y	Sport (softball)	14
64	R	L	Retired	2006	1	None	N	N	Hyperextension	5
55	R	L	Retired Police	2009	1	None	N	Y	Lifting in hyperextension	8
48	R	R	Paramedic	2008	1	None	N	N	Hyperextension and twisted	6
62	R	R	Foreman rebar installer	2019	1	U/S, MIR	Y	N	Lifting	191
56	R	L	Firefighter	2007	1	U/S, MRI	Y	N	Sport (slow pitch)	11

SS: Surgical Side; Physio 0=No, 1=Yes

Table 4. Descriptive statistics

Variables	**Descriptive Statistics**
Study Participants	60 (Male)
Age	Median 47 IQR3 (52)-IQR1 (42)
Imaging Ultrasound	 25/60 44.1%
MRI	4/60 5.9%
Both MRI and US	7/60 2.9%
Clinical Exam	34/60 56.7%
Hand Dominance	(R) 50/60. (L) 10/60 % 83 %17
Surgical Side	(R) 42/60 50%
Physiotherapy Adherence	47/60 72%
Smoking History	12/60 20%
Steroid History	8/60 13.3%
Mechanism of Injury Lifting	 31/60 47.1%
Sport	19/60 29.4%
Hyperextension/Fall	10/60 23.6%
Days to Surgery	Mean 15.5 SD 22.6 CI (9.66-21.34)
DASH Score	Med 0 IQR3 (6.25)–IQR1 (0)
PREE Score	Med 0 IQR3 (7.65)- IQR1 (0)
Flexion Strength Difference	Mean -.61 kg SD (3.01) CI (-1.38-.17)
Supination Strength Difference	Mean -.03 SD (2.28) CI (-.62-.56)
Grip Strength Difference	Mean -1.36 SD 8.98 C1 -4.38, 1.66

Table 5. Strength and range of motion

DASH	PREE	Range of Motion (Degrees)	R Flex (kg)	L Flex (kg)	DIFF	R Sup (kg)	L Sup (kg)	DIFF	R Grip (kg)	L Grip (kg)	DIFF
0	0	N (R15deg sup lag, L 5deg flex lag)	24.33	24.7	-0.37	16.27	16.73	-0.46	50	50	0
0	0	N (5 Sup Lag)	21.5	23.13	1.63	19.7	18.53	1.17	56	52	4
0	0	Y	28.9	31.46	2.56	19.83	22.23	-2.4	52	42	10
11.67	13.33	Y	24.43	19.67	-4.76	21.53	17.97	-3.56	46	46	0
0.83	0	Y	21.83	23.2	1.37	8.47	10.87	2.4	35	45	10
0.83	0	Y	42.57	41.47	1.1	10.67	8.57	2.1	55	50	5
0	0	N (10 deg sup lag)	40.55	46.13	5.58	21.93	20.02	-1.91	52	52	0
0	0	Y	22.9	22.7	0.2	12.77	14.8	2.27	51	50	-1
5.83	3	Y	19.37	23.67	-4.3				47	38	-9
12.9	16.33	N (12-degree sup lag on R, 5-degree lag on L)	21.93	24.03	-2.1	18.73	14.6	4.13	63	56	7
0	0	N (R 10 sup lag)	23.97	23.97	0	7.67	7.77	-0.1	40	40	0
0	0	Y	58	54.6	3.4	12.53	8.93	3.6	57	58	-1
3.33	6.33	Y (5 degree a sup lag on non-op side)	29.5	28.1	1.4	7.73	8.03	-0.3	65	60	5
9.17	17	N (10 sup lag, 5 flex lag)				16	15.23	-0.77	61	55	-6
43.1	34.33	Y	13.13	23.73	-10.6	14.03	14.07	-0.04	48	58	-10
0	0	N (R 5 sup lag)	20.93	24.03	-3.1	10.17	9.3	0.87	60	58	2
0	0	Y	47.4	49.43	2.03	9.67	11.8	2.13	45	50	5
0	0	Y	19.97	24.33	0	8.7	9.53	-0.83	55	55	0
0	0	N (R sup lag 10)	34.27	33.7	-0.57	10.27	12.1	1.83	40	40	0
3.33	6	Y	35.83	37.7	-1.87	10.3	11.07	-0.77	70	80	-10
40	44.33	N (15 deg sup lag, -20-degree extension lag, -20 deg flexion lag)	24.64	34.47	-9.83	17.45	17.23	0.22	36	42	-6
0.83	1	Y	47.4	51.3	-3.9	16.03	10.43	5.6	50	45	5
0	0	N (15 sup lag, 5 flex lag)	23.23	24.5	-1.27	9.17	7.1	-2.07	45	45	0
5.83	19	N (R 5deg sup lag)	25.2	27.2	-2	7.37	7.57	-0.2	44	38	6
0	0	N (R 10 sup lag)	21.86	23.2	1.34	8.1	6.9	1.2	56	58	-2
10	29.3	N (5 lag flexion)	22.7	23.77	1.07	9.7	9.53	0.17	50	52	-2

0	0	Y	17.73	17.73	0	18.4	18.63	0.23	51	49	-2
0	1	Y	19.07	20.63	1.56	10.23	10.53	-0.3	56	52	-4
0	0	Y	24.57	24.77	0.2	14.03	13.37	-0.66	49	47	-2
0	0	N(R 10 sup lag)	24.53	20.83	-3.7	15.13	16.6	-1.47	42	43	-1
6.67	2.67	Y (L 5deg Sup Lag)	22.5	23.4	-0.9	28.4	28.73	-0.33	54	48	6
0	6	Y	18.56	16.17	-2.39	16.17	15.03	-1.14	53	51	-2
1.67	2.67	Y	24.93	24.7	0.23	15.2	10.47	4.73	32	36	-4
0	0	Y	24.96	24.13	-0.83	9.43	11.13	-1.7	54	54	0
9.17	0	N (R sup lag)	24.57	23.27	1.3	15.27	13.9	1.37	39	41	-2
0	0	Y	54.4	58.5	-4.1	8.53	8.77	-0.24	46	46	0
4.17	9.67	Y	50.03	46.43	3.6	19.4	14.57	-4.83	55	45	-10
6.7	9	Y	23.53	23.43	0.1	12.13	13.53	1.4	47	53	6
0.83	0	Y	49.83	50.36	-0.53	12.37	17	-4.63	55	59	-4
0	0	Y	40.2	38.33	1.87	22.43	18.67	-3.76	42	52	10
0	0	N (ext. lag 15, supination lag 5)	22.33	24.37	2.04	11.77	12.13	0.36	48	46	-2
9.17	0.67	N (B lag flexion)	23.26	22.97	0.29	12.4	15.17	2.77	50	48	-2
0	0.66	Y	48.8	48.5	0.3	21.37	15.93	5.44	52	46	6
0	0	N(L 5 deg. Sup lag)	19.3	16.83	2.47	15.9	18.87	-2.97	44	44	0
0.83	2	Y	24.87	24.63	0.24	22.47	19.63	2.84	61	54	7
0	1	Y	55.67	55.77	-0.1	16.4	17.97	-1.57	54	50	4
0	12	N(R8 deg sup lag)	26.83	27.93	-1.1	5.76	7.73	-1.97	25	35	-10
0	0	N (10 deg sup lag)	23.17	22.53	0.64	10.43	10	0.43	58	57	1
0	0	N(L 5 deg. Sup lag, R 5 deg. Flex lag)	28.17	30	1.83	19.1	21.13	-2.03	58	56	2
1.67	10.33	Y	23.63	21.63	2	18.8	17.06	1.74	56	54	2
0	0	Y	26.27	29.77	3.5	21.3	20.36	-0.94	60	58	-2
15.83	12.67	Y	19	26.7	-7.7	22.7	24.5	-1.8	50	48	2
3.33	0	Y	19.34	19.63	-0.29	7.2	7.67	-0.47	36	45	-9
0	0	N (20-degree sup lag on r, 10-degree sup lag on L)	49.63	49.7	-0.07	9.23	10.67	-1.44			
5	2.67	Y	16.3	19.37	-3.07	20.6	21.4	-0.8	46	43	3
5.83	17.67	N (5-degree sup lag)	42.4	37.8	-4.6	25.2	27.07	-1.87	56	52	4
5	5	Y	18.9	20.03	1.13	9.43	10.23	0.8	42	46	4
10.83	28	N (15-degree lag in supination)	17.76	17.5	0.26	10.27	8.97	1.3	51	52	-1
6.67	2.33	Y	34.4	37.84	-3.44	13.97	16.9	-2.93	43	44	-1
3.33	11.33	N (3 deg. Lag in L flexion) (supination	16.97	18.67	1.7	8.4	8.4	0	65	60	5

		lag on non-op side)									
0	0	Y (lag in supination performed on other side by another surgeon)	18	21	3	9	9.53	0.53	52	52	0
1.67	1	N (7 deg. Lag in R supination	21.1	18.23	2.87	11.87	11.27	0.6	60	60	0
0	0	N (significant lag of 45 degree in supination)	17.7	19.4	1.7	10.23	4	-6.23	57	54	-3
5	0.67	N (3 deg lag in supination)	17.07	16.2	-0.87	9.27	10.2	0.93	52	58	6
5.83	11.67	N(4 deg lag in flexion and 25 deg lag in sup)	17.27	18.67	1.4	8.07	9.9	1.83	42	54	12
0	0	Y	23.07	23.37	0.3	9.73	8.93	-0.8	45	56	11
0	0	N (7 deg sup lag)	24.8	21.57	3.23	12.13	12.73	-0.6	58	58	0
0	0	Y	18.63	19.17	-0.54	10.13	9.5	0.63	47	50	-3
0	2	Y	19.87	22.27	2.4	9.5	9.53	0.03	56	50	-6
0	0	(N 5 deg lag in flex)	19	18.43	-0.57	9.6	8.5	-1.1	47	46	-1

Appendix A. STROBE statement with assessment

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding

		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarize follow-up time (e.g., average and total amount)
Outcome data	15*	Report numbers of outcome events or summary measures over time
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarize key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of

		analyses, results from similar studies, and other relevant evidence
Generalizability	21	Discuss the generalizability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	*(a) Yes: Page 1 (Title)*
		(b) Yes: Page 2 (Abstract)
Introduction		
Background/rationale	2	*Yes: Page 3, Line 25-32*
Objectives	3	*Yes: Page 3, Line 36-41*
Methods		
Study design	4	*Yes: Page 3, Line 44-47*
Setting	5	*Yes: Page 3-4, Line 44-58*
Participants	6	*Yes: Page 4, Line 45-47*
Variables	7	*Yes: Page 4-5, Line 59-73*
Data sources/ measurement	8*	*Yes: Page 5-7, Line 74-114*
Bias	9	*Yes: Page 4, Line 46-54*
Study size	10	*Yes: Page 8, Line 147*
Quantitative variables	11	*Yes: Page 7, Line 126-132*
Statistical methods	12	*(a) Yes: Page 7-19, Line 115-140*
		(b) N/A
		(c) Yes: Page 8, Line 145-146
		(d) Yes: Page 7, Line 123-125
		(e) N/A

Continued on next page

Results		
Participants	13*	*(a) Yes: Page 8, Lines140-143*
		(b) Yes: Page 8, Line 143
		(c) N/A
Descriptive data	14*	*(a)Yes: Page 16-18, Table 3, 4*
		(b) Yes: Page 8, Line 144-146
		(c) N/A
Outcome data	15*	
		Yes: Page 19, Table 5
Main results	16	*(a) Yes: Page 8, Line 152-155; Page 9 Figure 1*
		(b) N/A
		(c) N/A
Other analyses	17	*N/A*
Discussion		
Key results	18	*Yes: Page 9-10, Line 166-183*
Limitations	19	*Yes: Page 12-13, Line 231-254*
Interpretation	20	*Yes: Page 101-12, Line 184-230*
Generalizability	21	*Yes: Page 13, Line 256-258*
Other information		
Funding	22	*Yes: Page 12, Line 260-261*

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

CHAPTER 4: PROGNOSTIC FACTORS ASSOCIATED WITH DISTAL BICEPS RECONSTRUCTION: A PROPSECTIVE OBSERVATIONAL ANALYSIS

Target Journal: Journal of Hand Surgery (To be submitted)

Authors
Pulak Parikh[1], Joy C. MacDermid[2], Vikas Tuli[3], Luciana Macedo[4], Julie Richardson[5], Michelle Manley[6]

[1]School of Rehabilitation Science, McMaster University
parikhp@mcmaster.ca

[2]Hand and Upper Limb Centre, St. Joseph's Health Centre, London, ON
jmacderm@uwo.ca

[3]Full Radius Orthopaedics, Newmarket, ON
tulivik@yahoo.ca

[4]School of Rehabilitation Science, McMaster University
jrichard@mcmaster.ca

[5]School of Rehabilitation Science, McMaster University
macedol@mcmaster.ca

[6]Spectrum Institute for Health and Rehabilitation, Newmarket, ON
michellemanley7@gmail.com

Corresponding Author
Pulak Parikh
School of Rehabilitation Science, McMaster University
1400 Main Street West
Hamilton, Ontario L8S 1C7
Email: parikhp@mcmaster.ca

Declaration of Interest: No conflicts of interest are declared by each of the authors, Pulak Parikh, Joy C. MacDermid, Vikas Tuli, Julie Richardson, Luciana Macedo and Michelle Manley

Acknowledgements: Joy MacDermid was supported by a Canadian Institutes of Health Research Chair in Gender, Work and Health and the Dr James Roth Chair in Musculoskeletal Measurement and Knowledge Translation.

Abstract

Introduction/Background: Rupture of the distal biceps tendon is relatively rare, usually occurring in the middle aged male population with an eccentric loading of the elbow; and typically, surgically repaired. The purpose of this cohort study was to prospectively identify factors associated with less favorable pain, strength and disability outcomes (following surgical repair). **Methods**: This prospective cohort study evaluated 34 participants at 6-12 months after double-incision distal biceps reconstruction. Two patient-reported outcome measures (PROM) were administered; the PREE (Patient Rated Elbow Evaluation) and the DASH (Disability of the Arm, Shoulder and Hand). Elbow flexion, supination and grip strength were tested using a hand-held dynamometer for both surgical and non-surgical arms. Factors included in the analysis were hand dominance, smoking history, steroid use, strength differential (surgical vs. non-surgical side), duration of time to surgery and physiotherapy attendance and completion. The extent of the difference of between pre and post-surgical functional scores for both the PREE and DASH and strength between surgical and non-surgical arms was determined using Wilcoxon signed rank sum tests. A hierarchical multivariable regression model was used to evaluate the relationship between any of the independent variables and functional outcome measures. In the first step we evaluated demographic and baseline factors (those collected prior to surgery) in association with functional outcome measure scores. Then we entered characteristics pertaining to surgery (days to surgery, complications and physiotherapy compliance post-surgery) with both the primary and secondary outcome measures. Finally, we examined physical factors such as strength and range of motion in

association with functional scores. **Results**: Post-operative PREE scores (mean difference=36.07, 95% CI 25.98 to 46.16; ES 1.81) and DASH scores (mean difference = 33.90, 95% CI 25.76-42.04; ES 2.1) were significantly better than pre-operative scores. A hierarchical multivariable regression analysis established that having the surgery on the non-dominant hand and weaker grip strength at follow-up accounted for 43.4% of the variability of PREE scores 6-12 months post-operative. **Discussion:** Minimal strength deficits and excellent PROM were present after a two-incision approach distal biceps repair. Having surgical repair on the non-dominant arm and having poor grip strength predicted poor functional outcomes at 6-12 months post-surgery. Functional use and intensity of rehabilitation may explain or modify these factors.

Background

The estimated incidence of distal biceps ruptures has been reported as 1.2-5.35 per 100,000 patient-years (E. W. Kelly, Sanchez-Sotello, et al., 2003; Safran & Graham, 2002). The majority of ruptures occur in the dominant extremity of male patients between the ages of thirty and sixty years (Miyamoto et al., 2010). The mechanism of injury is usually with a sudden eccentric load to the of the biceps in an outstretched position of the arm (Baker & Bierwagen, 1985; Morrey et al., 1985). Rupture of the distal biceps tendon can lead to pain and functional limitations specifically with elbow flexion and supination (Legg et al., 2016; Schmidt et al., 2019). The etiology of a distal biceps ruptures has been theorized to be multi-factorial. This has included a mechanical impingement of the tendon between the radius and ulna (Davis & Yassine, 1956) and degenerative and arterial supply factors (Seiler et al., 1995). Commonly reported risk factors have included weight training (Wentzell, 2018), smoking (Safran & Graham, 2002), anabolic steroid use (Visuri & Lindholm, 1994) and those participating in manual labor occupations (Morrey et al., 1985) . Although these have been introduced within the literature, many factors predicating distal biceps rupture remain unknown or controversial (Schneider et al., 2009).

Although historically non-operative management and non-anatomical repairs yielded acceptable results, anatomical surgical repair has become the gold standard treatment for distal biceps pathology (Mazzocca et al., 2007; Sarda et al., 2013; Schmidt et al., 2013). A recent systematic review reported that approximately 90% of clinical studies pertaining to distal biceps rupture are comprised of retrospective designs with a

significant lack of clinical usefulness and a high risk of bias (Nyland et al., 2015). It was concluded that future research directions be prospective, include an investigator independent of the surgeon with eccentric "break" testing for elbow flexion and supination in addition to the standard isometric and concentric "make test" strength testing. Hence, the purpose of this study was to conduct a prospective longitudinal cohort study to evaluate outcomes and identify factors associated with less favourable outcomes following distal biceps repair post a double incision technique.

Methods

Participants referred for surgery at one multi-regional hospital in Southern Ontario, Canada between 2015-2019 were eligible for inclusion. Eligibility was assessed during one clinical visit prior to surgery. The diagnosis for distal biceps pathology was made by a fellowship-trained upper extremity orthopaedic surgeon. The initial examination included a through health history (eccentric mechanism of injury, history of ecchymosis, etc.), clinical examination (range of motion, flexion and supination strength evaluation, palpation of the avulsed tendon) and evaluation of diagnostic imaging (either diagnostic ultrasound or magnetic resonance imaging). Due to timing concerns for surgery, not all patients could have imaging prior to evaluation and surgical decisions were based upon clinical examination.

Patients were eligible for the study if they were between 18 and 65 years of age and have had no prior history of distal bicep repair. Patients were excluded if they had bilateral symptoms, diagnoses of any other elbow or shoulder pathology, any concurrent injury to the upper extremity including recent trauma, any upper extremity surgery within

the past 3 years or if they are unable to speak, read and write or understand English. Once eligibility was determined, patients provided informed consent and proceeded to complete study measures. After surgical repair was completed, patients were referred to a local outpatient physiotherapy clinic. All evaluations were conducted by 2 trained physiotherapists with greater than 15 years of clinical experience.

All demographic and surgical data was extracted by the physiotherapists from the clinical charts prior to participants visit and then confirmed by intake history forms. Functional outcome measures were completed in person on the day before surgery and then again at 6-12 months post-surgery with the addition of strength testing.

Outcome Measures

1)The PREE (Patient Rated Elbow Evaluation) is a 20 item patient-reported outcome questionnaire that measures elbow-related pain and disability of the affected upper extremity (J. Vincent & MacDermid, 2012) 2) The DASH (Disabilities of Arm, Shoulder and Hand) outcome measure is a 30 item, self-report questionnaire designed to measure physical function, pain and disability in patients with disorders of the upper limb (Hudak et al., 1996) (Table 1. Descriptions for outcome measures). Both the PREE and DASH have demonstrated good validity and sensitivity for individuals after distal biceps reconstruction (J. I. Vincent, Macdermid, King, & Grewal, 2013).

Potential factors

Baseline Variables: Age (years), hand dominance (right or left), mechanism of injury (trauma, sport, eccentric load), smoking history (yes/no), steroid use (yes/no), activity level (minimal, moderate, high) occupation (desk work, labor profession)

Surgical Parameters: Days to surgery (number of days), complications (mild, moderate, severe), physiotherapy adherence (yes/no)

Range of Motion and Strength at Follow-up: Dynamometer strength for flexion and supination, grip strength, wrist/hand motion (Table 2. Descriptions for clinical factors).

Factors such as smoking, decreased strength and increased time to repair have been hypothesized to have had negative effects upon pain, function and disability for other tendon injuries such as rotator cuff repair (Santiago-Torres et al., 2015) and other orthopaedic surgery outcomes (Bedard, Dowdle, Owens, et al., 2018; Bulut et al., 2016; Delancey et al., 2018).

Isometric strength was measured for supination and flexion using a Layfayette handheld dynamometer (Model 01163). Three trials were conducted for each test using a "break test" methodology as described by Stratford (Paul W Stratford & Balsor, 1994) and reported the average. The starting position for testing had patients in sitting, right elbow flexed to 90 degrees and the forearm fully supinated. The right shoulder was stabilized, and the subject maintained this position until complete. Following a warm-up of submaximal and one maximal contraction for supination and flexion, the subjects performed 3 maximal elbow flexion and then 3 supination efforts with 30 second rest intervals with 2 minute rest intervals between flexion and supination tests. Resistance for the dynamometer was 1cm proximal to the wrist. Instructions for the break test were "Pull as hard as you can; now don't let me move your arm". Consistent verbal encouragement was given at the time. Values for the tests were recorded as kilograms (kg) of force.

The STROBE (Strengthening the Reporting of observational studies in Epidemiology) checklist for all types of observational studies was used as a guide for reporting (von Elm et al., 2007). This scale contains a list of 35 items that evaluate the degree, rigor and amount of information provided in each article section. Each item is scored by "yes", "no" or "unclear". (Appendix A).

Ethical Considerations

All participants provided voluntary written informed consent after discussion of potential risks and benefits for their participation within the study. Informed consent was obtained by the surgeon and treating physiotherapist prior to the initial assessment. Ethics approval was obtained from Southlake Hospital Institutional Review Board (Study number: 0043-1415).

Surgical Technique

All patients were repaired by a single upper extremity fellowship trained orthopaedic surgeon. During surgery, patients were placed supine with an Esmarch utilized and tourniquet set 250 mm Hg. A transverse incision was made at the flexor crease of elbow. Subsequently, identification and protection of the lateral antebrachial cutaneous nerve (LABCN) was completed. The distal biceps tendon was identified and tagged with 2 locking Krackow stiches (Ethibond or Hi-Fi). Before tagging, the last bit was trimmed (usually 2-3 mm) until a good quality tendon was fabricated. Next, a digital tunnel was recreated into the radial tuberosity. For the anterior incision, the arm was kept supinated.

Additionally, a lateral incision was made 2 fingerbreadths distal to the radio-capitellar joint. The incision was made through EDC with arm pronated. The radial tuberosity was identified along with a footprint of the distal biceps tendon. Once complete, a trough was made with a high-speed burr usually 10 mm long and 4 mm wide. Two transosseus holes were made anterior to the trough with wide enough bone bridges so a fracture was avoided. Irrigation with saline was done in order to not leave any bone dust behind. Two, 28 G wires were passed from transosseus holes into the trough.

Once complete, the tendon was passed through the anterior incision with its four arms of suture. Sutures were color coded to be identified easily. The distal biceps were then passed deep to radial tuberosity with a snap. The LABCN was visualized to ensure it was not trapped/irritated by distal biceps tendon. It was retrieved in the lateral incision. Multiple attempts were avoided for fear of injury the LABCN. Each strand of the suture was then passed separately through the tranosseous holes and tied to each other. The EDC fascia was closed with Vicryl and both incisions were closed with nylon. Hemostasis was ensured prior closure. Finally, plaster of paris was applied to the arm with 80 degrees flexion of the elbow.

Rehabilitation

Immediately after tendon repair, patients are casted with a back-slab cast for one week. During their first clinical visit the cast is removed, and passive movement exercises are demonstrated. A custom removal splint is fitted with the elbow in 90 degrees of flexion and neutral supination/pronation. This is worn for six weeks from surgery, with strict restrictions given for movement involving for the shoulder or elbow other than

passive exercises. Strengthening exercises including the elbow are restricted for 12 weeks with no heavy manual work for 6 months post repair. Patients are seen for four total clinical visits (week 1, week 6, week 12 and week 24).

Figure 1. Primary incision and identification of distal biceps tendon

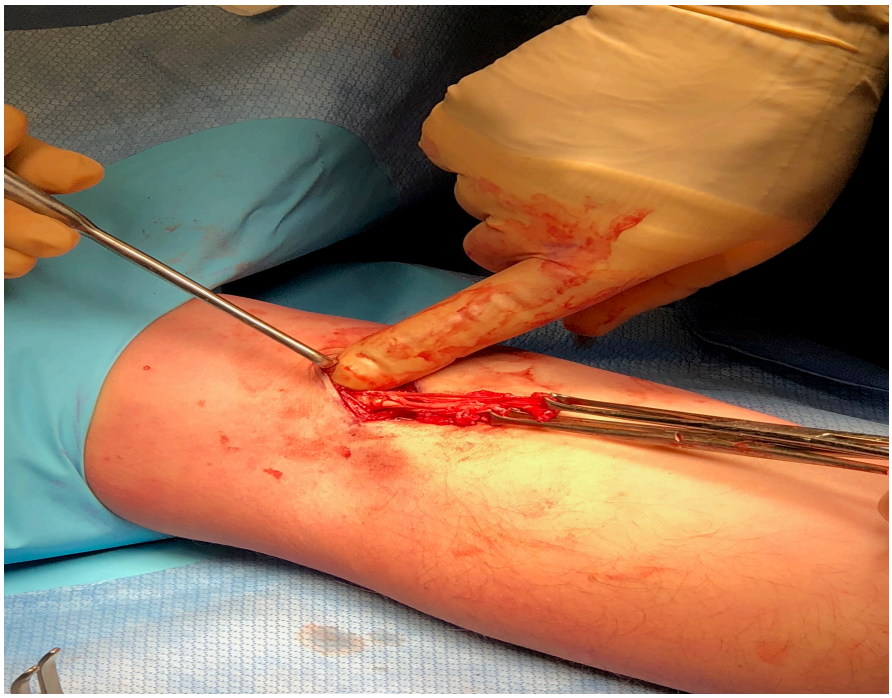
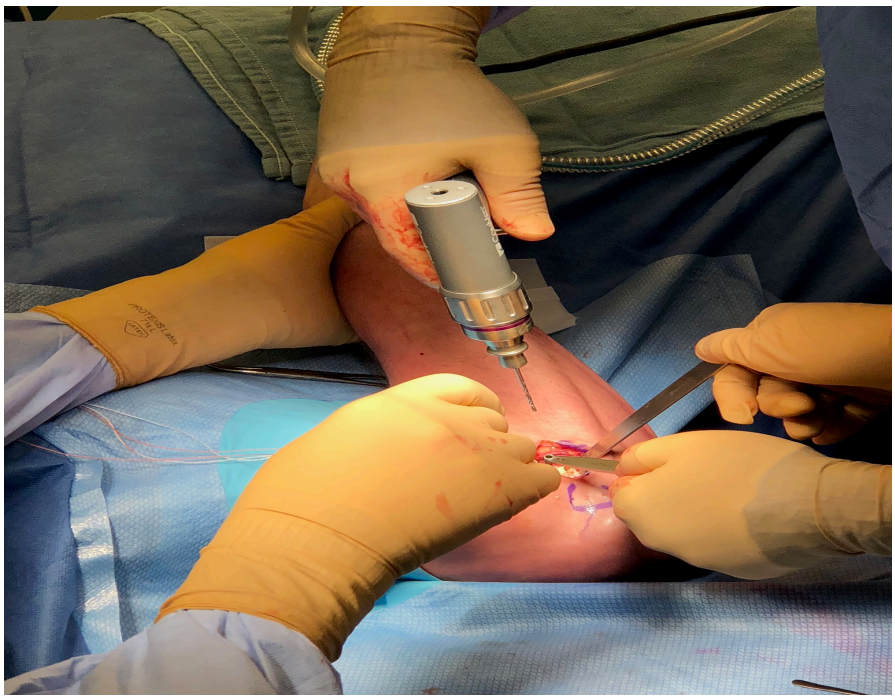


Figure 2. Digital tunnel drilled into radius after second incision



Statistical Analysis

Descriptive statistics were calculated as means and standard deviations for continuous variables with normal distributions. Median and inter-quartile ranges were given for variables with skewed distributions. Counts and percentages were applied to categorical data. All statistical analyses were done using STATA version 13.1. Initial analysis began with box plots to visualize change scores from pre-surgery to post-surgery for the primary and secondary outcome measures. Wilcoxon signed rank sum tests were conducted to determine if differences existed post-surgical reconstruction for both the PREE and DASH scores. Mean difference and effect size (ES) of the differences were calculated using Cohens *d* with ES>.80 considered large.

Further analysis was conducted with graph matrix scatter plots of all potential independent variables (strength difference-flexion, supination and grip, mechanism of injury, smoking, steroid use, duration of time from injury to surgery, hand dominance and physiotherapy compliance) with the primary outcome measure PREE and the secondary outcome measure DASH to evaluate if the associations were linear. Assumptions for regression were tested however not met secondary to skewed data for the dependent variable. A log transformation (natural log) for the both dependent variables was conducted prior to regression analysis. This transformation is the most widely used method to address skewed data in biomedical and psychological research (Feng et al., 2014). Distributions were checked pre and post transformations with a Shapiro-Wilk tests as well as histograms and kernel density graphs with normality curves. Assumptions for multicollinearity and singularity were checked with visual inspection. Outliers were examined visually and were reviewed for clinical relevance. We investigated the relative contribution of the predictor variables using a hierarchical multivariable linear regression model. In this analysis, variables were added to the model in stages. First, we evaluated demographic and baseline factors in association with functional outcome measure scores (at 6-12 months post-operative). Second, we investigated characteristics pertaining to surgery (days to surgery, complications and physiotherapy compliance post-surgery) with both the primary and secondary outcome measures. Finally, we examined physical factors such as strength, hand dominance and range of motion in association with functional scores.

All other assumptions for regression, (normality of residuals, linearity and homoscedasticity) were checked and met following transformation. Fit for the model was examined visually. All tests were two tailed and considered significant at $p<.05$.

The model was cross validated using a bootstrapping method with 200 repetitions within an add-on component from STATA version 13.1 using the "regvalidate" command. A robust regression analysis was also conducted secondary to the skewness of the dependent variable. This would not require the assumption of normality and results would be compared using both methods.

Results

Sixty two participants agreed to participate in the study and filled out initial study measures, however 28 (45%) did not follow-up for subsequent evaluation for unknown reasons despite being contacted. Thirty-four patients (55%) with surgical repair of the distal biceps that followed up at 6-12 months were included. None of the participants refused to participate with measurement or documentation. Table 3-5 summarize demographic data and results for all the participants. All surgical patients were male with a median age of 44.5 years. The majority were with either referred for surgery from a clinical exam (47.1%) or and ultrasound evaluation (44.1%). All participants were compliant with their attendance and physiotherapy exercise protocols at the hospital. A significant number had a smoking history (32.4%) and steroid use history (20.6%). The mean duration of days from the time of rupture to surgery was 25.86 days.

The results indicate there was a significant improvement in Pre-Operative ($m=44.45$, $SD=24.91$) and Post-Operative PREE scores ($m=8.38$, $SD=13.27$) (mean

difference=36.07, 95% 95% CI 25.98 to 46.16; ES 1.81); z = 4.94, p<.000 (Figure 3). There was also a significant difference in pre-operative DASH scores (M=39.86, SD=22.06) and post-operative DASH scores (m=5.96, SD=7.30) (mean difference = 33.90, 95% CI 25.76-42.04; ES 2.1); z = 5.09, p<.000. (Figure 4). A hierarchical regression (Figure 5) established that having the surgery on the non-dominant hand and weaker grip strength could statistically predict higher pain and disability scores as measured by the PREE, F (2,21) = 9.82, P=<.001, R^2= .48, Adj R^2=.43. Therefore, both having the surgery on the non-dominant hand and grip strength accounted for 43.4% of the variability of PREE scores. Variables included with co-efficient, t-values and p-values (confidence intervals) are presented in Table 3. Regression diagnostics were performed, and the assumptions were met. The secondary outcome (DASH) did not demonstrate any association to the independent variables included in the analysis. Regression results are presented with log values as the transformed data has the potential to share little in common with the original data set, therefore possibly biasing predictions (Feng et al., 2014).

Figure 3. PREE Scores Pre-Operative vs. Post-Operative

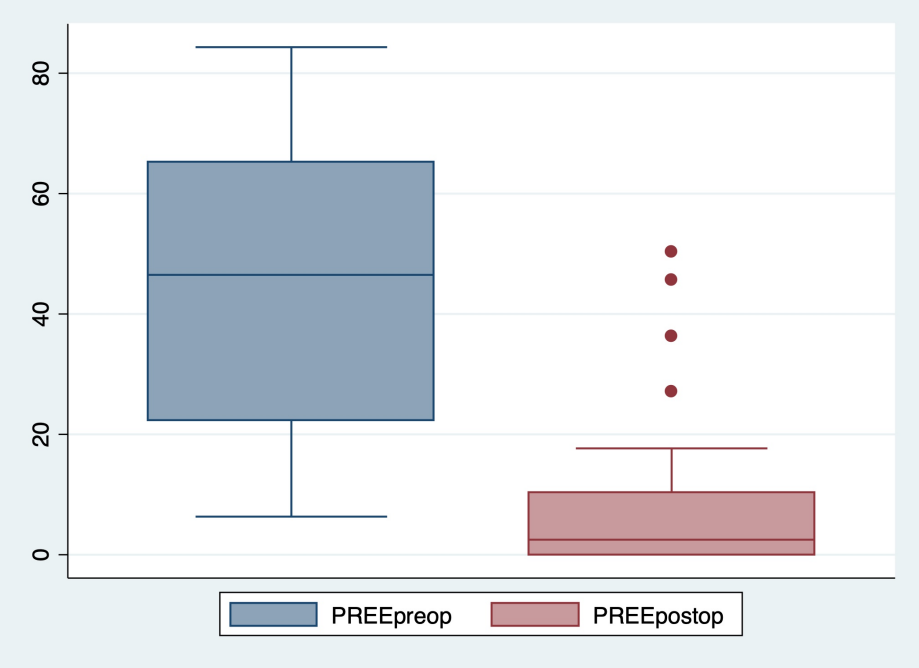


Figure 4. DASH Scores Pre-operative vs. Post-Operative

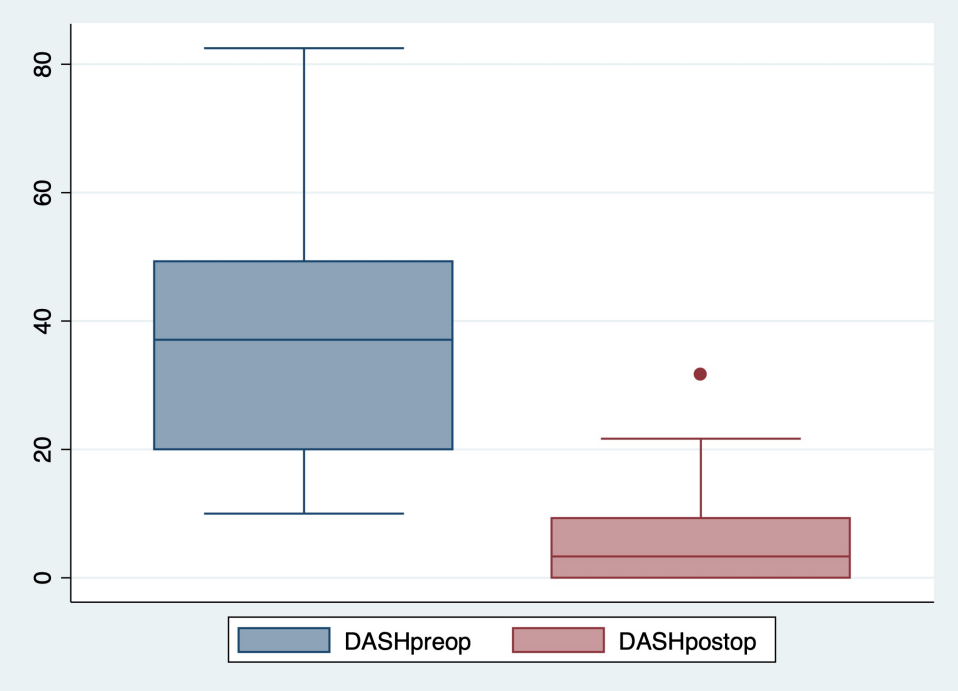


Figure 5. Regression model for primary predictors

Source	SS	df	MS		
Model	20.2875603	2	10.1437802	Number of obs =	24
Residual	21.702496	21	1.03345219	F(2, 21) =	9.82
				Prob > F =	0.0010
Total	41.9900564	23	1.82565462	R-squared =	0.4832
				Adj R-squared =	0.4339
				Root MSE =	1.0166

logpree	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
GripDiff	-.0432781	.0196742	-2.20	0.039	-.0841928	-.0023634
SS	1.457647	.4272377	3.41	0.003	.5691576	2.346137
_cons	.6035369	.3261593	1.85	0.078	-.0747485	1.281822

Discussion

This study found like prior clinical studies that patient outcomes are excellent following biceps repair with a statistically and clinically significant change in outcomes. (D'Arco et al., 1998; El-Hawary et al., 2003; Ruby Grewal et al., 2012). In addition, we identified two factors predicting 43% of the variance in outcomes. Having a surgical repair on the non-dominant arm and decreased grip strength were predictors of poor prognosis of disability and functional scores.

Prior prognostic studies have been limited and have not focused on predicting PROM. Previously, anatomic re-attachment, a posterior surgical approach and limited supinator muscle fat were significant predictors of supinator strength post distal biceps repair (Schmidt, Brown, et al., 2016). Tendon heterogeneity, heterotopic bone, workers compensation, post-operative DASH scores, arm dominance, time from injury to surgery and duration of follow-up did not correlate with supination strength scores.

In addition, patient variables including age, diabetes and BMI and surgical variables (time to surgery, use of graft) have been studied as potential predictors of

complications after a two-incision technique (Austin, Mathur, Simpson, & Lazarus, 2009). None of the variables were found to statistically predict the complications observed.

Characteristics of individuals with bilateral distal biceps ruptures found no correlation between outcomes and the following: surgical treatment and manual labor, workers compensation claims, past medical history, prescription medications, prior tendon injury, BMI, sports activity participation, use of nutritional supplements or androgenic steroid use (Schneider et al., 2009). However, there was a higher prevalence of patients that used nicotine products (50%) and anabolic steroids (20%), greater than that of the general population.

Furthermore, data pertaining to patient age, sex, hand dominance, smoking status, occupation and workers compensation claims found workers compensation patients that underwent distal biceps reconstruction took longer to return to work and had greater disability as measured by the DASH compared to non-workers compensation patients (Atanda et al., 2013).

In comparison, our study did not find any significant relationship between age, strength (flexion and supination), range of motion, adherence (clinic attendance and rehabilitation protocol followed), complications with surgical procedure, mechanisms of injury, smoking history, activity level, prior health status, occupation and demographic information (age, sex, ethnicity, medication or steroid use) in relation to functional scores other than arm dominance and grip strength.

Although no similar investigations or findings regarding hand dominance for distal biceps or elbow surgery are present within the literature, a prospective evaluation of rotator cuff repairs between dominant and non-dominant sides found no difference in functional outcomes (M. A. Kelly, Mc Donald, Boland, Groarke, & Kaar, 2017). However, a significant difference was observed in the usage between dominant and non-dominant arms as measured by a body worn sensors post rotator cuff surgery, although most patients recovered their normal use within 12 months regardless of surgical side (Pichonnaz et al., 2015). Our strength and functional measurements were taken between 6-12 months post-operatively. Further follow-up greater than 12 months can distinguish if arm dominance can predict poor functional outcomes in future studies.

Hand grip has been known to be a predictor for many surgical and non-surgical outcomes (Milgrom, Schaffler, Gilbert, & Van Holsbeeck, 1995; Otto et al., 2014; Sato et al., 2018). Poor hand grip has been known to predict poor functional outcomes post orthopaedic surgeries such as carpal tunnel release (Bae, Kim, Yoon, Kim, & Ho, 2018), lumbar stenosis surgery (Shen et al., 2018) and even total knee arthroplasty (Hashimoto et al., 2019). Although no previous studies have reported on grip strength and distal biceps repair, this metric has been well established to have high predictive value for functional outcomes, post-operative complications, length of hospital stay and remission rates post-surgery (Webb, Newman, Taylor, & Keogh, 1989). However, the biological and physiological mechanisms for which these predictive values are based are largely unknown. It has been hypothesized that grip strength is an indicator for overall functional strength and overall health status (Lauretani et al., 2003; Rantanen, Era, & Heikkinen,

1994). It is also possible that recovery of grip reflects greater resumption of normal activity or engagement in rehabilitation which is reflected in less functional disability. However, it is interesting to note that strength measured for biceps flexion and supination did not demonstrate any significant relationship to overall functional scores. This might suggest that either it is overall strength/health status that is a more important determinant; or there may be challenges in measuring strength of proximal muscles with hand-held dynamometry versus grip strength dynamometers which have high reliability, since measurement error tends to dilute correlations (Hamilton, Balnave, & Adams, 1994). Another potential reason for lower correlations is when there is little variation. Therefore, consistently high outcomes and narrow ranges of predictor variables may make it more difficult to assess correlations across a broader range.

Strengths and Limitations

While this study was prospective, used validated outcome measures and minimized variation in surgical procedures it has limitations that should be considered. The small sample size (34 participants) with a shorter than expected follow up time (6-12 months) limited precision and power for modelling. This may have resulted in failure to detect true predictors. Although given the low incidence of biceps ruptures this a relatively large prospective cohort from a single center. Recruitment is often complicated by the excellent outcomes and wide geographic catchment for this specialty surgery that decreases the motivation and feasibility of longer-term follow-up. Since the majority of the patients were experiencing excellent outcomes, they may not have been motivated to return for follow-up visits. This was also the reason for the skewed data set as most

scores for the PREE and DASH were close to or at zero. In contrast, patients that did follow-up may have had lingering symptoms that could have introduced selection bias. While we evaluated outcomes 6-12 months, we did not report or predict longer-term outcomes since patients regularly refused longer follow up timelines. Further, there was a possibility that those patients that followed up were those that had lingering symptoms, introducing selection bias.

We also did not adjust scores for hand dominance. Hand dominance has been known to cause variations in strengths between individuals (as much as 10-20% between arms) (Güleçyüz et al., 2017). However, since differences pertain to groups more than individuals, we could not be confident that adjustment for individuals would be appropriate. Finally, although all surgeries were performed by one orthopaedic upper extremity surgeon, the difference in surgical techniques between allograft, chronic and acute repairs may have introduced performance bias.

Measurements were also taken knowing the dominant upper extremities which can introduce measurement bias. Once again, patients had consistently good outcomes and had their surgery was up to 12 months prior which also introduced recall bias when completing functional measures.

Conclusion

The majority of surgical outcomes for distal biceps repair using a two-incision approach have minimal complications and good functional outcomes as measured by the PREE and DASH. Having surgical repair on the non-dominant arm and having poor grip strength predicted poor functional outcomes within 6-12 months post-surgery

References

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and*

Elbow Surgery, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375.

https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J.

W. (2003). Distal biceps tendon repair: Comparison of surgical techniques. *Journal of Hand Surgery*, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps

tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147. https://doi.org/10.1097/JSA.0b013e3181824e76

Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5

Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003

Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009

Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025

Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130

Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336

Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287

Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006

Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687

Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001

Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.

Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper

Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and Head), *608*(1 996).

Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382

Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005

Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035

Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.

Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030

Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214

Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009

Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.

Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896

Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1

Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562

Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017.

https://doi.org/10.1177/0363546515587738
Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405
Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690
Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144
Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049
Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5
Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003
Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358
Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa
Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694
Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003
Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008
Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T. (2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave

therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291. https://doi.org/10.2343/geochemj.2.0468

Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7

O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016

Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.

Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6

Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004

Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349

Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014

Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017

Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5

Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032

Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries:

Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2), 103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the “Salento technique”, a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. *Clinical Orthopaedics and Related*

Research, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon

Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014

Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098

Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041

Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.

Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276

Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.

Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030

Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4

Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9

Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029

Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0

Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002

von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J. (2007). The strengthening the reporting of observational studies in epidemiology

(STROBE) statement: guidelines for reporting observational studies. *Bulletin of the World Health Organization*, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623

Table 1. Description of Outcome Measures

Construct	Measure	Scale Range	Details	Validity	Reliability	Responsiveness	Minimal Clinically Important Difference
Primary Outcome							
Pain, Function and Disability	Patient Rated Elbow Evaluation (PREE)(MacDermid, 2010; J. Vincent & MacDermid, 2012)	0-100 Lower Better	Rate the average amount of pain over the past week of the elbow and rate the amount of difficult you experienced performing each of the items listed from 0 (no difficulty) to 10 (most difficult)	**Construct validity**: Moderate to high correlations to ASES, DASH, SF-36	Excellent ICC: .89 SEM: .27-3.28	Excellent Effect size (all studies) .8-1.6	7-11 depending on baseline scores
Secondary Outcomes							
Function and Disability	Disabilities of the Arm, Shoulder and Hand (DASH)(Wylie et al., 2014)	0-100 Lower Better	30 items Physical activities in arm, shoulder, hand (21); Symptoms of pain, tingling, weakness (5); Impact of social activities (4) **Must answer 27 questions to be scored	**Criterion Validity:** Correlated with other scores over different regions of the upper extremity and general outcome measures including SF-36 **Construct Validity:** Difference between working/not able to work; disease and health state, ability to do what they want versus not able	Excellent ICC: .77-.98 SEM: 2.8-5.2	Excellent Effect size (all studies) .4-1.4	10 for shoulder complaints, 17 for elbow wrist and hand

Table 2. Description of Potential Predictors

Potential Predictor	Measure	Details
Days to Surgery	Number of days from rupture to surgical repair	Measured by retrospective chart review
Smoking History	Past/present smoking history (Y/N)	Measured by health questionnaire administered during first visit
Steroid Use/History	Past/present steroid use (including cortico-steroids) (Y/N)	Measured by health questionnaire administered during first visit
Dynamometer Strength (Flexion and Supination)	Isometric strength was measured for supination and flexion using a Layfayette handheld dynamometer (Model 01163).	Three trials for each test were conducted using a "break test" methodology as described by Stratford(Paul W Stratford & Balsor, 1994) with the average reported
Pain free grip strength	Isometric grip strength measured by Jamar hydraulic hand dynamometer	Three trials conducted as described by Stratford(P. W. Stratford et al., 1989) with average reported
Hand Dominance	Right or Left hand dominance	Measured by health questionnaire administered during first visit
Physiotherapy Adherence	Patient attendance for physiotherapy appointments and protocol completion	Measured by retrospective chart review and physiotherapy discharge summary
Surgical Complications	Mild complications (temporary <2 weeks) Moderate Complications (2-4 weeks) Serious Complications (>1 month)	Assessed by the surgeon at follow up visits for 6 month period
Activity level	Minimal (exercise <1 x / week) Moderate (exercise 1-3x/week) High (exercise >3x/week)	Measured with health questionnaire administered during first visit
Education	Less than high school education High school diploma College or University diploma or degree	Measured with health questionnaire administered during first visit
Age	At the time of surgical repair	Measured by retrospective chart review
Occupation	Laborious profession Desk work	Measured by health questionnaire administered during first visit

Table 3. Demographic and surgical data

Age	Hand Dominance	Surgical Side	Occupation	Physio	Imaging	Smoking	Steroid	Mechanism	Days to Surgery	Year of Surgery
56	R	R	Business Owner	1	None	Y	N	Lifting	11	2018
41	R	L	IT	1	None	N	N	Lifting	23	2015
37	R	R	Teacher	1	None	N	N	Sport (hockey)	34	2017
41	R	R	Civil engineer	1	U/S	N	N	Sport (hockey)	9	2016
43	R	R	Quality Analyst	1	U/S	N	N	Hyperextension	11	2017
27	R	L	Security	1	U/S	Y	Y	Lifting	13	2017
48	R	R	Carpenter	1	U/S	N	N	Lifting	15	2016
28	R	L	Pump Op	1	MRI	N	Y	Lifting	22	2015
58	R	L	Physician	1	None	N	Y	Hyperextension	11	2018
50	R	R	Police officer	1	None	N	Y	Lifting	9	2015
39	R	R	Personal Trainer	1	U/S	Y	Y	Lifting	23	2018
49	R	R	Business Owner	1	U/S	N	N	Lifting	8	2015
39	R	L	Graphic designer	1	None	Y	N	Hyperextension	9	2018
43	R	L	Construction	1	None	N	Y	Lifting	14	2017
43	R	L	Sign installer	1	None	Y	N	Sport (hockey)	9	2018
41	R	L	Land Op	1	U/S	N	N	Lifting	22	2016
60	R	L	Manager	1	U/S	N	N	Sport (water skiing)	11	2016
53	R	L	Teacher	1	None	N	N	Lifting	3	2016
50	R	L	IT support	1	None	N	N	Lifting	24	2015
49	R	L	Insurance	1	MRI	N	N	Sport (hockey)	217	2016
49	R	R	Banking	1	None	N	N	Sport hyperextension	11	2018
54	R	L	Labor	1	U/S	Y	N	Lifting	24	2017
56	R	L	Retired	1	U/S	Y	N	Pulling in hyperextension.	11	2017
57	R	L	Caregiver	1	U/S	N	N	Lifting	10	2015
37	R	R	Police officer	1	None	Y	Y	Sport (hockey)	12	2017
44	R	L	Computer Consultant	1	None	N	N	Sport (boxing)	9	2015
58	R	L	Mechanist	1	None	N	N	Hyperextension	11	2018
41	R	R	Banquet manager	1	U/S	N	N	Lifting	13	2018
56	R	R	Engineer/Prof	1	None	N	N	Hyperextension	7	2018
43	R	L	IT consultant	1	U/S	N	N	Sport (hockey)	78	2015
50	L	R	Fleet Manager	1	None	Y	N	Sport (hockey)	98	2019
42	R	R	Business owner	1	U/S	Y	N	Hyperextension	27	2019
23	R	L	Electrician	1	U/S, MRI	N	N	Lifting	54	2019
45	R	L	Pump Op	1	U/S	Y	N	Hyperextension	16	2019

Table 4. Descriptive statistics

Variables	Descriptive Statistics	
Study Participants	34 (Male)	
Age	Median 44.5 Q3 (52.25), Q1 (41) IQR (11.25)	
Imaging Ultrasound	15/34 44.1%	
MRI	2/34 5.9%	
Both MRI and US		
Clinical Exam	1/34 2.9%	
	16/34 47.1%	
Hand Dominance	(L) 1/34 2.9%	(R) 33/34 97.1%
Surgical Side	(L) 17/34 50%	(R) 17/34 50%
Physiotherapy Compliance	34/34 100%	
Smoking History	11/34 32.4%	
Steroid History	7/34 20.6%	
Mechanism of Injury Lifting	16/34 47.1%	
Sport	10/34 29.4%	
Hyperextension/Fall	8/34 23.6%	
Days to Surgery	Mean 25.86 SD CI	
DASH Score	**Pre-op** Mean 39.86 SD 22.06 CI 32.16 – 47.56	**Post-op** Median 3.33 Q3 (9.0), Q1 (0.0) IQR 9.0
PREE Score	**Pre-op** Mean 44.45 SD 24.91 CI 35.47 – 53.43	**Post-op** Median 2.5 Q3 (9.7), Q1 (0) IQR 9.7
Flexion Strength Difference	Mean -0.31 SD 3.33 CI 0.80, -1.43	
Supination Strength Difference	Mean -0.27 SD 1.39 CI -0.74, 0.20	
Grip Strength Difference	Mean -1.36 SD 8.98 C1 -4.38, 1.66	

Table 5. Strength and ROM values measured greater than 6 months post-operatively

DASH	PREE	ROM	R Flex	L Flex	Diff	R Sup	L Sup	Diff	R Grip	L Grip	Diff
0	2	N (10-degree lag in sup)	19.1	18.43	0.67	10.13	10.43	-0.3	54	56	-2
0	0	Y	19.2	18.13	-1.07	8.37	8.77	0.4	54	54	0
0	0	N (10-degree lag in sup)	18.6	18.8	-0.2	10.3	11.3	-1	60	62	-2
0	0	N (4-degree flex lag)	33.37	32.67	0.7	17.64	17.33	0.31	62.67	53.67	9
8.33	0.33	Y	57.67	53.83	3.84	20.43	24.13	-3.7	50	40	10
21.67	50.33	N (10-degree sup lag)	17.47	19.13	-1.66	12.33	11.36	0.97	55	54	1
6.67	4		36.43	35.6	0.83	16.17	14.13	2.04	35	48	-13
31.67	36.33	Y	14.67	11.3	-3.37	12.1	10.33	-1.77	53.67	24.67	-29
0	0	(N 5-degree lag in supination)	17.93	17.7	-0.23	9.2	8.43	-0.77	43	44	1
5.83	2	Y	22.6	24.53	-1.93	9.97	8.87	1.1	46	48	-2
10.83	10.67	N (15-degree sup lag)	15.83	13.9	1.93	8.63	8.2	0.43	53	51	2
0.83	2	Y	32.67	41.7	-9.03	21.2	19.07	2.13	57	58	-1
2.5	45.67	N (10-degree supination lag)	23.8	20.9	-2.9	9.83	9.57	-0.26	66	55	-11
0	0	Y (Lag on non-surgical side)	23.4	23.3	-0.1	11.5	10.67	-0.83	51	60	9
3.33	5.67	Y	22.97	24.76	1.79	9.67	10.23	0.56	58	48	-10
9.17	12	Y	11.07	21.3	10.23	8.03	9	0.97	30	52	22
12.5	17.67	N (5-degree sup lag)	28.1	30.2	2.3	16.5	14.2	-2.3	54.67	38.67	-16
6.67	10.33	Y	15.9	19.3	3.4	10.03	9.13	-0.9	42	42	0
0	0	N (5-degree sup lag)	18.27	20.33	2.06	10.26	10.3	0.04	44	49	5
6.67	8	Y	17.97	17.2	-0.77	13.57	11.23	-2.34	50	46	-4
1.67	0	Y	19.5	19.57	0.07	8.57	7.47	-1.1	40	38	-2
0.83	0	Y	18.27	18.5	0.23	7.93	7.83	-0.1	50	58	8
15	1.33	Y	22.63	21.4	-1.23	11.13	9.6	-1.53	42	48	6
0	3	Y	27.5	19.3	-8.2	20.46	18.3	-2.16	60.67	56	-4.67
0	0	N (10-degree supination lag)	21.9	20.77	1.13	10.33	9.7	0.63	52	52	0
3.33	5.67	Y	23.9	23.36	-0.54	12.83	14.1	1.27	41.67	44	2.33
3.33	0.33	N (20-degree sup lag on R, 10-degree flexion lag on R)	15.2	19.03	-3.83	10.1	9.3	0.8	32	44	-12
15.83	11.67	N (5-degree flexion lag)	19.27	18.17	1.1	9.17	10.87	-1.7	51	58	-7
9.17	3.33	Y	19.23	19	0.23	9.2	8.8	0.4	45	45	0
15	27	N (10-degree lag in sup)	23.9	24.2	0.3	9.87	8.6	-1.27	50	50	0
0.83	0	Y	26.53	31.1	-4.57	9.3	9.97	-0.67	59	57	2
7.5	5.67	Y (3 deg sup. Lag)	23	24.2	-1.2	10.17	9.27	0.9	64	64	0
3.33	2	Y	25.6	25.97	0.37	10.4	9	-1.4	66	56	-10
0	3	N (5 deg sup lag, 3 deg flex lag)	22.27	23.27	-1	10.7	8.67	2.03	60	58	2

Appendix A. STROBE statement with assessment

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at

Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) If applicable, explain how loss to follow-up was addressed
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—e.g. numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analyzed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (e.g. demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) Summarize follow-up time (e.g., average and total amount)
Outcome data	15*	Report numbers of outcome events or summary measures over time
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—e.g. analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarize key results with reference to study objectives

Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalizability	21	Discuss the generalizability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	*(a) Yes: Page 1 (Title)*
		(b) Yes: Page 2 (Abstract)
Introduction		
Background/rationale	2	*Yes: Page 4-5, Line 61-84*
Objectives	3	*Yes: Page 5, Line 85-87*
Methods		
Study design	4	*Yes: Page 5, Line 90-98*
Setting	5	*Yes: Page 5, Line 90-91*
Participants	6	*Yes: Page 5-6, Line 99-107*
Variables	7	*Yes: Page 6-7, Line 112-129*
Data sources/ measurement	8*	*Yes: Page 6-7, Line 112-119*
Bias	9	*Yes: Page 7, Line 130-141*
Study size	10	*Yes: Page 12, Line 223-226*
Quantitative variables	11	*Yes: Page 12, Line 227-233*
Statistical methods	12	*(a) Yes: Page10-11, Line 187-221*
		(b) N/A
		(c) Yes: Page 11, Line 226-227
		(d) Yes: Page 11, Line 224-226
		(e) N/A

Continued on next page

Results		
Participants	13*	*(a) Yes: Page 12, 223-227*
		(b) Yes: Page 12, Line 224-225
		(c) N/A
Descriptive data	14*	*(a)Yes: Page12, Line 225-232; Table 3, 4*
		(b) Yes: Page 12, Line 224
		(c) N/A
Outcome data	15*	
		Yes: Page 12, Line 223
Main results	16	*(a) Yes: Page 12, Line 233-238; Page 14 Figure 5*
		(b) N/A
		(c) N/A
Other analyses	17	*N/A*
Discussion		
Key results	18	*Yes: Page 14, Line 269-273*
Limitations	19	*Yes: Page 17-18, Line 334-359*
Interpretation	20	*Yes: Page 15-17, Line 274-332*
Generalizability	21	*Yes: Page 19, Line 361-364*
Other information		
Funding	22	*Yes: Page 19, Line 366-367*

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

CHAPTER 5: DISTAL BICEPS TENDON RUPTURE: IS SURGERY THE BEST COURSE OF TREATMENT? TWO CASE REPORTS

Target Journal: Journal of Hand Therapy (Accepted for publication)

Authors
Pulak Parikh[1], Joy C. MacDermid[2], Vikas Tuli[3], Michelle Manley[4]

[1]School of Rehabilitation Science, McMaster University
parikhp@mcmaster.ca

[2]Hand and Upper Limb Centre, St. Joseph's Health Centre, London, ON
jmacderm@uwo.ca

[3]Full Radius Orthopaedics, Newmarket, ON
tulivik@yahoo.ca

[4]Spectrum Institute for Health and Rehabilitation, Newmarket, ON
michellemanley7@gmail.com

Corresponding Author
Pulak Parikh
School of Rehabilitation Science, McMaster University
1400 Main Street West
Hamilton, Ontario L8S 1C7
Email: parikhp@mcmaster.ca
Email 2: pulakpar@yahoo.com

Declaration of Interest: No conflicts of interest are declared by each of the authors, Pulak Parikh, Joy C. MacDermid, Vikas Tuli, Michelle Manley

Acknowledgements: Joy MacDermid was supported by a Canadian Institutes of Health Research Chair in Gender, Work and Health and the Dr James Roth Chair in Musculoskeletal Measurement and Knowledge Translation.

Abstract

Study Design: Case series. **Background:** Complete rupture of the distal biceps tendon occurs mostly within the middle-aged male population. Surgical repair is traditionally recommended. Given the potential for complications, questions remain whether surgical repair is indicated. The purpose of this case series was to explore options for non-operative management for full distal biceps ruptures. **Case Description:** Two participants with complete tears of the distal biceps tendon confirmed with Magnetic Resonance Imaging (MRI) /Ultrasound (US) had chosen to not undergo surgical repair. The first, a 48-year-old police officer was an avid weight-lifter and recreational athlete. The second, a 43-year-old detailer has minimal physical activity participation other than work duties and light recreational sports. Strength testing was done immediately post rupture and at 24 weeks following a structured rehabilitation program focused on strengthening and stretching the elbow flexors and supinator's. **Outcomes**: Initial strength deficits of 17/21% in flexion and 13/19% for supination were detected. In both patients, flexion and supination strength significantly increased back to normal limits when compared to the opposite upper extremity. Post intervention, functional outcomes and disability scores returned to normal and patients reported return to pre-injury repetitive work and weight training. **Discussion:** Although patients are typically counselled that a reason for surgical repair following biceps rupture is substantial loss of flexion and supination strength, these cases indicate that full recovery of strength and function is possible following a rehabilitation program. This questions traditional wisdom whether

surgical repair is needed for all distal biceps ruptures. Level of Evidence: Therapy, level 5. Key words: Distal Biceps, Surgery, Rehabilitation **ICD-10 Code: M66.3**

Background

The biceps brachii is the second largest muscle in the arm that acts as the prime supinator and secondary flexor of the elbow, with three to four musculotendinous units (Kulshreshtha et al., 2007). The first two attach proximally; the long head at the superior aspect of the glenoid and the short head at the coracoid process of the scapula (Athwal et al., 2007). The distal biceps has two distinct heads and has been shown to have one or two attachment locations near the radial tuberosity of the forearm (Eames et al., 2007; Van den Bekerom et al., 2016). Rupture of the distal aspect of the tendon often occurs with avulsion of both musculotendinous sites with two heads often held together with areolar tissue and with the lacertus fibrosus intact (Alentorn-Geli et al., 2016). Typically this has been reported with a history of an eccentric flexion load to the arm with a traumatic pop, ecchymosis and pain (Schmidt, Savoie, et al., 2016).

Distal bicep tears are relatively rare with an incidence of 2.55-5.35 per 100,000 people (M. Kelly et al., 2015), however most common within the middle aged male population (Haverstock et al., 2015; Safran & Graham, 2002). A significant amount of controversy exists between many factors associated with this condition (Schmidt, Savoie, et al., 2016). Questions exist surrounding the efficacy of diagnosis (Alentorn-Geli et al., 2016), prognosis (Hinchey et al., 2014; Kettler et al., 2007), surgical technique (Chavan et al., 2008; Citak et al., 2011; Guglielmino et al., n.d.; Watson et al., 2014), complication rates (Amin et al., 2016; Cohen & Katolic, 2003) as well as rehabilitation (Cheung et al., 2005; Spencer et al., 2008b). Overtly, some have questioned whether surgical repair has been validated for all cases (Lopez-Zabala, Fernandez-Valencia, López-Zabala, &

Fernández-Valencia, 2013b; Ring et al., 2017a). Yet, surgery is the most common intervention offered for this condition (Baker & Bierwagen, 1985). Although good outcomes from surgical repair are expected, complication rates have been reported as high 63% (Haverstock et al., 2017); the most common being the neuropraxia of the lateral antebrachial cutaneous nerve (Beks, Claessen, Oh, Ring, & Chen, 2016). Other complications include posterior interosseous nerve injury, heterotopic ossification, stiffness, weakness, wound infections, complex regional pain syndrome, re-rupture, median and ulnar nerve injuries, brachial artery injury, proximal radius fracture and hardware failure (Garon & Greenberg, 2016). Furthermore, current concepts in evidence for this pathology have generally consisted of retrospective designs, lack of eccentric flexor or supinator strength testing and varied surgical and rehabilitation descriptions (Nyland et al., 2015). The purpose of this case series was to explore options for non-operative management for full distal biceps ruptures.

Case Descriptions

Two patients were evaluated post injury to their left non-dominant arm. Both were evaluated in the emergency room and then referred to an orthopaedic surgeon for surgical evaluation. Medical evaluation for both individuals demonstrated edema, weakness in both flexion and supination strength along with a positive hook test. This test first described by O'Driscoll (O'Driscoll et al., 2007) attempts to hook the distal biceps from lateral to medial, while the patient holds the arm in 90 degree elbow flexion and supination; an intact tendon would allow the examiner to "hook" the tendon and pull it forward. With partially intact fibers the patient may experience pain with the anterior pull

during the test. Clinically this test was shown to have higher specificity and sensitivity (100%) when compared to MRI (92% and 85%) (O'Driscoll et al., 2007). A lack of tendon detection and minimal pain suggested full rupture in both cases. Neuro-vascular examination was normal without any associated injury noted. Both were informed of the risk and benefits of surgical vs. non-surgical treatment options and both declined surgery. These risks included the potential for 30-40% supination strength loss and greater than 20% loss of flexion in the long term (Schmidt et al., 2019). They were then referred to physiotherapy for pain control, manual therapy and a therapeutic exercise program.

Imaging

Both individuals were referred for imaging to rule out any associated pathology and to confirm the clinical diagnosis prior to commencing therapy. The first (Case 1) underwent an ultrasound (US) examination 2 weeks post injury which indicated a tear with 1.7cm of retraction of the distal biceps tendon from the radial tuberosity. The second (Case 2) underwent a magnetic resonance imaging (MRI) examination US examination 4 weeks post injury. Both tests confirmed a tear of the distal biceps with 6cm of retraction from the radial tuberosity outlined in the MRI.

History

Case 1 was a 48-year-old police officer that was active (attending the gym and weightlifting 5-6 days per week). His injury was on his non-dominant hand. He did not have any past surgical history, smoking history or any history of steroid use. His injury occurred while he was at the end of his bicep work out completing a pull-up exercise. On

his last repetition he heard an audible "pop" that forced him to let go of the bar. He noticed bruising and immediate applied ice to the injured area.

Case 2 was a 43-year-old car detailer that plays recreational soccer, volleyball and ice hockey. His initial injury occurred while playing indoor soccer as a goalie; he went to block a shot and it hit his left arm that caused some minimal bruising. His pain was minimal therefore he continued to play and complete most activities (including repetitive work duties) without limitation. Subsequently a week later his was moving a dresser and the arm gave out during the lifting action in which he heard a large audible "pop". Heavy bruising preceded with pain and stiffness.

Initial Evaluation and Pre-Measurement

Case 1 presented to the initial physiotherapy examination 2 weeks post distal biceps rupture on his non-dominant arm. Slight bruising was visible on his left arm however there was darker bruising initially which had since subsided according to the history. There was a palpable lump just above the antecubital fossa that was slightly tender. Initial Numeric Pain Rating Scale (NPRS) score was 6/10 at rest with range of motion full during flexion, extension, pronation and supination (Table 1). He had a positive hook test (distal biceps were not visible nor had the ability to be hooked). Strength was limited and painful during testing (4/5 Flexion, 4-/5 supination). Isometric strength was measured for supination and flexion using a Layfayette handheld dynamometer (Model 01163). We conducted three trials for each test using a "break test" methodology as described by Stratford (Paul W Stratford & Balsor, 1994) and reported the average. Supination scores were measured at 7.8 kg compared to 9.5 kg for the

opposite arm (17% deficit) (Table 2). Flexion was recorded as 21.6 kg for the affected arm vs. 24.8 kg for the unaffected arm (13% deficit). There was a slight discomfort during the trial's, but this did not seem to limit effort during testing or substantially increase from rest pain.

Case 2 presented to the initial physiotherapy examination 8 weeks post distal biceps rupture on his non-dominant arm. There was no bruising visible however a large palpable lump was visible and palpable above the cubital fossa. According to his history significant bruising was prevalent immediately after the injury Initial NPRS score was 5/10 at rest with active range of motion only limited in extension (-3 degrees). Passive range of motion was full but slightly painful. Strength was limited and painful during testing (flexion 4-/5, supination 3+/5). Dynamometer strength testing also revealed strength deficits for supination 7.1 kg for the affected arm vs. 9.0 kg for the unaffected arm (21% deficit). Flexion was also limited to 13.5 kg for the affected arm and 16.6 kg for the unaffected extremity (19% deficit). Minimal to no pain was observed during the trials.

Three functional outcome measures were administered for both cases immediately post rupture and at 6 months post rehabilitation. These included the Upper Extremity Functional Index (UEFI) (Chesworth et al., 2014), Disability of the Arm, Shoulder and Hand (DASH) (Hudak et al., 1996) and the Patient Rated Elbow Evaluation (PREE) (J. Vincent & MacDermid, 2012).

Rehabilitation and Intervention

Physical therapy interventions for complete distal bicep ruptures have not been adequately described in the literature. Therefore, the initial goals for physiotherapy were to decrease edema and pain, improve ROM and strength and protect muscle tissue from further injury. These interventions were based upon common approaches used for muscle tearing and tissue healing (Helton, 2014; Petri et al., 2016). Each patient received 8 sessions of physiotherapy (bi-weekly) that included three phases for treatment (Table 4). The first phase (1-3 visits) for treatment included education strategies for edema control such as home icing with elevation along with light use of the upper extremity with minimal weight and repetitive movement. Passive stretching and light elbow strengthening were given as a clinical and home exercise program. The exercises were given in written and picture form and were reviewed during every visit. A log was given for the patient to complete daily and checked by the therapist on every visit. Passive stretching for elbow flexion, extension and rotation were used to maintain full ROM and reduce adhesions during healing. Light strengthening was also given initially with mild resistance using a yellow TheraBand for scapular and rotator cuff muscles along with wrist flexion, extension, pronation and supination to maintain muscular function of the entire upper extremity. Manual therapy was given for soft tissue mobilization (STM) to the affected elbow for range of motion and edema control. Extracorpeal shockwave therapy and interferential current with ice was also applied to the affected area to reduce pain and promote healing.

Extracorpeal shockwave has been known to promote regeneration and rehabilitation after injuries affecting humoral and cellular factors that enhance tissue remodelling (Kisch et al., 2016). It has demonstrated positive effects with distal biceps cases even after a single session (Furia, Rompe, Maffulli, Cacchio, & Schmitz, 2017). The mechanism of action for shockwave therapy have been poorly understood. However, experimental results have shown that it significantly stimulated the ingrowth of neovascularization associated with increased expressions of angiogenic growth indicators in tendon, bone and tendon-bone interfaces (Notanicola & Moretti, 2017). Therefore, microscopically it can cause interstitial and extracellular biological responses with the potential for tissue regeneration (Ioppolo, Rompe, Furia, & Cacchio, 2014).

Shockwave was administered on each session at a frequency of 11hz, for 2000 pulses on the affected area. A Storz machine model "Masterplus (MP200), Ultra line radial shockwave machine was used for all treatments.

The second phase (4-6 visits) of rehabilitation consisted of light use of the affected elbow with some repetitive movements. Both patients did not take any time off from work and had jobs that required repetitive use of the upper extremity. Therefore, repetitive movements were not restricted (only during week 1-2 post injury as self-reported). Full ROM had been achieved by both patients during this phase and were progressed to increased strengthening for the elbow and scapular muscles. Manual therapy was used for pain control and soft tissue mobilization with wrist mobilization included. All other interventions remained the same for all phases.

The third phase (6-8 visits) of rehabilitation did not restrict any movements for the biceps including light functional tasks including gym work. Combined movement patterns were encouraged with proprioceptive neuromuscular facilitation (PNF) given for the biceps and entire UE. Manual therapy consisted of mobilization for the tissues and joints in association with the biceps and focused upon enforcing movement patterns. Interferential current with icing was discontinued as the pain and edema had resolved.

Both patients were discharged with a home exercise program for progressive strengthening with isolated flexion and supination activities with functional movements. Patients were able to consult the therapist if any concerns arose; both were followed up 6 post rupture.

Outcomes

Objective measurements were tracked throughout each phase of rehabilitation and post 6 months after distal biceps rupture. Numeric Pain Rating Scale (NPRS) and Range of Motion (ROM) returned back to normal limits in comparison to the opposite extremity. Dynamometer strength measurements were equal to the opposite extremity with no pain reported during testing. Disability scores on three outcome measures (DASH, PREE and UEFS) were reported as zero with patients returning back to their normal level of function without any limitation. Case 2 did have a remaining palpable lump ("Popeye sign") but this was no longer painful to touch or bothersome during functional activities. No adverse events were reported with therapy or exercise intervention. Both individuals returned back to recreational activities including returning the gym and weight training including sports.

Figure 1. Case 1 affected Biceps (6 months post rupture)

Figure 2. Case 2 affected Biceps (6 Months Post rupture)

Discussion

Injuries to the distal biceps tendon, however uncommon are usually treated surgically with acceptable results. However, the majority of outcomes data is based upon case series and retrospective study designs. These two cases suggest that acceptable outcomes can be achieved through physical therapy and question if repair is necessary for all cases.

Most of the literature in favour of surgical vs. non-surgical repair have been based upon retrospective case series. A historical case series first compared 10 repaired cases to 5 unrepaired (Baker & Bierwagen, 1985). Three of the unrepaired individuals had self-reported residual functional deficits for using a screwdriver and swinging a baseball bat. Biomechanical studies have demonstrated isolated strength loss with regards to elbow flexion and supination post distal biceps ruptures. These have been reported between 30-40% loss in flexion and up to 60% loss of supination (Morrey et al., 1985). A comparison of non-operative repairs vs. endo button repairs reported repair cases faired significantly better the those treated non-operatively (Legg et al., 2016).

In contrast, many studies that report on operative success have also reported that functional outcome scores and disability can remain the same for both operative and non-operative groups (Bauer et al., 2018; Hetsroni et al., 2008). Our results indicate that non-operative treatments may have the ability to achieve optimal results for some individuals.

A case series of 16 non-operative patients with a historical control group (operative patients) found non-operative patients achieved satisfactory results as measured with strength testing and three functional outcome surveys (DASH, MEPI and

Bromberg and Morrey Survey) (Freeman et al., 2009). These individuals had no loss of flexion strength with only modest loss of supination strength. In addition, another retrospective cohort of ten cases found no difference in operative and non-operative patients with regards to functional outcomes and strength scores (Geaney et al., 2010a). Supination was found to only be decreased by 3% in the non-operative group compared to those having an operative procedure. Another case series of non-operative musculotendinous partial ruptures had perfect scores on disability indexes on the Mayo Clinic performance index one year post rupture without the need for surgical repair (Lopez-Zabala et al., 2013a). Unfortunately, there was limited description of the physical therapy provided and whether imaging was used to confirm a tear in all cases.

Their remains substantial variation between surgeons with respect to the need for and timing for distal biceps repair (Ring et al., 2017a). Non-operative management for this condition has been reserved for those with low-demand and low-endurance type occupations (Beazley et al., 2017) who refuse surgery or where the delay in diagnosis has led to concerns about retraction compromising the potential for successful repair. In contrast, endurance for bicep flexion and supination has not been affected immediately post rupture and over time (Nesterenko, Domire, Morrey, & Sanchez-Sotelo, 2010). Several factors may have contributed to optimal success in these 2 cases. Both individuals were adherent, motivated, working and one was previously engaged in regular exercise and weight training. We used a standardized multi-modal physical therapy program and provided feedback on strength using dynamometer strength testing.

Limitations for this case series include those of case study designs such as observer bias, difficulty to replicate and time factors. In particular, this case study included limitations for the use of a hand-held dynamometer, which may have missed deficits that could be measured with isokinetic testing. Hand-held dynamometry has shown high to moderate correlation in upper extremity strength testing when compared to isokinetic standards such as the Cybex machine (Holt, Raper, Boettcher, Waddington, & Drew, 2016). Older studies that have measured strength have usually measured these in isolation without taking to account time factors for compensation of muscles nor taken measurements for combined movements.

Conclusion

These cases describe two individuals that have high demand and endurance professions returning to their prior level of strength and functional activities after physical therapy management of a complete rupture of their distal biceps tendon. Although surgical repair has been usual management for this patient population, non-surgical options may be considered in selected cases; and avoid potential surgical complications. Positive outcomes like these achieved in these two cases may require motivated patients. A trial comparing operative versus non-operative management, while challenging to perform is warranted.

References

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps

Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and Elbow Surgery*, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375. https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J. W. (2003). Distal biceps tendon repair: Comparison of surgical techniques. *Journal*

of Hand Surgery, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D.

(2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147.

https://doi.org/10.1097/JSA.0b013e3181824e76
Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5
Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003
Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009
Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025
Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130
Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336
Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287
Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006
Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687
Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001
Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.
Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and

Head), *608*(1 996).
Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382
Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005
Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035
Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.
Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030
Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214
Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009
Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.
Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896
Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1
Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562
Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017. https://doi.org/10.1177/0363546515587738

Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405

Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690

Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144

Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049

Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5

Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003

Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358

Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa

Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694

Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003

Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008

Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T.

(2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291.

https://doi.org/10.2343/geochemj.2.0468
Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7
O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016
Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.
Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6
Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004
Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349
Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017
Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5
Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032
Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries: Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2),

103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the “Salento technique”, a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. *Clinical Orthopaedics and Related Research*, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First

Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair

and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014

Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098

Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041

Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.

Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276

Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.

Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030

Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4

Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9

Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029

Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0

Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002

von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bulletin of the*

World Health Organization, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623

Table 1. Clinical Examination Findings

	Observation	Palpation	Initial NPRS	AROM	PROM	MMT (Initial)	Special Tests
Case 1	2 weeks post tear; Slight bruising visible	Palpable lump slightly above cubital fossa	6/10	Flexion 140 Ext full Full Pro/Sup	Full with minimal pain	Flexion 4/5 Supination 4-/5	+Hook Test +US
Case 2	8 weeks post tear; No bruising; lump visible	palpable lump above cubital fossa minimal pain	5/10	Flexion 140 Ext -3 Full Pro/Sup	Full but painful with extension	Flexion 4- Supination 3+	+Hook Test +MRI and US

NPRS-Numeric Pain Rating Scale; AROM: Active Range of Motion; PROM: Passive Range of Motion; MMT: Manual Muscle Test

Table 2. Dynamometer Strength Measurements (kg)

	Initial Supination (Affected)	Initial Supination (Non-Affected)	Initial Flexion (Affected)	Initial Flexion (Non-Affected)	>6 months Supination (Affected)	>6 Months Supination (Non-Affected)	>6 months Flexion (Affected)	>6 Months Flexion (Non-Affected)
Case 1	7.82	9.47	21.64	24.82	9.46	9.37	24.93	24.97
Case 2	7.10	9.03	13.47	16.60	9.07	9.07	16.96	16.56

Table 3. Functional Outcome Scores

	Initial UEFI	Initial DASH	Initial PREE	>6months UEFI	>6 months DASH	>6 months PREE	Final NPRS
Case 1	65	21.62	54	80	0	0	0
Case 2	66	34.17	83	80	0	0	0

UEFI-Upper Extremity Functional Index; DASH: Disabilities of the Arm, Shoulder and Hand; PREE: Patient Rated Elbow Evaluation

Table 4. Phases of Rehabilitation and Intervention

Intervention	Phase 1 (# 1-3 Tx Sessions)	Phase 2 (# 4-6 Tx Sessions	Phase 3 (# 6-8 Tx. Sessions)
Education regarding edema control, joint protection and activities of daily living	Home icing and elevation program given, light use of UE with minimal repetitive movement or heavy lifting (<10 pounds)	Light use of UE with functional movements, minimal joint protection and moderate lifting.	Full use of UE with repetitive tasks. Return to light gym routine with combined functional movements of elbow including light weightlifting exercises
Therapeutic Exercises	Passive elbow stretching and yellow band strengthening (flexion, extension, pronation and supination). Scapular program (retractions, lower trapezius activation)	Full ROM achieved; increased strengthening w/ progression to red/green band. Scapular program (retractions, T's, Y's, W's with lower trapezius activation)	Functional movement patterns (PNF shoulder patterns with weight), wall and light ground push-ups, bicep flexion/ext., pro/sup with weight (5-10 pounds)
Manual Therapy	STM Distal biceps; elbow, shoulder and wrist mobilization, effleurage and lymph drainage techniques	STM distal biceps, elbow, shoulder and wrist mobilization	STM distal biceps, elbow, shoulder and wrist mobilization
Extracorpeal Shockwave Therapy	2000 pulses, 11hz	2000 pulses, 11 hz	2000 pulses, 11hz
Interferential Current with ice	80/150 hz w/ ice on affected area	80/150 hz w/ ice on affected area	None

Legend: STM-Soft tissue mobilization; UE: Upper extremity; PNF: Proprioceptive Neuromuscular Facilitation exercises; flex: flexion; ext.: extension

CHAPTER 6. DISCUSSION

Although considered rare, the incidence of distal biceps tendon ruptures is higher than previously reported; 2.55 cases per 100,000 nationally within the United States and 5.35 cases per year per 100,000 locally (Safran & Graham, 2002). Given this low incidence, the vast majority of research for this condition has consisted of retrospective and case series designs with a low number of subjects and few prospective studies (Nyland et al., 2015). Surgical repair remains the most consistent treatment modality for this condition although many questions have surrounded this practice including the research for which these recommendations are based upon (Ring et al., 2017a; Schmidt, Savoie, et al., 2016). Further research was needed to identify significant gaps in the literature including best practice recommendations to manage this rare but extremely debilitating condition.

This thesis included 4 manuscripts that aimed to advance our knowledge needed to better understand the management for distal biceps ruptures. Together these papers outline rehabilitation procedures associated with distal bicep rupture management, identified risk and prognostic factors and characterized outcomes associated with surgical repair or rehabilitation without repair. A brief synopsis of the findings of each paper, the contributions this body of work has made to the scientific literature, limitations of the research and the future directions are described from each chapter.

Summary of Findings

Chapter 2: "Rehabilitation interventions for operative and non-operative distal biceps ruptures: A scoping review"

The purpose of this review was to present the current state of knowledge with respect to rehabilitation for surgical and non-surgical management for distal biceps ruptures. To date, there has been no consensus for rehabilitative decisions regarding this injury as protocols for management have varied greatly. The results of this review detailed that rehabilitation descriptions for distal biceps ruptures are of extremely poor quality for surgical and non-surgical outcomes. Consensus on exercise reporting template (CERT) guidelines were used to evaluate distal biceps literature with a median score of score 26% for operative studies and 11% for non-operative interventions. A mean of 2.5 sentences were given for descriptions of rehabilitation procedures including post-operative immobilization, medication use, restriction post-surgery, exercise progression and timelines for return to work and sporting activities. Although many have improved within the last three years, poor rehabilitation descriptions remain common place for this condition. The implications outlined within the manuscript describe ongoing issues that if uncorrected will continue to decrease clinical validity and generalizability for all distal bicep's studies.

Chapter 3: "Factors associated with poor prognosis following distal biceps reconstruction"

The purpose of the retrospective study (Chapter 3) was to determine which factors were associated with less favourable outcomes (as measured by pain, function and disability) following surgical repair of 60 participants after distal biceps tendon rupture. The results of this cross sectional analysis suggested that having both a smoking history and weaker biceps flexion strength contributed to a model that explained 50.4% of the variability of disability and functional scores. One the most important implications of this study is that smoking can have serious implications on surgical outcomes. In addition, the study found no implications for delayed surgical repairs along with physiotherapy adherence. This manuscript provides both surgeons and those diagnosed with tears of the distal biceps tendon knowledge of factors that are associated with reduction in function and implications for surgical reconstruction.

Chapter 4: "Prognostic Factors associated with distal biceps rupture: A prospective observational analysis"

The third manuscript (Chapter 4) is one of only four prospective studies to ever be conducted regarding distal biceps reconstruction. Very few studies have conducted analysis prior to surgical management without lengthy follow-ups. This study had been ongoing for 4 years with follow up times between 6-12 months for those surgically repaired. The results of this prospective cohort study suggest that surgical outcomes for distal biceps repair are consistently very good with minimal complications however

having a surgical repair on the non-dominant arm and decreased grip strength contributed to a model that explained 43.4 % of the variability of disability and functional scores. The implications for this study will outline prognostic factors related to surgical repair along with complication profiles that can affect outcomes.

Chapter 5: "Distal biceps tendon rupture: Is surgery the best course of treatment? Two case reports"

The purpose of this repeated case study (Chapter 5) was to describe two cases where patients chose to not undergo surgical reconstruction for a complete distal biceps tear. Although patients are typically counselled that a reason for surgical repair following biceps rupture is substantial loss of flexion and supination strength, the results of these cases indicated that full recovery of strength and function was possible through physical therapy. The implications for this paper questioned traditional wisdom whether surgical repair is needed for all distal biceps ruptures. It provided a unique representation, that was not yet reported in the literature, that non-surgical intervention can be possible with complete distal biceps ruptures. In addition, rehabilitation interventions have been poorly reported within the literature (as detailed within the scoping review). This paper detailed a rehabilitation protocol for those choosing a non-operative course.

Overall Findings

The findings of each of the studies included within this thesis inform one another. Firstly, the finding that rehabilitation descriptions of distal biceps ruptures are of extremely poor quality for both surgical and non-surgical interventions and that research

designs are typically low-quality and underpowered suggests there is decreased clinical validity and generalizability for all distal biceps literature (Chapter 2). This reflects the low incidence of these tears and the lack of multi-centre research for this condition. Significant heterogeneity in recommendations were found for post-operative procedures such as length of immobilization, mobilization timelines, strengthening exercises (duration and dosage) along with return to work guidelines. Non-operative treatment procedures were also poorly described. While this review challenges us to move towards a multisite research enterprise to generate larger samples, this can be challenging without funding. However, obtaining funding when outcomes are consistently good may be difficult. This is a dilemma for creating evidence based treatment guidelines. Another possible implication from this finding is that interventions to target distal biceps pathology may need to be further explored and considerate of multiple factors associated with reduced function in this patient population.

A cross sectional analysis identified factors with less favourable outcomes for distal biceps repair (Chapter 3). Although having both a smoking history and weaker flexion strength were predictors for poor prognosis, many factors such as physiotherapy adherence, age, days to surgery, grip and strength, mechanism of injury and prior health status did not predict poor functional outcomes post-surgical repair. Having a smoking history can be a determinant for surgical decision making as this factor (along with weaker flexion strength) explained a significant amount of the variance in patient rated functional measures. Since this study was retrospective, the possibility of selection bias

or lack of access to data on some potential predictors emphasized the need for a prospective design.

The results of a prospective study (Chapter 4) suggest that although the majority of surgical outcomes for distal biceps repair using a two-incision approach have minimal complications and good functional outcomes, having surgical repair on the non-dominant arm and having poor grip strength predicted poor functional outcomes. The clinical implications are important to consider. Although, functional outcomes regarding surgery on non-dominant and dominant extremities may even out over time, it is important to note differences in the short term and account for variability. In addition, the findings suggest that grip may be an overall strength/health status determinant for distal biceps repair which can be easier to measure in clinical examination vs. hand-held dynamometry (Hamilton et al., 1994). This can be particularly useful for clinicians and surgeons to assess progress and identify functional changes for those surgically repaired via a 2-incision technique. Both these factors can contribute to the understanding of prognostic factors associated with surgical repair for distal biceps ruptures within 6-12 months.

The variance of interventional recommendations for distal biceps ruptures in Chapter 2 suggested non-surgical management can be an option for those individuals that choose to not undergo surgical repair. This was evaluated in Chapter 5 with a description of two cases that demonstrated individuals that have high demand and endurance professions returning to their prior level of strength and functional activities after physical therapy management for a complete rupture of their distal biceps tendon. Both individuals returned back to all recreational activities including returning to the gym, sports and

weight training. This was somewhat surprising considering that surgical repair remains as the gold standard for distal biceps pathology (Srinivasan, Pederson, & Morrey, 2020). Although surgical repair has been usual management for this patient population, non-surgical options may be considered in selected cases; and avoid potential surgical complications. In addition, this concept has the potential to change the way rehabilitation is directed from operative rehabilitation to non-operative rehabilitation. This can reduce the resources needed in hospital-based settings considering the significant costs related to surgery.

Contributions to the Scientific Literature

The four manuscripts included in this thesis, together make a substantial contribution to the knowledge of the distal biceps tendon rupture. This includes a methodology for diagnosis, prognosis and surgical and non-surgical management.

Chapter 2 makes an important contribution to the scientific literature in that the review confirmed the hypothesis that the majority of descriptions for research regarding distal biceps ruptures is of extremely poor quality for both surgical and non-surgical outcomes. This was used as a guide for Chapter 3 and 4 with regards to better reporting for exercise interventions, conducting high quality studies for distal biceps repairs as well as identifying the need for a prospective trial (Chapter 4) that was greatly lacking within the literature. It was also used as a guide for Chapter 5 where non-surgical outcomes were identified as an interventional option for distal biceps ruptures.

One of the overall strengths of this research was the large number of subjects surgically repaired within a single centre by one fellowship trained surgeon. Due to the

rarity of this injury, most of the literature related to distal biceps has largely consisted of small sample sizes and multiple surgeons combining results. The importance of having a larger sample from a single surgeon allowed to control for confounding factors and increase the confidence that the results can be generalized to the entire population.

The importance of sample size was particularly useful in Chapter 3 and Chapter 4 outlining prognostic factors associated with repair for this condition. With the majority of trials for distal biceps being retrospective this trial was not unique (Chapter 3); however, this is the largest trial (60 participants) to date that had a retrospective (greater than 10 year) follow up for subjects that included strength testing and functional outcome assessment. Sample sizes for similar cohort studies in the literature that measure both strength and functional outcomes range from 1-49 (Siebenlist et al., 2014).

Chapter 4 was one of only four prospective trials conducted for distal biceps ruptures and was the first ever study to conduct a review of prognostic factors associated with poor prognosis as measured by functional scores pre and post distal biceps repair. Although the sample size was small (34 participants) this is still considered quite large in comparison to all trials where surgery is performed by a single surgeon.

The results of Chapter 3 (the cross sectional study) complement the results of Chapter 4 (the prospective study). Multiple prognostic factors were identified including smoking, weaker flexion and grip strength along with surgical repair on the non-dominant extremity. Interestingly, supination strength was not identified as a predictor as it is the primary function of the distal biceps (Kokkalis et al., 2013). Previously, three studies examined prognostic factors for distal biceps repair (Atanda et al., 2013; Austin et al.,

2009; Schneider et al., 2009), but were compared to supinator strength and return to work. These two studies were the first to compare prognostic factors in relation to patient rated functional outcome measures post distal biceps reconstruction.

Further, having a smoking history has been poorly associated with many orthopedic surgical conditions including rotator cuff repair (Chalmers et al., 2018; Santiago-Torres et al., 2015), glenoid labrum surgery (Santiago-Torres et al., 2015) and total knee replacement (Bedard, Dowdle, Wilkinson, et al., 2018). Although smoking history has been implicated as a risk factor for distal biceps ruptures (Safran & Graham, 2002), this is the first study to report it as a predictor for poor functional outcomes after surgical repair.

Although this thesis includes a prospective and retrospective study along with a scoping review, perhaps the most novel contribution to the literature was found through a repeated case study. The findings reported that some cases of a full distal biceps tendon rupture can recover with minimal to no deficit in strength and function post a significant rehabilitation program has not been previously reported. This was the first manuscript to present detailed non-surgical outcomes for full ruptures of the distal biceps tendon as surgical management has been the gold standard for this diagnosis for over 60 years (Schmidt et al., 2019). The most recent publication regarding surgical outcomes for distal biceps repair using both single and double incision techniques reported an average of 20-40% decrease in supination strength with surgical repair (Stockton et al., 2019). Previous reports indicated a supination loss of 20-30% without repair (Legg et al., 2016). Therefore, this manuscript further indicates that non-surgical rehabilitation should be

considered for certain sub-types of this patient population. The novelty of this case study, that is considered a low quality study, highlights the importance of lower quality study as a hypothesis-generating or proof of principles. Without cases studies showing that recovery was potentially excellent without surgery, it is unlikely that surgeons could be convinced to consider a comparative trial.

Defining practice patterns is inherently challenging and fundamentally important for surgery to ensure changes are readily adapted by surgeons, considering the current high variability of surgical practice (Webber, Ronson, Gorman, Taber, & Harris, 2016). Therefore, going against the inherent belief that if something is broken (i.e. the distal biceps tendon) should always be fixed, although challenging to accept, can be further strengthened with future research.

The majority of studies for distal biceps ruptures are conducted within the United states where a national average of surgical costs for distal biceps repair is $19,676 (MDsave, 2019). In contrast, a Canadian surgeon practicing in Ontario is paid $350.00 to conduct a repair. This could potentially suggest a conscience or unconscious bias towards surgical repair versus recommendations of non-surgical management.

Granted that the preponderance of literature pertaining to distal biceps is of poor quality, the combination of all four manuscripts greatly enhances what we know about prognosis, functional outcomes and management for those with a ruptured tendon.

Limitations and Future Directions

One of the major limitations in applying the results of this thesis is that there were potentially some elements of bias that could have been introduced. Subject recruitment was difficult as the majority of the patients were experiencing excellent outcomes and lived greater than 60km away so were not motivated to return for follow-up visits. Those that did follow up could have potentially been those that were having lingering symptoms introducing selection bias. Although typically large for distal biceps research, this factor also was a reason for a small overall sample. Ideally, future research should better recruit larger samples with longer follow-up times.

Another important limitation was identified in Chapter 2, where although it was found that the majority of distal biceps literature has methodological limitations, studies were further selected based upon the length of their rehabilitation descriptions rather than the quality of the research. It should be noted that we excluded studies where the descriptions of rehabilitation were not present since that was the focus of the review. It is possible that there were high quality surgical trials, without adequate rehabilitation descriptions. However, considering the majority of the papers were either retrospective or case series reviews most had methodological limitations and it is unlikely anything of high quality was missed. Future directions should include revisiting the notion of conducting systematic reviews for distal biceps literature where the literature is so poor in quality and description. Future clinical studies should consider multisite collaboration to conduct high quality randomized clinical trials once the important questions are established.

The second manuscript (Chapter 3) also had many limitations. First, this was a cross sectional study. Therefore, it is exposed to risk of error (random and sampling bias) along with other confounding factors. There were also limited smokers recorded within the trial. Although statistical significance was achieved the results must be taken with caution secondary to the small number of observations. Another limitation for both Chapter 3 and 4 was that we did not adjust scores for hand dominance. Hand dominance has been known to cause variations in strengths between individuals (as much as 10-20% between arms) (Güleçyüz et al., 2017). However, since differences pertain to groups more than individuals, we could not be confident that adjustment for individuals would be appropriate.

The prospective manuscript (Chapter 4) had similar limitations as the retrospective study. These included a smaller sample size, subject recruitment difficulties and lack of adjustment for hand dominance scores. In addition, follow-up times for patients post-surgical repair ranged between 6-12 months. Future research needs to have greater than 12 month follow-ups and better monitoring.

The final manuscript (Chapter 5) had numerous limitations; the first being that case-controlled researched is low-quality where conclusions can be difficult to generalize to the wider distal biceps rupture population. The research was conducted by rehabilitation professionals that can have an indeterminant observer bias which can also influence the results of the two cases presented. Both the individuals were adherent, motivated, working and had a history of regular exercise compliance during the treatment

phase of recovery. This can be a significant factor for optimal success for the protocol used for treatment.

Another limitation noted for Chapters 3, 4 and 5 include the use of a hand-held dynamometer for strength testing. Although hand-held dynamometry has been shown to have high to moderate correlation in upper extremity strength testing when compared to isokinetic standards such as a Cybex machine (Holt et al., 2016), there could have been slight variations in protocols with three testing investigators. Testing protocols were reviewed and practiced however individual variation cannot be ruled out.

It is recommended that future research attempt to conduct a randomized control trial for operative vs. non-operative distal biceps ruptures with adequate rehabilitation procedures included for both groups. There seems to be sufficient evidence to support that non-operative rehabilitation can result in substantively adequate functional and strength outcomes for both surgical and non-surgical choices post distal biceps ruptures. Strength testing should include standardized machinery such as a Cybex machine along with outcome measures such as the Disability of the Shoulder and Hand (DASH) and Patient Rated Elbow Evaluation (PREE).

Conclusion

This thesis contributes to the literature by suggesting the majority of research regarding distal biceps ruptures if of poor methodological quality with poor rehabilitation descriptions for both non-surgical and surgical outcomes. In addition, those individuals that smoke and have a weaker strength in flexion have a poor long-term prognosis post-surgical reconstruction in regard to functional outcomes. In the short term (6-12 months)

those individuals that have had surgical repair on their non-dominant arm and have weaker grip strength have decreased functional scores. Furthermore, this thesis suggests that non-operative management should be further investigated and offered for those affected with a completed distal biceps ruptures depending upon certain prognostic profiles. While a clinical trial may be difficult to perform between operative and non-operative groups, it may be warranted.

References

Al-Taher, M., & Wouters, D. B. (2014). Fixation of Acute Distal Biceps Tendon Ruptures Using Mitek Anchors: A Retrospective Study. *The Open Orthopaedics Journal*, *8*(1), 52–55. https://doi.org/10.2174/1874325001408010052

Alentorn-Geli, E., Assenmacher, A. T., & Sanchez-Sotelo, J. (2016). Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Reviews*, *1*(9), 316–324. https://doi.org/10.1302/2058-5241.1.000053

Alonso-Coello, Pablo; Oxman, Andrew; Moberg, Jenny; Brignardello-Petersen, Romina, Akl, Elie; Davoli, Marina; Treweek, Shaun; Mustafa, Reem; Vandvik, Per; Meerpohl, Joerg; Guyatt, Gordon; Schunemann, Holger, T. G. W. G. (2016). GRADE: Evidence to Decision (EtD) frameworks - a systematic and transparent approach to making well informed healthcare choices. 2: Clinical Practice Guidelines. *BMJ*, *353*(i2089), 1–9. https://doi.org/10.1016/j.zefq.2018.05.004

Amin, N. H., Volpi, A., Lynch, T. S., Patel, R. M., Cerynik, D. L., Schickendantz, M. S., & Jones, M. H. (2016). Complications of Distal Biceps Tendon Repair. *Orthopaedic Journal of Sports Medicine*, *4*(10), 232596711666813. https://doi.org/10.1177/2325967116668137

Anakwenze, O. A., Baldwin, K., & Abboud, J. A. (2013). Distal biceps tendon repair: An analysis of timing of surgery on outcomes. *Journal of Athletic Training*, *48*(1), 9–11. https://doi.org/10.4085/1062-6050-48.1.10

Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, *8*(1), 19–32. https://doi.org/10.1080/1364557032000119616

Atanda, A., O'Brien, D. F., Kraeutler, M. J., Rangavajjula, A., Lazarus, M. D., Ramsey, M. L., … Dodson, C. C. (2013). Outcomes after distal biceps repair in patients with workers' compensation claims. *Journal of Shoulder and Elbow Surgery*, *22*(3), 299–304. https://doi.org/10.1016/j.jse.2012.11.011

Athwal, G. S., Steinmann, S. P., & Rispoli, D. M. (2007). The Distal Biceps Tendon: Footprint and Relevant Clinical Anatomy. *Journal of Hand Surgery*, *32*(8), 1225–1229. https://doi.org/10.1016/j.jhsa.2007.05.027

Atkinson, H. L., & Nixon-cave, K. (2011). A Tool for Clinical Reasoning and Reflection Using the ICF Framework and Patient Management Model. *Physical Therapy*, *91*(3), 416–430. https://doi.org/10.1111/j.1756-185x.2012.01809.x

Austin, L., Mathur, M., Simpson, E., & Lazarus, M. (2009). Variables Influencing Successful Two-Incision Repair. *Orthopedics*, *32*(2), 88–93.

Bae, J. Y., Kim, J. K., Yoon, J. O., Kim, J. H., & Ho, B. C. (2018). Preoperative predictors of patient satisfaction after carpal tunnel release. *Orthopaedics and Traumatology: Surgery and Research*, *104*(6), 907–909. https://doi.org/10.1016/j.otsr.2018.04.004

Bain, G. I., Prem, H., Heptinstall, R. J., Verhellen, R., & Paix, D. (2000). Repair of distal biceps tendon rupture: A new technique using the Endobutton. *Journal of Shoulder and Elbow Surgery*, *9*(2), 120–126. https://doi.org/10.1067/2000.102581

Baker, B. Y. B. E., & Bierwagen, D. (1985). Rupture of the Distal Tendon of the Biceps

Brachii Treatment, Operative Versus Non-operative. *Journal of Bone and Joint Surgery*, *67-A*(3), 414–417.

Bandy, W. D., Lovelace-Chandler, V., & Holt, A. L. (1991). Rehabilitation of the Ruptured Biceps Brachii Muscle of an Athlete. *Journal of Orthopaedic & Sports Physical Therapy*, *13*(4), 184–190. https://doi.org/10.2519/jospt.1991.13.4.184

Barret, H., Winter, M., Gastaud, O., Saliken, D. J., Gauci, M. O., & Bronsard, N. (2019). Double incision repair technique with immediate mobilization for acute distal biceps tendon ruptures provides good results after 2 years in active patients. *Orthopaedics and Traumatology: Surgery and Research*, *105*(2), 323–328. https://doi.org/10.1016/j.otsr.2018.10.012

Bauer, T. M., Wong, J. C., & Lazarus, M. D. (2018). Is nonoperative management of partial distal biceps tears really successful? *Journal of Shoulder and Elbow Surgery*, *27*(4), 720–725. https://doi.org/10.1016/j.jse.2017.12.010

Beazley, J. C., Lawrence, T. M., Drew, S. J., & Modi, C. S. (2017). Distal Biceps and Triceps Injuries. *The Open Orthopaedics Journal*, *11*, 1364–1372. https://doi.org/10.2174/1874325001711011364

Bedard, N. A., Dowdle, S. B., Owens, J. M., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What is the Impact of Smoking on Revision Total Hip Arthroplasty ? *The Journal of Arthroplasty*, 1–4. https://doi.org/10.1016/j.arth.2017.12.041

Bedard, N. A., Dowdle, S. B., Wilkinson, B. G., Duchman, K. R., Gao, Y., & Callaghan, J. J. (2018). What Is the Impact of Smoking on Revision Total Knee Arthroplasty? *Journal of Arthroplasty*, *33*(7), S172–S176. https://doi.org/10.1016/j.arth.2018.03.024

Behun, M. A., Geeslin, A. G., O'Hagan, E. C., & King, J. C. (2016). Partial Tears of the Distal Biceps Brachii Tendon: A Systematic Review of Surgical Outcomes. *Journal of Hand Surgery*, *41*(7), e175–e189. https://doi.org/10.1016/j.jhsa.2016.04.019

Beks, R. B., Claessen, F. M. A. P., Oh, L. S., Ring, D., & Chen, N. C. (2016). Factors associated with adverse events after distal biceps tendon repair or reconstruction. *Journal of Shoulder and Elbow Surgery*, *25*(8), 1229–1234. https://doi.org/10.1016/j.jse.2016.02.032

Bell, R. H., Wiley, W. B., Noble, J. S., & Kuczynski, D. J. (2000). Repair of distal biceps brachii tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *9*(3), 223–226. https://doi.org/10.1067/mse.2000.104775

Berlet, G., Johnson, J., Milne, A., Patterson, S., & King, G. (1998). Distal biceps brachii tendon repair: an in vitro biomechanical study of tendon reattachment. *American Journal of Sports Medicine*, *26*(3), 428–432. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=rzh&AN=107300395&site=ehost-live

Bisson, L. J., Perio, J. G. De, Weber, A. E., Ehrensberger, M. T., & Buyea, C. (n.d.). Is It Safe to Perform Aggressive Rehabilitation After Distal Biceps Tendon Repair Using the Modified.pdf, *2*, 21–25.

Bosman, H. A., Fincher, M., & Saw, N. (2012). Anatomic direct repair of chronic distal biceps brachii tendon rupture without interposition graft. *Journal of Shoulder and Elbow Surgery*, *21*(10), 1342–1347. https://doi.org/10.1016/j.jse.2012.01.012

Boyd, H. B., & Anderson, L. D. (1961). A Method for Reinsertion of the Distal Biceps Brachii Tendon. *JBJS*, *43*(7). Retrieved from https://journals.lww.com/jbjsjournal/Fulltext/1961/43070/A_Method_for_Reinsertion_of_the_Distal_Biceps.12.aspx

Bulut, T., Akgün, U., Çitlak, A., Aslan, C., Şener, U., & Şener, M. (2016). Prognostic factors in sensory recovery after digital nerve repair. *Acta Orthopaedica et Traumatologica Turcica*, *50*(2), 157–161. https://doi.org/10.3944/AOTT.2015.15.0140

Caputo, A. E., Cusano, A., Stannard, J., & Hamer, M. J. (2016). Distal biceps repair using the lacertus fibrosus as a local graft. *Journal of Shoulder and Elbow Surgery*, *25*(7), 1189–1194. https://doi.org/10.1016/j.jse.2016.02.005

Chalmers, P. N., Granger, E., Nelson, R., Yoo, M., & Tashjian, R. Z. (2018). Factors Affecting Cost, Outcomes, and Tendon Healing After Arthroscopic Rotator Cuff Repair. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *34*(5), 1393–1400. https://doi.org/10.1016/j.arthro.2017.11.015

Chavan, P. R., Duquin, T. R., & Bisson, L. J. (2008). Clinical Sports Medicine Update: Repair of the Ruptured Distal Biceps Tendon. *The American Journal of Sports Medicine*, *36*(8), 1618–1624. https://doi.org/10.1177/0363546508321482

Chesworth, B. M., Hamilton, C. B., Walton, D. M., Benoit, M., Blake, T. A., Bredy, H., … Yardley, D. (2014). Reliability and validity of two versions of the upper extremity functional index. *Physiotherapy Canada*, *66*(3), 243–253. https://doi.org/10.3138/ptc.2013-45

Cheung, E. V, Lazarus, M. D., Cheung, E. V, Lazarus, M., & Taranta, M. (2005). Immediate range of motion after distal biceps tendon repair Immediate range of motion after distal biceps tendon repair, (September), 12–15. https://doi.org/10.1016/j.jse.2004.12.003

Chillemi, C., Marinelli, M., & De Cupis, V. (2007). Rupture of the distal biceps brachii tendon: Conservative treatment versus anatomic reinsertion - Clinical and radiological evaluation after 2 years. *Archives of Orthopaedic and Trauma Surgery*, *127*(8), 705–708. https://doi.org/10.1007/s00402-007-0326-7

Cil, A., Merten, S., & Steinmann, S. P. (2009). Immediate active range of motion after modified 2-incision repair in acute distal biceps tendon rupture. *American Journal of Sports Medicine*, *37*(1), 130–135. https://doi.org/10.1177/0363546508323749

Citak, M., Backhaus, M., Seybold, D., Suero, E. M., Schildhauer, T. A., & Roetman, B. (2011). Surgical repair of the distal biceps brachii tendon: A comparative study of three surgical fixation techniques. *Knee Surgery, Sports Traumatology, Arthroscopy*, *19*(11), 1936–1941. https://doi.org/10.1007/s00167-011-1591-0

Cohen, M. S., & Katolic, L. (2003). Complications if distal biceps tendon repairs. *Operative Techniques in Sports Medicine*, *11*(1), 60–66. https://doi.org/10.1053/otsm.2003.35888

Cucca, Y. Y., McLay, S. V. B., Okamoto, T., Ecker, J., & McMenamin, P. G. (2010). The biceps brachii muscle and its distal insertion: Observations of surgical and evolutionary relevance. *Surgical and Radiologic Anatomy*, *32*(4), 371–375. https://doi.org/10.1007/s00276-009-0575-y

D'Arco, P., Sitler, M., Kelly, J., Moyer, R., Marchetto, P., Kimura, I., & Ryan, J. (1998). Clinical, functional, and radiographic assessments of the conventional and modified Boyd-Anderson surgical procedures for repair of distal biceps tendon ruptures. *American Journal of Sports Medicine*, *26*(2), 254–261. https://doi.org/10.1177/03635465980260021601

Darlis, N. A., & Sotereanos, D. G. (2006). Distal biceps tendon reconstruction in chronic ruptures. *Journal of Shoulder and Elbow Surgery*, *15*(5), 614–619. https://doi.org/10.1016/j.jse.2005.10.004

Daudt, H. M. L., Van Mossel, C., & Scott, S. J. (2013). Enhancing the scoping study methodology: A large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Medical Research Methodology*, *13*(1), 1. https://doi.org/10.1186/1471-2288-13-48

Davis, W., & Yassine, Z. (1956). Etiological Factor of the in Tear Biceps of the Distal Tendon. *The Journal of Bone and Joint Surgery.*, *38A*, 6–9.

De la Fuente, J., Pérez-Bellmunt, A., Miguel-Pérez, M., Martínez, S., Zabalza, O., Blasi, M., & Casasayas, O. (2018). High-resolution ultrasound in the assessment of the distal biceps brachii tendinous complex. *Skeletal Radiology*, 395–404. https://doi.org/10.1007/s00256-018-3043-0

DeFroda, S. F., Mehta, N., & Owens, B. D. (2018). Physical Therapy Protocols for Arthroscopic Bankart Repair. *Sports Health*, *10*(3), 250–258. https://doi.org/10.1177/1941738117750553

Delancey, J. O., Blay, E., Hewitt, D. B., Engelhardt, K., Bilimoria, K. Y., Holl, J. L., … Stulberg, J. J. (2018). The American Journal of Surgery The effect of smoking on 30-day outcomes in elective hernia repair. *The American Journal of Surgery*, 1–4. https://doi.org/10.1016/j.amjsurg.2018.03.004

Ding, D. Y., Ryan, W. E., Strauss, E. J., & Jazrawi, L. M. (2016). Chronic Distal Biceps Repair With an Achilles Allograft. *Arthroscopy Techniques*, *5*(3), e525–e529. https://doi.org/10.1016/j.eats.2016.02.016

Dobbie, R. P. (1941). Avulsion of the lower biceps brachii tendon: Analysis of fifty-one previously unreported cases. *The American Journal of Surgery*, *51*(3), 662–683. https://doi.org/10.1016/S0002-9610(41)90203-9

Durr, Hans; Stabler, Axel, Pfahler, M; Matzko, Matthias, Refior, H. (2000). Partial Rupture of the Distal Biceps Tendon. *Clinical Orthopaedics and Related Research*, (374), 195–200.

Eames, M. H. A., Bain, G. I., Fogg, Q. A., & Van Riet, R. P. (2007). Distal biceps tendon anatomy: A cadaveric study. *Journal of Bone and Joint Surgery - Series A*, *89*(5), 1044–1049. https://doi.org/10.2106/JBJS.D.02992

Eardley, W. G. P., Odak, S., Adesina, T. S., Jeavons, R. P., & McVie, J. L. (2010). Bioabsorbable interference screw fixation of distal biceps ruptures through a single anterior incision: A single-surgeon case series and review of the literature. *Archives of Orthopaedic and Trauma Surgery*, *130*(7), 875–881. https://doi.org/10.1007/s00402-009-0974-x

El-Hawary, R., MacDermid, J. C., Faber, K. J., Patterson, S. D., Haven, W., & King, G. J. W. (2003). Distal biceps tendon repair: Comparison of surgical techniques. *Journal*

of Hand Surgery, *28*(3), 496–502. https://doi.org/10.1053/jhsu.2003.50081

ElMaraghy, A., & Devereaux, M. (2013). The "bicipital aponeurosis flex test": Evaluating the integrity of the bicipital aponeurosis and its implications for treatment of distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, *22*(7), 908–914. https://doi.org/10.1016/j.jse.2013.02.005

ElMaraghy, A., Devereaux, M., & Tsoi, K. (2008). The biceps crease interval for diagnosing complete distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, *466*(9), 2255–2262. https://doi.org/10.1007/s11999-008-0334-0

Failla, J., Amadio, P., Morrey, B., & Beckenbaugh, R. (1990). Proximal Radioulnar Synostosis After Repair of Distal Biceps Brachii Rupture by the Two-Incision Technique. *Clinical Orthopaedics and Related Research*, *NA;*(253), 133???136. https://doi.org/10.1097/00003086-199004000-00018

Feng, C., Wang, H., Lu, N., Chen, T., He, H., Lu, Y., & Tu, X. M. (2014). Log-transformation and its implications for data analysis, *26*(2), 105–109.

Festa, A., Mulieri, P. J., Newman, J. S., Spitz, D. J., & Leslie, B. M. (2010). Effectiveness of Magnetic Resonance Imaging in Detecting Partial and Complete Distal Biceps Tendon Rupture. *Journal of Hand Surgery*, *35*(1), 77–83. https://doi.org/10.1016/j.jhsa.2009.08.016

Ford, S. E., Andersen, J. S., Macknet, D. M., Connor, P. M., Loeffler, B. J., & Gaston, R. G. (2018). Major complications after distal biceps tendon repairs: retrospective cohort analysis of 970 cases. *Journal of Shoulder and Elbow Surgery*, *27*(10), 1898–1906. https://doi.org/10.1016/j.jse.2018.06.028

Forthman, C. L., Zimmerman, R. M., Sullivan, M. J., & Gabel, G. T. (2008). Cross-sectional anatomy of the bicipital tuberosity and biceps brachii tendon insertion: Relevance to anatomic tendon repair. *Journal of Shoulder and Elbow Surgery*, *17*(3), 522–526. https://doi.org/10.1016/j.jse.2007.11.002

Frank, T., Seltser, A., Grewal, R., King, G. J. W., & Athwal, G. S. (2019). Management of chronic distal biceps tendon ruptures: primary repair vs. semitendinosus autograft reconstruction. *Journal of Shoulder and Elbow Surgery*, *28*(6), 1104–1110. https://doi.org/10.1016/j.jse.2019.01.006

Freeman, C. R., McCormick, K. R., Mahoney, D., Baratz, M., & Lubahn, J. D. (2009). Nonoperative treatment of distal biceps tendon ruptures compared with a historical control group. *Journal of Bone and Joint Surgery - Series A*, *91*(10), 2329–2334. https://doi.org/10.2106/JBJS.H.01150

Functioning and Disability Reference Group. (2010). *The ICF: An Overview*. *World Health Organization*.

Furia, J. P., Rompe, J. D., Maffulli, N., Cacchio, A., & Schmitz, C. (2017). Radial Extracorporeal Shock Wave Therapy Is Effective and Safe in Chronic Distal Biceps Tendinopathy. *Clinical Journal of Sport Medicine*, *27*(5), 430–437. https://doi.org/10.1097/JSM.0000000000000399

Garon, M. T., & Greenberg, J. A. (2016). Complications of Distal Biceps Repair. *Orthopedic Clinics of North America*, *47*(2), 435–444. https://doi.org/10.1016/j.ocl.2015.10.003

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D.

(2010a). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Geaney, L. E., Brenneman, D. J., Cote, M. P., Arciero, R. A., & Mazzocca, A. D. (2010b). Outcomes and Practical Information for Patients Choosing Nonoperative Treatment for Distal Biceps Ruptures. *Orthopedics*, *33*(6). https://doi.org/10.3928/01477447-20100429-10

Goljan, P., Patel, N., Stull, J. D., Donnelly, B. P., & Culp, R. W. (2016). Single Incision Distal Biceps Repair With Hemi-Krackow Suture Technique: Surgical Technique and Early Outcomes. *Hand*, *11*(2), 238–244. https://doi.org/10.1177/1558944716628491

Golshani, K., Cinque, M. E., O'Halloran, P., Softness, K., Keeling, L., & Macdonell, J. R. (2018). Upper extremity weightlifting injuries: Diagnosis and management. *Journal of Orthopaedics*, *15*(1), 24–27. https://doi.org/10.1016/j.jor.2017.11.005

Green, J. B., Skaife, T. L., & Leslie, B. M. (2012). Bilateral distal biceps tendon ruptures. *Journal of Hand Surgery*, *37*(1), 120–123. https://doi.org/10.1016/j.jhsa.2011.09.043

Grewal, R., Athwal, G. ., MacDermid, J. ., Faber, K. ., Drosdowech, D. S., El-Hawary, R., & King, G. J. . (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L365190078%5Cnhttp://jbjs.org/data/Journals/JBJS/24278/1166.pdf%5Cnhttp://dx.doi.org/10.2106/JBJS.K.00436%5Cnhttp://za2uf4ps7f.search.serialssolutions.com/?sid=EMBASE&issn=00219355&i

Grewal, Ruby, Athwal, G. S., MacDermid, J. C., Faber, K. J., Drosdowech, D. S., El-Hawary, R., & King, G. J. W. (2012). Single versus double-incision technique for the repair of acute distal biceps tendon ruptures: A randomized clinical trial. *Journal of Bone and Joint Surgery - Series A*, *94*(13), 1166–1174. https://doi.org/10.2106/JBJS.K.00436

Guglielmino, C., Massimino, P., Ioppolo, F., Castorina, S., Musumeci, G., Giunta, A. Di, & Musumeci, G. (n.d.). Single and dual incision technique for acute distal biceps rupture : clinical and functional outcomes Original article Corresponding author :, 453–460. https://doi.org/10.11138/mltj/2016.6.4.453

Güleçyüz, M. F., Pietschmann, M. F., Michalski, S., Eberhard, F. M., Crispin, A., Schröder, C., … Müller, P. E. (2017). Reference Values of Flexion and Supination in the Elbow Joint of a Cohort without Shoulder Pathologies. *BioMed Research International*, *2017*. https://doi.org/10.1155/2017/1654796

Haldeman, S., Carroll, L. J., Cassidy, J. D., Disorders, B. and J. D. 2000-2010 T. F. on N. P. and I. A., Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders, Schubert, J., … Peloso, P. M. (2008). The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders: executive summary. *Spine*, *33*(4 Suppl), S5-7. https://doi.org/10.1097/BRS.0b013e3181643f40

Hamer, M. J., & Caputo, A. E. (2008). Operative treatment of chronic distal biceps tendon ruptures. *Sports Medicine and Arthroscopy Review*, *16*(3), 143–147.

https://doi.org/10.1097/JSA.0b013e3181824e76
Hamilton, A., Balnave, R., & Adams, R. (1994). Grip Strength Testing Reliability. *Journal of Hand Therapy*, *7*(3), 163–170. https://doi.org/10.1016/S0894-1130(12)80058-5
Hashimoto, S., Hatayama, K., Terauchi, M., Saito, K., Higuchi, H., & Chikuda, H. (2019). Preoperative hand-grip strength can be a predictor of stair ascent and descent ability after total knee arthroplasty in female patients. *Journal of Orthopaedic Science*, (xxxx). https://doi.org/10.1016/j.jos.2019.03.003
Haverstock, J., Athwal, G. S., & Grewal, R. (2015). Distal Biceps Injuries. *Hand Clinics*, *31*(4), 631–640. https://doi.org/10.1016/j.hcl.2015.06.009
Haverstock, J., Grewal, R., King, G. J. W., & Athwal, G. S. (2017). Delayed repair of distal biceps tendon ruptures is successful: a case-control study. *Journal of Shoulder and Elbow Surgery*, *26*(6), 1031–1036. https://doi.org/10.1016/j.jse.2017.02.025
Heinzelmann, A. D., Savoie, F. H., Randall Ramsey, J., Field, L. D., & Mazzocca, A. D. (2009). A combined technique for distal biceps repair using a soft tissue button and biotenodesis interference screw. *American Journal of Sports Medicine*, *37*(5), 989–994. https://doi.org/10.1177/0363546508330130
Helton, M. S. (2014). Conservative Treatment of a Proximal Full-Thickness Biceps Brachii Muscle Tear in a Special Operations Soldier. *Physical Therapy*, *94*(4), 571–577. https://doi.org/10.2522/ptj.20130336
Hetsroni, I., Pilz-Burstein, R., Nyska, M., Back, Z., Barchilon, V., & Mann, G. (2008). Avulsion of the distal biceps brachii tendon in middle-aged population: Is surgical repair advisable?. A comparative study of 22 patients treated with either nonoperative management or early anatomical repair. *Injury*, *39*(7), 753–760. https://doi.org/10.1016/j.injury.2007.11.287
Hinchey, J. W., Aronowitz, J. G., Sanchez-Sotelo, J., & Morrey, B. F. (2014). Re-rupture rate of primarily repaired distal biceps tendon injuries. *Journal of Shoulder and Elbow Surgery*, *23*(6), 850–854. https://doi.org/10.1016/j.jse.2014.02.006
Hoffmann, T. C., Glasziou, P. P., Boutron, I., Milne, R., Perera, R., Moher, D., … Michie, S. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ (Online)*, *348*(March), 1–12. https://doi.org/10.1136/bmj.g1687
Holt, K. L., Raper, D. P., Boettcher, C. E., Waddington, G. S., & Drew, M. K. (2016). Hand-held dynamometry strength measures for internal and external rotation demonstrate superior reliability, lower minimal detectable change and higher correlation to isokinetic dynamometry than externally-fixed dynamometry of the shoulder. *Physical Therapy in Sport*, *21*, 75–81. https://doi.org/10.1016/j.ptsp.2016.07.001
Horschig, A., Sayers, S. P., LaFontaine, T., & Scheussler, S. (2012). Rehabilitation of a Surgically Rehabilitation of a Surgically Repaired Rupture of the Distal Biceps Tendon in an Active Middle Aged Male: a Case Report. *The International Journal of Sports Physical Therapy*, *7*(6), 663–671.
Hudak, P. L., Amadio, P. C., & Bombardier, C. (1996). Development of an Upper Extremity Outcome Measure : The DASH (Disabilities of the Arm , Shoulder , and

Head), *608*(1 996).
Hurov, J. R. (1996). Controlled Active Mobilization Following Surgical Repair of the Avulsed Radial Attachment of the Biceps Brachii Muscle: A Case Report. *Journal of Orthopaedic & Sports Physical Therapy*, *23*(6), 382–387. https://doi.org/10.2519/jospt.1996.23.6.382
Hutchinson, H. L., Gloystein, D., Gillespie, M., & Antonio, S. (2008). Distal biceps tendon insertion : An anatomic study. *Journal of Shoulder and Elbow Surgery*, *17*(2), 342–346. https://doi.org/10.1016/j.jse.2007.05.005
Ioppolo, F., Rompe, J. D., Furia, J. P., & Cacchio, A. (2014). Clinical application of shock wave therapy (SWT) in musculoskeletal disorders. *European Journal of Physical and Rehabilitation Medicine*, *50*(2), 217–230. https://doi.org/10.1016/j.injury.2015.06.035
Iwamoto, Akira; Kearney, Patrick; Goyal, Geetinder, Viegas, S. (2009). The Incidence of Subsequent Contralateral Distal Biceps Tendon Rupture Following Unilateral Rupture. *Orthopedics*, *31*(4), 356–359.
Jarrett, C. D., Weir, D. M., Stuffmann, E. S., Jain, S., Miller, M. C., & Schmidt, C. C. (2012). Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *21*(7), 942–948. https://doi.org/10.1016/j.jse.2011.04.030
Kale, A. A., Jazrawi, L. M., & Kale, N. K. (2018). Minimally Invasive Anterior Two-Incision Approach for Repair of a Chronic Neglected Distal Biceps Tendon Rupture. *Journal of Orthopaedic Case Reports*, *8*(5), 61–66. https://doi.org/10.13107/jocr.2250-0685.1214
Keener, J. D. (2011). Controversies in the surgical treatment of distal biceps tendon ruptures: single versus double-incision repairs. *Journal of Shoulder and Elbow Surgery*, *20*(2), S113–S125. https://doi.org/10.1016/j.jse.2010.11.009
Kelly, Edward; Morrey, Bernard; O'Driscoll, S. (2000). Complications of Distal Biceps with Double incision.pdf. *The Journal of Bone and Joint Surgery. American Volume*, *82*(11), 7.
Kelly, E. W., Sanchez-Sotello, J., Morrey, B. F., & O'Driscoll, S. W. (2003). Rapair of chronic distal biceps tendon ruptures: Indications and use of tendon grafts. *Operative Techniques in Sports Medicine*, *11*(1), 55–59. https://doi.org/10.1053/otsm.2003.35896
Kelly, E. W., Steinmann, S., & O'Driscoll, S. W. (2003). Surgical treatment of partial distal biceps tendon ruptures through a single posterior incision. *Journal of Shoulder and Elbow Surgery*, *12*(5), 456–461. https://doi.org/10.1016/S1058-2746(03)00052-1
Kelly, M. A., Mc Donald, C. K., Boland, A., Groarke, P. J., & Kaar, K. (2017). The Effect of Hand Dominance on Functional Outcome Following Single Row Rotator Cuff Repair. *The Open Orthopaedics Journal*, *11*(1), 562–566. https://doi.org/10.2174/1874325001611010562
Kelly, M., Perkinson, S. G., Ablove, R. H., & Tueting, J. L. (2015). Distal Biceps Tendon Ruptures. *The American Journal of Sports Medicine*, *43*(8), 2012–2017. https://doi.org/10.1177/0363546515587738

Kent, P., O'Sullivan, P. B., Keating, J., & Slade, S. C. (2018). Evidence-based exercise prescription is facilitated by the Consensus on Exercise Reporting Template (CERT). *British Journal of Sports Medicine*, *52*(3), 147–148. https://doi.org/10.1136/bjsports-2016-097405

Kettler, M., Lunger, J., Kuhn, V., Mutschler, W., & Tingart, M. J. (2007). Failure Strengths in Distal Biceps Tendon Repair. *The American Journal of Sports Medicine*, *35*(9), 1544–1548. https://doi.org/10.1177/0363546507300690

Khalil, H., Peters, M., Godfrey, C. M., Mcinerney, P., Soares, C. B., & Parker, D. (2016). An Evidence-Based Approach to Scoping Reviews. *Worldviews on Evidence-Based Nursing*, *13*(2), 118–123. https://doi.org/10.1111/wvn.12144

Kisch, T., Wuerfel, W., Forstmeier, V., Liodaki, E., Stang, F. H., Knobloch, K., … Kraemer, R. (2016). Repetitive shock wave therapy improves muscular microcirculation. *Journal of Surgical Research*, *201*(2), 440–445. https://doi.org/10.1016/j.jss.2015.11.049

Kjaer, B. H., Magnusson, S. P., Warming, S., Henriksen, M., Krogsgaard, M. R., & Juul-Kristensen, B. (2018). Progressive early passive and active exercise therapy after surgical rotator cuff repair - study protocol for a randomized controlled trial (the CUT-N-MOVE trial). *Trials*, *19*(1), 1–12. https://doi.org/10.1186/s13063-018-2839-5

Kokkalis, Z. T., Ballas, E. G., Mavrogenis, A. F., & Soucacos, P. N. (2013). Distal biceps and triceps ruptures. *Injury*, *44*(3), 318–322. https://doi.org/10.1016/j.injury.2013.01.003

Królikowska, A., Kozińska, M., Kuźniecow, M., Bieniek, M., Czamara, A., Szuba, Ł., … Reichert, P. (2018). Treatment of distal biceps tendon injuries with particular emphasis on postoperative physiotherapy. *Ortopedia Traumatologia Rehabilitacja*, *20*(4), 257–270. https://doi.org/10.5604/01.3001.0012.3358

Kulshreshtha, R., Singh, R., Sinha, J., & Hall, S. (2007). Anatomy of the distal biceps brachii tendon and its clinical relevance. *Clinical Orthopaedics and Related Research*, (456), 117–120. https://doi.org/10.1097/BLO.0b013e31802f78aa

Landa, J., Bhandari, S., Strauss, E. J., Walker, P. S., & Meislin, R. J. (2009). The effect of repair of the lacertus fibrosus on distal biceps tendon repairs: A biomechanical, functional, and anatomic study. *American Journal of Sports Medicine*, *37*(1), 120–123. https://doi.org/10.1177/0363546508324694

Lauretani, F., Russo, C. R., Bandinelli, S., Bartali, B., Cavazzini, C., Di Iorio, A., … Ferrucci, L. (2003). Age-associated changes in skeletal muscles and their effect on mobility: An operational diagnosis of sarcopenia. *Journal of Applied Physiology*, *95*(5), 1851–1860. https://doi.org/10.1152/japplphysiol.00246.2003

Legg, A. J., Stevens, R., Oakes, N. O., & Shahane, S. A. (2016). A comparison of nonoperative vs. Endobutton repair of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(3), 341–348. https://doi.org/10.1016/j.jse.2015.10.008

Levac, Danielle; Colquhoun, Heather; O'Brien, K. (2010). Scoping Studies: advancing the methodology. *Implementation Science*, *5*(69), 1–9. https://doi.org/10.1017/cbo9780511814563.003

Logan, C. A., Shahien, A., Haber, D., Foster, Z., Farrington, A., & Provencher, M. T.

(2019). Rehabilitation Following Distal Biceps Repair. *International Journal of Sports Physical Therapy*, *14*(2), 308–317. https://doi.org/10.26603/ijspt20190308

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013a). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/10.1155/2013/970512

Lopez-Zabala, I., Fernandez-Valencia, J. A., López-Zabala, I., & Fernández-Valencia, J. A. (2013b). Nonoperative treatment of distal biceps brachii musculotendinous partial rupture: a report of two cases. *Case Reports in Orthopedics*, *2013*(Figure 1), 970512. https://doi.org/http://dx.doi.org/10.1155/2013/970512

Lynch, SA; Beard, D. R. P. (1999). Repair of distal biceps tendon rupture. *Master Techniques in Orthopaedic Surgery: The Elbow*, *7*, 125–131.

Lynch, J., Yu, C. C., Chen, C., & Muh, S. (2019). Magnetic resonance imaging versus ultrasound in diagnosis of distal biceps tendon avulsion. *Orthopaedics and Traumatology: Surgery and Research*, 1–6. https://doi.org/10.1016/j.otsr.2019.01.021

MacDermid, J. C. (2010). *The Patient-Rated Elbow Evaluation (PREE) © User Manual*.

Matzon, J. L., Graham, J. G., Penna, S., Ciccotti, M. G., Abboud, J. A., Lutsky, K. F., & Beredjiklian, P. K. (2019). A Prospective Evaluation of Early Postoperative Complications After Distal Biceps Tendon Repairs. *Journal of Hand Surgery*, *44*(5), 382–386. https://doi.org/10.1016/j.jhsa.2018.10.009

Mazzocca, A. D., Burton, K. J., Romeo, A. A., Santangelo, S., Adams, D. A., & Arciero, R. A. (2007). Biomechanical evaluation of 4 techniques of distal biceps brachii tendon repair. *American Journal of Sports Medicine*, *35*(2), 252–258. https://doi.org/10.1177/0363546506294854

MDsave. (2019). Biceps Repair National Average Cost.

Milgrom, C., Schaffler, M., Gilbert, S., & Van Holsbeeck, M. (1995). Rotator-cuff changes in asymptomatic adults. The effect of age, hand dominance and gender. *Journal of Bone and Joint Surgery - Series B*, *77*(2), 296–298. https://doi.org/10.1302/0301-620x.77b2.7706351

Miyamoto, R. G., Elser, F., & Millett, P. J. (2010). Distal biceps tendon injuries. *Journal of Bone and Joint Surgery - Series A*, *92*(11), 2128–2138. https://doi.org/10.2106/JBJS.I.01213

Morrey, B. F., Askew, L. J., An, K. N., & Dobyns, J. H. (1985). Rupture of the distal tendon of the biceps brachii. A biomechanical study. *Journal of Bone and Joint Surgery - Series A*, *67*(3), 418–421. https://doi.org/10.2106/00004623-198567030-00011

Nesterenko, S., Domire, Z. J., Morrey, B. F., & Sanchez-Sotelo, J. (2010). Elbow strength and endurance in patients with a ruptured distal biceps tendon. *Journal of Shoulder and Elbow Surgery*, *19*(2), 184–189. https://doi.org/10.1016/j.jse.2009.06.001

Nielsen, K. (1987). Partial rupture of the distal biceps brachii tendon: A case report. *Acta Orthopaedica*, *58*(3), 287–288. https://doi.org/10.3109/17453678709146488

Notanicola, A., & Moretti, B. (2017). The biological effects of extracorpeal shock wave therapy (Eswt) on tendon tissue. *Geochemical Journal*, *51*(3), 277–291.

https://doi.org/10.2343/geochemj.2.0468
Nyland, J., Causey, B., Wera, J., Krupp, R., Tate, D., & Gupta, A. (2015). Distal biceps brachii tendon repair: a systematic review of patient outcome determination using modified Coleman methodology score criteria. *Knee Surgery, Sports Traumatology, Arthroscopy*, 1–5. https://doi.org/10.1007/s00167-015-3899-7
O'Driscoll, S. W., Goncalves, L. B. J., & Dietz, P. (2007). The hook test for distal biceps tendon avulsion. *American Journal of Sports Medicine*, *35*(11), 1865–1869. https://doi.org/10.1177/0363546507305016
Organization, W. H. (2001). *International Classification of Functioning, Disability, and Health (ICF). Full version*. Geneva, Switerland.
Otto, M., Kautt, S., Kremer, M., Kienle, P., Post, S., & Hasenberg, T. (2014). Handgrip Strength as a Predictor for Post Bariatric Body Composition. *Obesity Surgery*, *24*(12), 2082–2088. https://doi.org/10.1007/s11695-014-1299-6
Peeters, T., Ching-Soon, N. G., Jansen, N., Sneyers, C., Declercq, G., & Verstreken, F. (2009). Functional outcome after repair of distal biceps tendon ruptures using the endobutton technique. *Journal of Shoulder and Elbow Surgery*, *18*(2), 283–287. https://doi.org/10.1016/j.jse.2008.10.004
Petri, M., Ettinger, M., Brand, S., Stuebig, T., Krettek, C., & Omar, M. (2016). Non-Operative Management of Rotator Cuff Tears. *The Open Orthopaedics Journal*, *10*(Suppl 1: M11), 349–356. https://doi.org/10.2174/1874325001610010349
Phadnis, J., Flannery, O., & Watts, A. C. (2016). Distal biceps reconstruction using an Achilles tendon allograft, transosseous EndoButton, and Pulvertaft weave with tendon wrap technique for retracted, irreparable distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *25*(6), 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Phadnis, J., Tr, F., Flannery, O., Tr, F., Watts, A. C., & Tr, F. (2016). Distal biceps reconstruction using an Achilles tendon allograft , transosseous EndoButton , and Pulvertaft weave with tendon wrap technique for retracted , irreparable distal biceps ruptures, 1013–1019. https://doi.org/10.1016/j.jse.2016.01.014
Pichonnaz, C., Duc, C., Jolles, B. M., Aminian, K., Bassin, J. P., & Farron, A. (2015). Alteration and recovery of arm usage in daily activities after rotator cuff surgery. *Journal of Shoulder and Elbow Surgery*, *24*(9), 1346–1352. https://doi.org/10.1016/j.jse.2015.01.017
Piva, S. R., Moore, C. G., Schneider, M., Gil, A. B., Almeida, G. J., & Irrgang, J. J. (2015). A randomized trial to compare exercise treatment methods for patients after total knee replacement: Protocol paper Rehabilitation, physical therapy and occupational health. *BMC Musculoskeletal Disorders*, *16*(1), 1–11. https://doi.org/10.1186/s12891-015-0761-5
Pouwels, S., Hageman, D., Gommans, L. N. M., Willigendael, E. M., Nienhuijs, S. W., Scheltinga, M. R., & Teijink, J. A. W. (2016). Preoperative exercise therapy in surgical care: a scoping review. *Journal of Clinical Anesthesia*, *33*, 476–490. https://doi.org/10.1016/j.jclinane.2016.06.032
Quach, T., Jazayeri, R., Sherman, O., & Rosen, J. (2010). Distal biceps tendon injuries: Current treatment options. *Bulletin of the NYU Hospital for Joint Diseases*, *68*(2),

103–111. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L359189138%5Cnhttp://www.nyuhjdbulletin.org/Mod/Bulletin/V68N2/Docs/V68N2_7.pdf%5Cnhttp://sfx.library.uu.nl/utrecht?sid=EMBASE&issn=19369719&id=doi:&atitle=Distal+biceps+tendon+injur

Ramsey, M. (1999). Distal biceps tendon injuries: Diagnosis and management. *The Journal of the American Academy of Orthopaedic Surgeons*, *7*(3), 199–207.

Rantanen, T., Era, P., & Heikkinen, E. (1994). Maximal isometric strength and mobility among 75-year-old men and women. *Age and Ageing*, *23*(2), 132–137. https://doi.org/10.1093/ageing/23.2.132

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015a). Endobutton versus transosseous suture repair of distal biceps rupture using the two-incision technique : a comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Recordon, J. A. F., Misur, P. N., Isaksson, F., & Poon, P. C. (2015b). Endobutton versus transosseous suture repair ofdistal biceps rupture using the two-incision technique: A comparison series. *Journal of Shoulder and Elbow Surgery*, *24*(6), 928–933. https://doi.org/10.1016/j.jse.2014.12.032

Reichert, P; Krolikowska, , M; Witkowski, J; Szuba, L; Czamara, A. (2018). Surgical Management of Distal Biceps Tendon Anatomical Reinsertion Complications : Iatrogenic Posterior Interosseous Nerve Palsy. *Medical Science Monitor*, 782–790. https://doi.org/10.12659/MSM.907260

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017a). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Ring, D., Lubahn, J. D., & Beredjiklian, P. (2017b). Clinical Faceoff: Distal Biceps Rupture: Operative Versus Nonoperative Treatment. *Clinical Orthopaedics and Related Research*, *475*(2), 324–327. https://doi.org/10.1007/s11999-016-4956-3

Rollo, G., Meccariello, L., Rotini, R., Pichierri, P., Bisaccia, M., & Fortina, M. (2019). Efficacy of the “Salento technique”, a modified two-incision approach in distal biceps brachii tendon repair. Surgical description and outcomes analysis. *Journal of Clinical Orthopaedics and Trauma*, (xxxx), 6–11. https://doi.org/10.1016/j.jcot.2019.02.006

Ruch, D. S., Watters, T. S., Wartinbee, D. A., Richard, M. J., Leversedge, F. J., & Mithani, S. K. (2014). Anatomic Findings and Complications After Surgical Treatment of Chronic, Partial Distal Biceps Tendon Tears: A Case Cohort Comparison Study. *Journal of Hand Surgery*, *39*(8), 1572–1577. https://doi.org/10.1016/j.jhsa.2014.04.023

Ruland, R. T., Dunbar, R. P., & Bowen, J. D. (2005). The biceps squeeze test for diagnosis of distal biceps tendon ruptures. *Clinical Orthopaedics and Related Research*, (437), 128–131. https://doi.org/10.1097/01.blo.0000167668.18444.f5

Safran, M. R., & Graham, S. M. (2002). Distal biceps tendon ruptures: incidence, demographics, and the effect of smoking. *Clinical Orthopaedics and Related Research*, (404), 275–283. https://doi.org/10.1097/01.blo.0000026560.55792.02

Saltzman, B. M., Zuke, W. A., Go, B., Mascarenhas, R., Verma, N. N., Cole, B. J., … Forsythe, B. (2017). Does early motion lead to a higher failure rate or better outcomes after arthroscopic rotator cuff repair? A systematic review of overlapping meta-analyses. *Journal of Shoulder and Elbow Surgery*, *26*(9), 1681–1691. https://doi.org/10.1016/j.jse.2017.04.004

Santiago-Torres, J., Flanigan, D. C., Butler, R. B., & Bishop, J. Y. (2015). The effect of smoking on rotator cuff and glenoid labrum surgery: A systematic review. *American Journal of Sports Medicine*, *43*(3), 745–751. https://doi.org/10.1177/0363546514533776

Sarda, P., Qaddori, A., Nauschutz, F., Boulton, L., Nanda, R., & Bayliss, N. (2013). Distal biceps tendon rupture : Current concepts. *Injury*, *44*(4), 417–420. https://doi.org/10.1016/j.injury.2012.10.029

Sato, S., Nagai, E., Taki, Y., Watanabe, M., Watanabe, Y., Nakano, K., … Takagi, M. (2018). Hand grip strength as a predictor of postoperative complications in esophageal cancer patients undergoing esophagectomy. *Esophagus*, *15*(1), 10–18. https://doi.org/10.1007/s10388-017-0587-3

Savin, D. D., Watson, J., Youderian, A. R., Lee, S., Hammarstedt, J. E., Hutchinson, M. R., & Goldberg, B. A. (2017). Surgical management of acute distal biceps tendon ruptures. *Journal of Bone and Joint Surgery - American Volume*, *99*(9), 785–796. https://doi.org/10.2106/JBJS.17.00080

Schmidt, C. C., Brown, B. T., Qvick, L. M., Stacowicz, R. Z., Latona, C. R., & Miller, M. C. (2016). Factors that determine supination strength following distal biceps repair. *Journal of Bone and Joint Surgery - American Volume*, *98*(14), 1153–1160. https://doi.org/10.2106/JBJS.15.01025

Schmidt, C. C., Brown, B. T., Schmidt, D. L., Smolinski, M. P., Kotsonis, T., Faber, K. J., … Miller, M. C. (2019). Clinical and functional impairment after nonoperative treatment of distal biceps ruptures. *Journal of Shoulder and Elbow Surgery*, *28*(4), 757–764. https://doi.org/10.1016/j.jse.2018.09.017

Schmidt, C. C., Jarrett, C. D., & Brown, B. T. (2013). The distal biceps tendon. *Journal of Hand Surgery*, *38*(4), 811–821. https://doi.org/10.1016/j.jhsa.2013.01.042

Schmidt, C. C., Savoie, F. H., Steinmann, S. P., Hausman, M., Voloshin, I., Morrey, B. F., … Brown, B. T. (2016). Distal biceps tendon history, updates, and controversies: from the closed American Shoulder and Elbow Surgeons meeting???2015. *Journal of Shoulder and Elbow Surgery*, *25*(10), 1717–1730. https://doi.org/10.1016/j.jse.2016.05.025

Schneider, A., Bennett, J. M., O'Connor, D. P., Mehlhoff, T., & Bennett, J. B. (2009). Bilateral ruptures of the distal biceps brachii tendon. *Journal of Shoulder and Elbow Surgery*, *18*(5), 804–807. https://doi.org/10.1016/j.jse.2009.01.029

Seiler, J. G., Parker, L. M., Chamberland, P. D. C., Sherbourne, G. M., & Carpenter, W. A. (1995). The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *Journal of Shoulder and Elbow Surgery*, *4*(3), 149–156. https://doi.org/10.1016/S1058-2746(05)80044-8

Shamoon, S., Kotwal, R., Iorwerth, A., & Morgan, D. (2017). Distal Biceps Tendon Rupture Imaging, A Study to Compare the Use of USS Vs. MRI Scan as First

Choice of Investigation. *International Journal of Surgery*, *47*(2017), S87–S88. https://doi.org/10.1016/j.ijsu.2017.08.443

Sharma, D. K., Goswami, V., & Wood, J. (2004). Surgical repair of chronic rupture of the distal end of the biceps brachii. A modified anterior surgical repair technique. *Acta Orthopaedica Belgica*, *70*(3), 268–272. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15287407

Shen, F., Kim, H. J., Lee, N. K., Chun, H. J., Chang, B. S., Lee, C. K., & Yeom, J. S. (2018). The influence of hand grip strength on surgical outcomes after surgery for degenerative lumbar spinal stenosis: a preliminary result. *Spine Journal*, *18*(11), 2018–2024. https://doi.org/10.1016/j.spinee.2018.04.009

Shields, E., Olsen, J. R., Williams, R. B., Rouse, L., Maloney, M., & Voloshin, I. (2015). Distal biceps brachii tendon repairs: A single-incision technique using a cortical button with interference screw versus a double-incision technique using suture fixation through bone tunnels. *American Journal of Sports Medicine*, *43*(5), 1072–1076. https://doi.org/10.1177/0363546515570465

Siebenlist, S., Fischer, S. C., Sandmann, G. H., Ahrens, P., Wolf, P., Stöckle, U., … Brucker, P. U. (2014). The functional outcome of forty-nine single-incision suture anchor repairs for distal biceps tendon ruptures at the elbow. *International Orthopaedics*, *38*(4), 873–879. https://doi.org/10.1007/s00264-013-2200-2

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2014). Standardised method for reporting exercise programmes: Protocol for a modified Delphi study. *BMJ Open*, *4*(12), 1–5. https://doi.org/10.1136/bmjopen-2014-006682

Slade, S. C., Dionne, C. E., Underwood, M., & Buchbinder, R. (2016). Consensus on Exercise Reporting Template (CERT): Explanation and Elaboration Statement. *British Journal of Sports Medicine*, *50*(23), 1428–1437. https://doi.org/10.1136/bjsports-2016-096651

Slade, S., Dionne, C., Underwood, M., & Buchbinder, R. (2017). The Consensus on Exercise Reporting Template (CERT): An internationally-endorsed reporting guideline for exercise interventions. *Journal of Science and Medicine in Sport*, *20*, 57. https://doi.org/10.1016/j.jsams.2017.09.309

Sleeboom, C., & Regoort, M. (1991). Rupture of the distal tendon of the biceps brachii muscle. *Netherlands Journal of Surgery*, *43*(5), 195–197. https://doi.org/10.1078/0367-2530-00024

Smith, J. R. A., & Amirfeyz, R. (2016). Does immediate elbow mobilization after distal biceps tendon repair carry the risk of wound breakdown, failure of repair, or patient dissatisfaction? *Journal of Shoulder and Elbow Surgery*, *25*(5), 810–815. https://doi.org/10.1016/j.jse.2015.11.066

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008a). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Spencer, E. E., Tisdale, A., Kostka, K., & Ivy, R. E. (2008b). Is therapy necessary after distal biceps tendon repair? *Hand*, *3*(4), 316–319. https://doi.org/10.1007/s11552-008-9129-8

Srinivasan, R. C., Pederson, W. C., & Morrey, B. F. (2020). Distal Biceps Tendon Repair

and Reconstruction. *Journal of Hand Surgery*, *45*(1), 48–56. https://doi.org/10.1016/j.jhsa.2019.09.014

Steiner, W. A., Ryser, L., Huber, E., & Uebelhart, D. (2002). Use of the ICF Model as a Clinical Problem-Solving Tool in Physical Therapy and Rehabilitation Medicine. *Physical Therapy*, *82*(11), 1098–1107. https://doi.org/10.1093/ptj/82.11.1098

Stockton, D. J., Tobias, G., Pike, J. M., Daneshvar, P., & Goetz, T. J. (2019). Supination torque following single- versus double-incision repair of acute distal biceps tendon ruptures. *Journal of Shoulder and Elbow Surgery*, 1–8. https://doi.org/10.1016/j.jse.2019.07.041

Strandring, S. (2005). *Gray's Anatomy: The Anatomical Basis of Clinical Practice* (39th ed.). Edinburgh: Elsevier Churchill Livingstone.

Stratford, P. W., Norman, G. R., & McIntosh, J. M. (1989). Generalizability of grip strength measurements in patients with tennis elbow. *Physical Therapy*, *69*(4), 276–281. https://doi.org/10.1093/ptj/69.4.276

Stratford, Paul W, & Balsor, B. E. (1994). A Comparison of Make and Break Tests Using a Hand-Held Dynamometer and the Kin-Com. *Journal of Orthopaedic & Sports Physical Therapy*, *19*(I), 28–32.

Stucken, C., & Ciccotti, M. G. (2014). Distal biceps and triceps injuries in athletes. *Sports Medicine and Arthroscopy Review*, *22*(3), 153–163. https://doi.org/10.1097/JSA.0000000000000030

Sutton, K. M., Dodds, S. D., Ahmad, C. S., & Sethi, P. M. (2010). Surgical treatment of distal biceps rupture. *Journal of the American Academy of Orthopaedic Surgeons*, *18*(3), 139–148. https://doi.org/10.5435/00124635-201003000-00003

Tricco, A. C., Lillie, E., Zarin, W., O'Brien, K., Colquhoun, H., Kastner, M., … Straus, S. E. (2016). A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, *16*(1), 1–10. https://doi.org/10.1186/s12874-016-0116-4

Van den Bekerom, M. P. J., Kodde, I. F., Aster, A., Bleys, R. L. A. W., & Eygendaal, D. (2016). Clinical relevance of distal biceps insertional and footprint anatomy. *Knee Surgery, Sports Traumatology, Arthroscopy*, *24*(7), 2300–2307. https://doi.org/10.1007/s00167-014-3322-9

Vincent, J. I., Macdermid, J. C., King, G. J. W., & Grewal, R. (2013). Validity and Sensitivity to Change of Patient-Reported Pain and Disability Measures for Elbow Pathologies. *Journal of Orthopaedic & Sports Physical Therapy*, *43*(4), 263–274. https://doi.org/10.2519/jospt.2013.4029

Vincent, J., & MacDermid, J. C. (2012). The Patient-Rated Elbow Evaluation (PREE). *Journal of Physiotherapy*, *58*(4), 274. https://doi.org/10.1016/S1836-9553(12)70134-0

Visuri, T., & Lindholm, H. (1994). Bilateral distal biceps tendon avulsions with use of anabolic steroids. *Medicine and Science in Sports and Exercise*. https://doi.org/10.1249/00005768-199408000-00002

von Elm, E., Altman, D. G., Egger, M., Pocock, S., Gotzsche, P., & Vandenbroucke, J. (2007). The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *Bulletin of the*

World Health Organization, *85*(11), 867–872. https://doi.org/10.2471/BLT

Waterman, B. R., Navarro-Figueroa, L., & Owens, B. D. (2017). Primary Repair of Traumatic Distal Biceps Ruptures in a Military Population: Clinical Outcomes of Single- Versus 2-Incision Technique. *Arthroscopy - Journal of Arthroscopic and Related Surgery*, *33*(9), 1672–1678. https://doi.org/10.1016/j.arthro.2017.02.008

Watson, J. N., Moretti, V. M., Schwindel, L., & Hutchinson, M. R. (2014). Repair techniques for acute distal biceps tendon ruptures: a systematic review. *The Journal of Bone and Joint Surgery. American Volume*, *96*(24), 2086–2090. https://doi.org/10.2106/JBJS.M.00481

Webb, A. R., Newman, L. A., Taylor, M., & Keogh, J. B. (1989). Hand grip dynamometry as a predictor of postoperative complications. Reappraisal using age standardized grip strengths. *Journal of Parenteral and Enteral Nutrition*, *13*(1), 30–33. https://doi.org/10.1177/014860718901300130

Webber, E. M., Ronson, A. R., Gorman, L. J., Taber, S. A., & Harris, K. A. (2016). The Future of General Surgery: Evolving to Meet a Changing Practice. *Journal of Surgical Education*, *73*(3), 496–503. https://doi.org/10.1016/j.jsurg.2015.12.002

Wentzell, M. (2018). Post-operative rehabilitation of a distal biceps brachii tendon reattachment in a weightlifter: a case report. *The Journal of the Canadian Chiropractic Association*, *62*(3), 193–201. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/30662074%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6319429

Wylie, J. D., Beckmann, J. T., Granger, E., & Tashjian, R. Z. (2014). Functional outcomes assessment in shoulder surgery. *World Journal of Orthopaedics*, *5*(5), 623–633. https://doi.org/10.5312/wjo.v5.i5.623