The Physical Therapy Management of Individuals with Long Head of the Biceps Tendinopathy

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This is to certify that the thesis entitled ***The Physical Therapy Management of Individuals with Long Head of the Biceps Tendinopathy***, submitted in fulfilment of the requirements for the degree Doctor of Philosophy (Physiotherapy), is in a form ready for examination.

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I hereby certify that this thesis is in the form of a series of papers. I have included as part of the thesis a written declaration from each co-author, endorsed in writing by the Faculty Assistant Dean (Research Training), attesting to my contribution to any jointly authored papers (Appendix B).

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The following publications and presentations were a direct result of the work completed in this thesis:

Peer Reviewed Publications

- **McDevitt, A. W**., Cleland, J. A., Strickland, C., Mintken, P., Leibold, M. B., Borg, M., Altic, R., & Snodgrass, S. (2020). Accuracy of long head of the biceps tendon palpation by physical therapists; an ultrasonographic study. *Journal of Physical Therapy Science*, *32*(11), 760-767.
- **McDevitt, A. W**., Cleland, J. A., Addison, S., Calderon, L., & Snodgrass, S. (2022). Physical therapy interventions for the management of biceps tendinopathy: an international Delphi study. *International Journal of Sports Physical Therapy*, *17*(4), 677.
- **McDevitt, A. W**., Snodgrass, S. J., Cleland, J. A., Leibold, M. B. R., Krause, L. A., & Mintken, P. E. (2020). Treatment of individuals with chronic bicipital tendinopathy using dry needling, eccentric-concentric exercise and stretching; a case series. *Physiotherapy theory and practice*, *36*(3), 397-407.

Peer Reviewed Conference Presentations

- **McDevitt A,** Cleland J, Strickland C, Mintken P, Kretschmer R, Leibold M, Borg M, Snodgrass S. The accuracy of biceps tendon palpation by physical therapists; [platform presentation] American Academy of Orthopaedic Manual Physical Therapists Conference (AAOMPT), Reno, Nevada. 2018.
- **McDevitt A,** Young J, Cleland J, Hiefield P, Snodgrass S. Physical therapy management of individuals with proximal biceps tendinopathy: A scoping review. [platform presentation] AAOMPT; Cleveland. 2021.
- **McDevitt A,** Young J, Cleland J, Hiefield P, Calderon L, Snodgrass S. Physical therapy management of individuals with proximal biceps tendinopathy: A scoping review. [platform presentation] APTA Combined Sections Meeting, San Antonio, Texas. 2022.

Preamble

Amy McDevitt is a PhD candidate at the University of Newcastle (Australia) but based in the United States. All studies were completed in the United States which has a nomenclature that is different from the country of the degree-granting institution. In the United States, physiotherapy is referred to as physical therapy and physiotherapists are referred to as physical therapists. It has been recommended by journal editors in our field that the nomenclature used for practitioners be consistent with the naming conventions of the location where they work, and/or where the data were collected. Therefore, 'physical therapy' and 'physical therapists' will be used throughout the thesis to refer to 'physiotherapy' and 'physiotherapists'. The supervisory committee was comprised of an international group of collaborators from both Australia and the United States which agreed with the naming convention.

COVID-19 Circumstances and Plan for Original Thesis

Effective April 1, 2020, studies deemed non-COVID related, that included human participants at the University of Colorado were mandated to suspend enrollment. This was in effect for an undetermined period, further intervention studies were deprioritized. Therefore, the original plan for this PhD to conduct a randomized controlled trial for an intervention for long head of the biceps tendon (LHBT) tendinopathy had to be abandoned. A plan was created to continue to progress the PhD program without the inclusion of a randomized controlled trial (RCT) since patient recruitment was no longer feasible for an undetermined period. A pivot plan was deemed necessary to assure that the Ph.D. could be completed in a reasonable timeframe. The studies in Chapter 3 (scoping review), Chapter 5 (palpation study) and Chapter 7 (case series) were included in the original thesis plan with the final study originally proposed to be a multicenter RCT followed by a protocol paper. Approval had already been sought and granted by the Human Research Ethics Committee (HREC) at the University of Newcastle and the Colorado Multiple Institutional Review Board (COMIRB) at the University of Colorado to begin the recruitment process for the multi-center RCT titled: "Dry needling and eccentric concentric exercise versus traditional physical therapy (PT)in the treatment of individuals with bicipital tendinopathy". The aim of this RCT was to examine the short and long-term effectiveness of dry needling and eccentric-concentric exercise and stretching on pain, disability, and patient-perceived improvements in patients with bicipital tendinopathy. The rationale was to determine if combining the three evidence-based approaches to treating tendinopathy in other body regions is effective in treating bicipital tendinopathy. Considerable planning went into the development of the RCT, therefore, details of the study protocol can be found in Appendix A. On account of the need to abandon this trial due to COVID-19 related circumstances, the decision was made to develop two novel studies that would not require human subjects research yet still contribute to the aim of the thesis: Chapter 4 (retrospective study) and Chapter 6 (Delphi study). The purpose of Chapter 4, the retrospective chart review, was to investigate the use of PT prior to biceps tenodesis and tenotomy surgeries and report the types of PT interventions used in treatment. The purpose of Chapter 6, the Delphi study, was to establish consensus on conservative, non-surgical PT interventions for individuals with LHBT tendinopathy using the Delphi method approach. In retrospect, we believe these two studies are essential to developing a strong rationale for the intervention program to be investigated in a RCT. Prior to initial development of the RCT and the completion of the studies in this thesis, there was minimal evidence to inform the development of a targeted intervention for LHBT tendinopathy that could be tested in a RCT. A multimodal approach to treatment of LHBT tendinopathy had been selected for the RCT without an appreciation for alternative intervention options. The outcomes of the scoping review (Chapter 3) and retrospective chart review (Chapter 4) combined with other literature, provided evidence that suggested launching into a RCT without this information would have been premature. The additional studies completed in lieu of the RCT are essential for providing the rationale to investigate specific interventions for LHBT tendinopathy (discussed in Chapter 4 and Chapter 6). Therefore, while the COVID pandemic did impact this thesis, it prompted a valuable pause in the development of the rationale supporting a RCT for intervention for LHBT tendinopathy, which facilitated the gathering of important and essential information which will better inform a more robust and well developed RCT in the future.

Abstract

Background

Shoulder pain related to the long head of the biceps tendon (LHBT) tendinopathy can be debilitating and difficult to treat. Patients often elect for more aggressive management including surgical intervention. Conservative management is recommended but there are limited established guidelines on the physical therapy (PT) management of the condition.

Aims/Purpose

This thesis provides evidence-informed recommendations for PT based interventions while also contributing to the future development of RCTS and treatment guidelines focused on the management of LHBT tendinopathy. The overall aim of this thesis is to investigate PT interventions used to treat patients with LHBT tendinopathy. The thesis begins with a scoping review of interventions used to treat LHBT tendinopathy followed by a retrospective review of treatments utilized to treat suspected LHBT tendinopathy in a clinical setting. The results of the reviews identified a need for accurate diagnosis and informed a palpation study on the accuracy of clinicians' ability to palpate the LHBT. Then to further support and supplement the reviews, the thesis includes a Delphi study, using expert consensus, to further identify recommended PT based interventions. The results of the scoping review, retrospective review, and Delphi study clarified the need to investigate multimodal approaches utilized to treat local LHBT pain and regional impairments associated with the condition. Therefore, a case series investigating the use of a multimodal approach to treating local LHBT pain was performed to collate and assess a combination of known interventions.

Methods

By synthesizing the available information on management, the thesis will provide evidence informed interventions on the management of LHBT tendinopathy. A scoping review was performed to identify interventions used to treat LHBT tendinopathy. A retrospective chart review was conducted to understand interventions used by physical therapists to treat individuals with LHBT tendinopathy in a large hospital-based system. A need to better understand diagnosis drove an accuracy and reliability study to understand how well physical therapists can palpate the LHBT for purposes of examination and intervention. A Delphi study was performed to gain expert consensus on recommended interventions to treat individuals with LHBT tendinopathy. Information gathered from these studies supported a case series to determine how a multimodal approach to treatment impacts patient reported pain and disability.

Results

The main findings of this thesis were: 1) therapeutic modalities and multimodal approaches, including manual therapy, exercise, and patient education, are recommended for LHBT tendinopathy by existing evidence; 2) PT was not highly utilized by patients with LHBT tendinopathy (in a hospital based system) prior to surgery; patients who did attend received a combination of active and passive treatments across several intervention themes; 3) physical therapists had poor inter-rater reliability and accuracy in palpating the LHBT in 2 positions; 4) experts identified 61 interventions across 7 themes as being effective for LHBT tendinopathy management; and 5) PT using the multimodal approach of dry needling, eccentric-concentric exercise, and stretching was effective in improving pain and disability in 10 patients with suspected LHBT tendinopathy.

Conclusions

This thesis provides evidence informed recommendations for PT based interventions while also contributing to the future development of treatment guidelines for LHBT tendinopathy. The evidence presented in this thesis suggests that there are well-defined PT based interventions specifically designed to treat LHBT tendinopathy. While some research studies have examined interventions for managing initial tendon pain through therapeutic modalities and "physical therapy" has been generally recommended, there is a lack of detail on specific interventions, including the timing, dosage, and treatment progression. Thus, this thesis makes specific recommendations to inform next steps on understanding optimal interventions for the management of LHBT tendinopathy.

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CHAPTER 1. Introduction

1.1 Background Overview

The background (Chapter 1) describes what is known currently about LHBT tendinopathy and challenges with diagnosis. Further, this chapter describes in more detail the medical management of LHBT tendinopathy. Chapter 1 also describes the PT management of shoulder pain, tendinopathy, and shoulder tendinopathy as current management of LHBT tendinopathy is purported to be drawn from what is known regarding the management of other related conditions. Finally, Chapter 1 summarizes the importance of acquiring knowledge regarding optimal PT management.

1.2 Background

1.2.1 LHBT Tendinopathy

Shoulder pain is the third most common musculoskeletal condition with a reported incidence ranging from 7-30% in the general population, (Klintberg et al., 2015; Luime et al., 2004) up to 53% in certain working populations (Huisstede et al., 2006) and a reported lifetime prevalence of up to 67% (Luime et al., 2004). Additionally, studies have reported low rates of perceived recovery for individuals with a primary complaint of shoulder pain (Bang & Deyle, 2000). Shoulder pain is associated with a high economic burden on the medical system (Croft et al., 1996; Meislin et al., 2005; Winters, 1999) and in the United States; the financial burden associated with the evaluation and management of shoulder pain has been estimated at 3 billion dollars annually (Aurora et al., 2007). Rekola and colleagues (Rekola et al., 1997) reported that over 50% of individuals with shoulder pain are likely to experience a recurrence of their symptoms and pursue additional care within 12 months. Further, several authors have reported a low rate of perceived recovery for individuals with a primary complaint of shoulder pain (Bang & Deyle, 2000; Hill et al., 2010).

The long head of the biceps tendon (LHBT) has long been recognized as a source of shoulder pain (Gilcreest, 1936; Gill et al., 2007) and pathology of the tendon may include the terms: long head of the biceps tendinopathy, bicipital tendinopathy, and common bicipital syndrome. The LHBT tendon can be a primary source of anterior shoulder pain due to its sensory and sympathetic innervation (Alpantaki et al., 2005). Further, the sheath of the LHBT is an extension of the synovial lining of the glenohumeral joint therefore, rotator cuff pathology can directly compromise the LHBT tendon (Varacallo & Mair, 2022). Tendinopathy of the LHBT may start as an inflammatory condition or tenosynovitis of the LHBT as it courses through the bicipital groove (also referred to as intertubercular groove) of the humerus (Ahrens & Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). Degenerative tendinopathy of the LHBT may involve the presence of tendon thickening, disorganization, and irregularity of the tissue and hemorrhagic adhesions and scarring (Krupp et al., 2009) thus limiting the mobility of the LHBT in the intertubercular groove (Nho et al., 2010). The condition can be debilitating and often impacts an individual's quality of life due to consistent reports of pain with activity (Ahrens & Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). The overall incidence of bicipital tendinopathy remains unclear (Murthi et al., 2000; Nho et al., 2010) as it is considered a secondary pathology commonly associated with other pathologies of the shoulder including anterior glenohumeral instability, rotator cuff disease, subscapularis injury, internal impingement, and subacromial impingement (Ahrens & Boileau, 2007; Krupp et al., 2009; Murthi et al., 2000; Wilk & Hooks, 2016). Studies have reported that 76-85% of patients with rotator cuff tears had associated LHBT tendinopathy (C.-H. Chen et al., 2005; R. E. Chen & Voloshin, 2018; Gill et al., 2007). Primary bicipital tendinopathy is much less common and is often associated with a younger athletic population with a history of involvement in a provocative sport (Varacallo & Mair, 2022). Due to the lower overall incidence of primary LHBT compared to other upper extremity tendinopathies, little is known about its optimal management and if protocols used in treating shoulder pain or tendinopathy are effective when adapted to the LHBT. There is a wealth of information guiding the physical therapy (PT) management of individuals with shoulder pain and tendinopathy.

1.2.2 Shoulder Pain and Physical Therapy Management

Due to the reported prevalence of shoulder pain in the general population, (Klintberg et al., 2015; Luime et al., 2004) evidence exists for the PT management of individuals with shoulder pain (Gutkowski, 2021; Kelley et al., 2013a; Pieters et al., 2020). A multimodal approach to management, which includes manual therapy and exercise, has been reported to improve outcomes in individuals with shoulder pain (Bang & Deyle, 2000; Desmeules et al., 2003; Gebremariam et al., 2014; Tate et al., 2010). Exercise is often recommended for treating individuals with shoulder pain, with several systematic reviews reporting statistically and clinically important effects on pain and disability in individuals who had exercise as a component of treatment (Abdulla et al., 2015; Kromer et al., 2009; Kuhn, 2009). One systematic review concluded that supervised muscle strengthening combined with stretching were found to be equally as effective as corticosteroid injections or multimodal care in the management of impingement and nonspecific shoulder pain (Abdulla et al., 2015). Further, evidence suggests that inclusion of manual therapy interventions (both thrust and non-thrust techniques) alongside exercise may be helpful in the treatment of individuals with shoulder pain (Boyles et al., 2009; Desjardins-Charbonneau et al., 2015; Mintken et al., 2010, 2016; Pieters et al., 2020).

1.2.3 Tendinopathy and Physical Therapy Management

Tendinopathy has been described as a clinical syndrome often characterized by the presence of pain, swelling, and patient report of reduced performance and participation (Girgis & Duarte, 2020; Scott et al., 2020). Tendinopathy is a contemporary term used to describe persistent tendon pain and a loss of function due to mechanical loading of the tendon (Scott et al., 2020). Tendinopathy can occur at an early age but it is more common in individuals between the ages of 18 and 65 years old (Hopkins et al., 2016; Riel et al., 2019) and females are more prone to tendinopathy over males, however, prevalence is increased in males under the age of 18 (Hopkins et al., 2016; Riel et al., 2019). Pathogenesis of tendinopathies is complex, however, multiple theories suggest that tendinopathies tend to occur in individuals with a history of repetitive, high-load demand activity (Hopkins et al., 2016; Millar et al., 2021). A lack of intrinsic healing ability of tendinous tissue combined with a repetitive load situation can lead to matrix damage within the tendon (Millar et al., 2021). Patients may report soreness and stiffness with initial activity eventually progressing to constant pain that limits activity and participation (Millar et al., 2021). Diagnosis can be difficult as the pathophysiology of tendinopathy is not fully understood despite consistent histopathological findings across anatomical sites of tendinopathy (Abate et al., 2009; Dean et al., 2016). While patient history typically includes tendon pain, stiffness and a history of provocation from activity via load to the tendon (Millar et al., 2021), clinical examination findings may include pain with palpation of the tendon and positive findings on pain provoking tests (Dai & Zeng, 2020).

Conservative management is often recommended for individuals with tendinopathy (Mead et al., 2018) yet intervention decision-making is limited as optimal treatments and protocols are not well defined (Dilger & Chimenti, 2019; Girgis & Duarte, 2020). Therapeutic modalities (ultrasound, low-level laser, electrotherapy, extracorporeal shockwave therapy) are reported to be common interventions used to manage tendinopathy, however, therapeutic modalities are supported by weak evidence (Cardoso et al., 2019; Girgis & Duarte, 2020) and may only address initial symptomatology (Millar et al., 2021). Additional PT management strategies including manual therapy and exercise, have been used to treat upper and lower extremity tendinopathies successfully (Girgis & Duarte, 2020). Exercise therapy, specifically eccentric exercise, has historically been described as an effective component of an exercise program in treating individuals with tendinopathy in other body areas (Andres & Murrell, 2008; Girgis & Duarte, 2020; Jayaseelan et al., 2017) including tendinopathy of the Achilles (Alfredson et al., 1998), and patellar tendons (Rutland et al., 2010). Contemporary research on tendinopathy management describes exercise programs incorporating mechanical loading using concentric, eccentric and isometric muscle contractions to load the affected tendon (Coombes et al., 2015; Mellor et al., 2018; Pieters et al., 2020). Overall, a program containing elements of mechanical loading is an important and effective component of an exercise program for the management of tendinopathy with the overall intent of promoting tendon healing (Cardoso et al., 2019; Jayaseelan et al., 2017; Martin et al., 2018). However, it is unknown if these principles extend to the management of LHBT tendinopathy.

1.2.4 Shoulder Tendinopathy and Physical Therapy Management

The most common overuse tendinopathies in the upper extremity include the common flexor and extensor tendons of the elbow and the rotator cuff tendon (supraspinatus), (Millar et al., 2021). Rotator cuff tendinopathy is also commonly referred to as subacromial impingement syndrome (J. Lewis et al., 2015). According to reports, only 50% of individuals with rotator cuff tendinopathy achieve full and natural recovery within 12 months (Van der Windt et al., 1996). However, in persistent cases of tendinopathy, subacromial decompression and acromioplasty may be recommended.

Subacromial decompression or acromioplasty are the mainstay surgical treatments for persistent rotator cuff tendinopathy (Clement et al., 2015). Surgery is not associated with improved outcomes over exercise and a structured exercise program can significantly reduce the need for surgery (Holmgren et al., 2012; J. Lewis et al., 2015). A structured exercise program may include scapular strengthening, motor control exercises and shoulder stretching (Holmgren et al., 2012; Kelley et al., 2013a; Mintken et al., 2016; Tate et al., 2010). Additional interventions should include advice to rest and modify activity, reduction of pain, restoration of normal shoulder and scapular movement, and mechanics with varying approaches depending on the irritability of the tendinopathy (J. Lewis et al., 2015; Pieters et al., 2020).

Trials on the use of exercise for tendinopathy often describe programs as long as 12 weeks as tendon recovery can take 6-12 months (Irby et al., 2020). Several exercise approaches and strategies for treating rotator cuff tendinopathy have been described, yet uncertainty persists as to the most effective exercise approach (J. Lewis et al., 2015). Studies on tendon loading in lower extremity tendinopathies have shown beneficial effects (Lim & Wong, 2018) yet studies on upper extremity tendinopathies (rotator cuff and common extensor tendon) describe exercise including eccentric training (Camargo et al., 2012; Murtaugh & Ihm, 2013) and load (J. Lewis et al., 2015), but are not clear with specific recommendations related to mechanical tendon loading to the rotator cuff tendon using mixed contraction. Although eccentric training has historically been recommended, updated evidence does support the addition of mixed contraction types which have been shown to be beneficial in treating various tendinopathies including rotator cuff tendinopathy (Pieters et al., 2020). Therefore, it is a challenge to determine the best course of treatment to optimize outcomes for individuals with shoulder tendinopathy. Further, no studies have examined the effects of mechanical loading exercises specifically for individuals with LHBT tendinopathy.

1.3 Rationale for Thesis

Evidence exists for the PT management of individuals with shoulder pain and tendinopathies (Achilles, patellar, common flexor or extensor tendon, and rotator cuff), however, evidence is lacking for the PT management of individuals with LHBT tendinopathy. This thesis seeks to answer the question: What optimal PT based interventions are used to treat individuals with LHBT tendinopathy? Individuals who present with chronic pain of the LHBT, often elect to have more invasive interventions such as surgery (Hassan & Patel, 2019). Current interventions used to treat individuals with LHBT tendinopathy are purported to be drawn from literature reporting on the management of subacromial shoulder pain and/or rotator cuff tendinopathy. However, the LHBT functions differently from other tendons of the shoulder and is enveloped in an extensive synovial sheath which is an additional and unique characteristic (Varacallo & Mair, 2022). Further, most research for the management of tendinopathies is derived from study of lower extremity, weight bearing tendons (Achilles and patellar), (Ashe et al., 2004). Therefore, applying concepts related to intervention from other regions (especially weight bearing tendons), may not be adequate. There is a dearth of information specific to the PT management of individuals with LHBT tendinopathy. Each chapter and individual study involved a stepwise inquiry into the PT management of individuals with LHBT tendinopathy.

The overall aim of this thesis is to investigate PT interventions used to treat patients with LHBT tendinopathy. The specific sub aims corresponding to four studies are to: 1) identify and describe PT interventions used for individuals with LHBT tendinopathy; 2) investigate the use of PT prior to biceps tenodesis and tenotomy surgeries by assessing the number of visits and the types of interventions utilized; 3) assess physical therapists' inter-rater reliability and accuracy in palpating the LHBT in two positions, 4) describe the outcomes of 10 patients with LHBT tendinopathy who received PT interventions (dry needling, eccentric-concentric exercise, and stretching) directly to the tendon. The results of the reviews identified a need for more accurate clinical diagnosis and informed a palpation study on the accuracy of clinicians' ability to palpate the LHBT. To support and supplement the reviews, the thesis includes a Delphi study to identify more specific, recommended interventions. The results of the reviews, and the Delphi study clarified the need to investigate multimodal approaches utilized to treat local LHBT pain, therefore, a case series investigating the use of a multimodal approach to treating local LHBT pain was conducted. The combination of these studies represents the first steps in addressing the current gap in the literature while also identifying PT interventions purported to be effective in managing individuals with LHBT tendinopathy. The goal of PT management is to maximize patient outcomes and avoid more invasive techniques such as surgery. Therefore it is necessary to understand the current state of research and clinical practice prior to drawing conclusions.

1.4 Aims of the Thesis

1.4.1 Aims

The overall aim of the thesis is to investigate the PT based interventions used to treat patients with LHBT tendinopathy. To achieve the goal of this project, the overall aim has been broken down into sub-aims.

Aim 1: Identify and describe specific, PT based interventions recommended to treat individuals with LHBT tendinopathy (scoping review and Delphi study, Chapter 3, and Chapter 6).

Aim 2: Assess the types and frequency of interventions used for patients with LHBT tendinopathy in a large hospital-based system using billing codes and number of visits (retrospective chart review, Chapter 4).

Aim 3: Determine if physical therapists can accurately and reliably palpate the LHBT to guide the examination and treatment of individuals with LHBT tendinopathy including the implementation of interventions directly to the tendon (palpation reliability study, Chapter 5).

Aim 4: Describe the outcomes of patients with LHBT tendinopathy who received PT based interventions (dry needling, eccentric-concentric exercise, and stretching) directly to the tendon (case series, Chapter 7).

The combined aims of this thesis culminated in evidence informed recommendations for the management of individuals with LHBT tendinopathy which will hope to inform future research including randomized controlled trials and practice guidelines.

1.4.2 Operational Definitions for Intervention

For the purpose of this thesis, PT interventions were defined as interventions typically performed by a physical therapist within the scope of the practice of PT including therapeutic exercise, manual therapy, patient education, and therapeutic modalities (heat, cold, electricity, sound waves, radiation, and other interventions), (*Guide to Physical Therapist Practice 3.0*, 2014).

1.5 Overview of the Thesis

This thesis is presented as a series of published and draft manuscripts organized around the topic of PT interventions used to treat individuals with LHBT tendinopathy. The thesis consists of nine chapters, including three published peer-reviewed scientific journal articles (Chapters 5-7), and two manuscripts under review (Chapters 3-4). At the beginning of each of these chapters representing a publication, an overview is provided describing the contribution of the chapter to the overall thesis and its aims. The target population of study is individuals with a known or suspected diagnosis of LHBT tendinopathy. Chapters 3 and 4 were conducted to determine PT interventions recommended (in the literature) and performed by physical therapists in a large hospital-based system. Chapter 5 focuses on the accuracy of identification of the LHBT, essential for diagnosis of LHBT tendinopathy and implementation of interventions directly to the tendon. Chapter 6 maintains a focus on PT interventions recommended (based on consensus) to treat LHBT tendinopathy by a panel of international experts in a Delphi study. Chapter 7 presents a case series exploring multimodal PT interventions to the LHBT in individuals with suspected LHBT tendinopathy. Chapter 8, the final chapter, summarizes the key findings and conclusions that can be drawn from prior chapters, providing clarity surrounding the gap in knowledge that has been addressed with this thesis.

1.6 Significance

Findings from this thesis, based on a series of projects, are an initial step towards providing evidence-informed recommendations to guide the management of individuals with LHBT tendinopathy. Further, this thesis provides preliminary information that forms the basis for future research and practice guidelines to further inform optimal PT management of LHBT tendinopathy.

CHAPTER 2. Literature Review

2.1 Overview/Introduction

This chapter will provide specific background literature supporting the subsequent five studies presented in this thesis. To build on the introduction (Chapter 1), Chapter 2 reviews the current literature and provides a summary of what is known in the area of PT management for individuals with LHBT tendinopathy. The initial portion of this chapter focuses on the current evidence for the PT management of individuals with LHBT tendinopathy, followed by medical management of the condition and overall PT use, diagnosis of the condition through palpation, description of the multimodal approach to care and finally, management of the condition with a multimodal approach to treating tendon pain associated with LHBT tendinopathy.

2.2 Current Evidence on Physical Therapy Management of LHBT Tendinopathy

Pain specific to the LHBT is often difficult to treat and there is a lack of general agreement on the ideal approach to managing recalcitrant pain of the LHBT (Ahrens & Boileau, 2007; Becker & Cofield, 1989; Krupp et al., 2009). There are a number of disorders, varying in pathogenesis, which can cause pain to the LHBT and tendinopathy is one such term used to describe tendon disorders, which by definition are characterized by pain, swelling and impaired performance (Wang et al., 2006). It is purported that degeneration of the LHBT can be a primary condition, or more frequently, accompanies subacromial impingement and rotator cuff disease, both drivers of "shoulder pain"(Krupp et al., 2009). Physical therapy interventions are considered core management strategies for treating individuals with shoulder pain (Gutkowski, 2021; Kelley et al., 2013a; Pieters et al., 2020), however, literature is sparse describing PT management of LHBT tendinopathy. Recommendations for PT management of shoulder pain encompass a multimodal approach including exercise and manual therapy, (Desjardins-Charbonneau et al., 2015; Page et al., 2016; Pieters et al., 2020; Steuri et al., 2017) yet it is important to know if these evidence-based recommendations are applicable to LHBT tendinopathy. A Cochrane review of 26 studies describing PT for the management of several shoulder conditions, neglected to include recommendations for LHBT tendinopathy (Green et al., 2003). A recent evidence-based tendinopathy guideline also neglects to include recommendations for LHBT tendinopathy (Millar et al., 2021). If guidelines for management are not developed and conservative management is suboptimal and provides only partial relief of symptoms, individuals pursue more invasive surgical procedures including biceps tendon distal reattachment (tenodesis) or release (tenotomy), (Becker & Cofield, 1989; Nho et al., 2010).

There are some articles describing the conservative management of LHBT tendinopathy and include mention of PT (Ahrens & Boileau, 2007; Krupp et al., 2009; R. B. Lewis et al., 2016; Nho et al., 2010), however, the definition of "physical therapy" varies and the description of what this means often lacks detail. According to Krupp et. al. (2009) PT treatment begins with making an accurate diagnosis. Once initiated, PT should include a plan to address the underlying impairments which may be contributing to the pathology including decreased range of motion, accessory motion, and periscapular strength (Krupp et al., 2009). Exercise is frequently mentioned as an important component to a PT program (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; Paynter, 2004), however, there is sparse knowledge of exercise parameters including dosing and progression. A literature review by Krupp et al. (2009), is one of few articles, describing in depth, the management of LHBT tendinopathy utilizing a four-phase approach to rehabilitation. These recommendations were based on author opinion only, therefore what is lacking is the formal testing of these recommendations in a formal research trial.

Research trials investigating the management of individuals with LHBT, have high risk of bias, are of poor study quality, include small sample sizes, and are often unimodal in approach. Table 2.1 describes the methodological quality for six identified studies using the checklist proposed by Down's and Black (Downs & Black, 1998). Two of the six studies were deemed to be moderate quality studies (score >14) and four of the six were deemed to be limited quality (score 7-13). Overall, the risk of bias scores as assessed by the Downs and Black checklist ranged from 7 to 18 (out of a maximum score of 27).

Table 2.1 Downs and Black Scores for Individual Items in Identified Randomized Controlled Trials

Study	Downs and Black Items*																											
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Total Score
Alizadeh et al	1	1	1	1	0	0	0	0	1	1	0	0	1	0	0	1	1	1	0	1	1	1	1	0	0	1	1	16/27
Barbosa et al	1	0	1	1	0	0	1	0	0	1	1	0	1	0	0	1	1	1	0	0	1	1	1	0	0	0	0	13/27
Liu et al	0	1	0	1	0	0	1	1	0	1	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	10/27
Taskaynatan et al	1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	0	1	1	0	0	1	1	1	0	0	1	0	18/27
Zivanovic et al	1	0	0	1	0	1	0	0	0	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	8/27
Xiao et al	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	7/27

*Downs and Black Items indicate whether the study clearly described the following topics:
1, hypothesis/aim/objective 2, main outcomes in introduction or methods section; 3, characteristics of patients; 4, interventions of interest; 5, distributions of principle confounders in each group of subjects to be compared; 6, main findings of the study; 7, provide estimates of the random variability in the data for the main outcomes; 8, adverse events reported; 9, characteristics of patients lost to follow-up; 10, reported probability values for main outcomes (except where $p<0.001$); 11, describes source of population and how patients were selected; 12, subjects represent entire population from which they were recruited; 13, the intervention (staff, places and facilities) were representative of that in use in the source population; 14, blinded study subjects; 15, attempt to blind those measuring main outcome measures; 16, results based on "data dredging"; 17, adjustments for different lengths of follow-up of patients or time between intervention and outcomes; 18, statistical tests used to assess the main outcomes appropriate; 19, reliable compliance with interventions; 20, main outcome measures are valid and reliable; 21, subjects in different groups recruited from the same population; 22, subjects recruited over same period of time; 23, subjects randomized into intervention groups; 24, intervention group concealed from patients and healthcare staff; 25, adjustment for confounding in the analysis; 26, losses of patients to follow-up taken into account; 27, sufficient power to detect a clinically important effect ($p<0.05$).

Further, five randomized controlled trials (Alizadeh et al., 2018; Barbosa et al., 2008; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021) and one observational cohort study (Živanović et al., 2007) explore various therapeutic modalities in the management of LHBT tendinopathy. According to Millar et al. (Millar et al., 2021), therapeutic modalities should be utilized for the resolution of initial irritability and pain from tendinopathy, however, tendon loading programs remain an accepted approach to treatment. Researchers have examined the effects of ultrasound (Alizadeh et al., 2018; Barbosa et al., 2008), extracorporeal shockwave treatment (Liu et al., 2012; Xiao et al., 2021) and polarized light (Živanović et al., 2007). One study (Barbosa et al., 2008), examined the multimodal approach of joint mobilization, exercise, and ultrasound versus ultrasound and exercise alone, although the sample size was only 14, therefore, results must be interpreted with caution. Another study (Taskaynatan et al., 2007) investigated iontophoresis plus heat and exercise versus interferrential current (electrotherapy) plus heat and exercise. Again, the sample size was small (n=47) and the description of the exercise program ("strengthening and range of motion") was not informative enough to replicate in clinical practice. Two studies included the use of corticosteroid injection as the comparator treatment (Alizadeh et al., 2018; Taskaynatan et al., 2007; Živanović et al., 2007). Outcome measures utilized by identified studies included pain, disability and satisfaction. Table 2.2 describes in more detail, the sample sizes, outcomes (pain, function and other) and the results of these studies with the addition of the study by McDevitt et al. (2020) described in Chapter 7.

Table 2.2 Characteristics of Identified Studies

Author	Study Type	n	Intervention Group	Outcome Measures	Time to Outcome	Pain	Function	Other	Summary of Outcome
Alizadeh et al 2018	**RCT**	206	1. US 2. L/US 3. ISCl 4. ESCl	VAS CMSI	1 week 1 month 3 months 1 year	P<0.001 in all groups	P<0.001 in all groups (5 visits)	NA	All four therapeutic approaches could decrease pain and increase shoulder function in patients with LHB tendonitis.
Barbosa et al 2008	**RCT**	14	1. US, EMT, JM 2. Control	DASH CMSI	10 visits (4 weeks)	NA	DASH: 1. P<0.001 2. P=0.004	CMSI: 1.P<0.001 2. P=0.021	Both treatments were effective, however when joint mobilization techniques were added, the functional gains were more significant.
Liu et al 2012	**RCT**	79	1. rESWT 2. Sham	VAS LSQ	4 treatments 1 month 3 months 12 months	1. P=0.00 2. P=0.262	1. P=0.00 2. P-value not provided	NA	RESWT could be the preferred method for treating long bicipital tenosynovitis.
McDevitt et al 2018	**Case Series**	10	1. DN, EE	QuickDASH NPRS	2-8 treatment sessions	P<0.001 NPRS: P<0.02	QuickDASH	NA	The combination of these interventions stimulated tissue remodeling which may have led to improved scores.
Taskaynatan et al 2007	**RCT**	47	1. SI 2. ET	CMSI PSS S U	1 month	NA	CMSI: P<0.05 PSS: P<0.05	S: P=0.022 and P=0.046 U: NA	Overall improvements in pain, ROM, and, as a result, in function were likely better in the SI group.
Zivanovic et al 2007	**OCS**	65	1. CI, PL 2. Control	SP IIM TTP PCLS	10 days	1. P=0.022 2. P=0.05	IIM 1. P=0.001 2. P=0.002 PCLS P=0.002	TTP 1. P=0.022 2. P=0.005	Both methods of therapy lead to improved outcomes by patients.
Xiao et al 2021	**RCT**	93	1. OG 2. Control	VAS ROM YT CMSI	After session 1 week 2 weeks 4 weeks	P<0.05	CMSI: P<0.05	ROM: P<0.05 YT: P<0.05	CBI combined with MSUS is superior to rESWT when treating TLHBBT in the short-term.

Abbreviations: RCT= randomized controlled trial, OCS= observational cohort study, US=ultrasound, L/US=low level laser treatment and ultrasound, ISCI= intrasheath ultrasound guided corticosteroid injection, ESCI= extrasheath ultrasound guided corticosteroid injection, VAS= visual analogue scale, CMSI= constant-Murley score Index, EMT= eccentric muscle training (manual resistance), JM=joint mobilization, DASH= Disabilities of the Arm, Shoulder and Hand, rESWT= radial extracorporeal shock wave therapy, QuickDASH= Quick Disabilities of the Arm, Shoulder and Hand, NPRS= Numeric Pain Rating Scale, SI= steroid iontophoresis, ET=electrotherapy, PSS= Pennsylvania Shoulder Scale, S=satisfaction, U= ultrasonography, CI= Corticosteroid injection, PL= Polarized light, SP=subjective pain, TTP=tender to palpation, IIM=increase in movement, PCLS= Personal Condition and Loss of Suffering, TLHBBT= tenosynovitis of the long head of the biceps brachii, OG=observational group, CG=control group, ROM=range of motion, YT=Yergason's test, CBI= compound betamethasone injection, MSUS= musculoskeletal ultrasonography, DN=dry needling, EE=eccentric exercise

The overall lack of evidence for specific PT interventions used to treat LHBT tendinopathy combined with the knowledge that patients pursue more invasive approaches such as surgery indicates a need for further research studies investigating specific PT interventions. As a first step to determining the most efficient management of patients with LHBT tendinopathy, it would be useful to synthesize information about the interventions present in articles and research studies that are currently available.

2.3 Current Evidence on LHBT Management Prior to Patients Electing for Surgery

When conservative management is not pursued or fails, medical management of LHBT tendinopathy may include non-steroidal anti-inflammatory drugs, corticosteroid injections, and surgery (Ahrens & Boileau, 2007; Nho et al., 2010). Corticosteroid injections to the biceps tendon are relatively common for persistent symptoms, although controversy persists with respect to the type of technique (ultrasound-guided versus blind injection) and location (subacromial, intra-articular, bicipital groove/sheath), (Aly et al., 2015; Gofeld et al., 2019). More invasive surgical interventions include biceps tendon distal reattachment (tenodesis) or release (tenotomy), (Boileau et al., 2007; Nho et al., 2010). The LHBT tenodesis procedure releases the LHBT from the glenoid with subsequent anchoring to the humerus more distally. Tenotomy procedures involve the release of the biceps tendon just distal to its proximal insertion, however, this is typically only indicated in individuals exhibiting significant partial tears and/or instability of the LHBT in the intertubercular groove. However, both of these invasive procedures have been reported as recommended surgical interventions in cases of recalcitrant biceps tendinopathy (Boileau et al., 2007; Krupp et al., 2009; Walch et al., 1991). Other surgical procedures include arthroscopic debridement of the LHBT, subacromial decompression, and or decompression of the LHBT with the release of the transverse ligament (Krupp et al., 2009). A recent study comparing tenodesis versus tenotomy for biceps tendinopathy found equivocal results for function as measured by the Disabilities of the Arm, Shoulder and Hand (DASH) visual analog scale (VAS) and American Shoulder and Elbow Surgeons score (ASES) between the two procedures (Friedman et al., 2015). However, it has been hypothesized that both surgeries may lead to undesirable post-surgical sequelae, specifically superior migration of the humeral head and a potential decrease in the acromiohumeral interval (Slenker et al., 2012). Therefore, it is important to understand what interventions are utilized prior to surgery.

There is a paucity of information related to PT prior to patients electing to have surgery for LHBT tendinopathy. In a study of patients who had arthroscopic rotator cuff repair, only 20% of patients had PT in the year prior to their surgery (Malik et al., 2020). These findings are surprising considering evidence has shown PT to be effective for managing shoulder pain (Diercks et al., 2014; Pieters et al., 2020). According to one study, patient expectations or lack of information regarding the rehabilitation process and physical therapy may be a barrier to patients attending physical therapy (Subialka et al., 2022). It is also unknown if physicians typically refer patients for a course of PT prior to recommending more invasive treatment. Therefore, investigations focused on PT prior to surgery including rehabilitation codes billed, number of visits and types of interventions would determine if and how physical therapy is utilized prior to surgery. A retrospective chart review is a first step in determining the typical PT interventions utilized in this population to support next steps, which may include the development of randomized intervention trials.

2.4 Current Evidence on Diagnosis of LHBT Tendinopathy

Controversy persists in the literature regarding not only the function of the LHBT but also proper diagnosis (Murthi et al., 2000; Nho et al., 2010). Long head of the biceps tendon tendinopathy is difficult to identify yet diagnosed through a combination of patient-identified pain, clinical palpation, and clinical tests (specific movements of the shoulder designed to reproduce the patient’s pain), (Gazzillo et al., 2011). Clinical tests or examination maneuvers target either the LHBT pathology in the intertubercular groove or target the proximal attachment of the tendon at the supraglenoid tubercle (Ben Kibler et al., 2009). A component of the examination is meant to differentiate LHBT pain from other sources of shoulder pain including the acromioclavicular joint and the glenoid labrum (Ponnappan et al., 2015). Clinical tests used in the examination may include the Speed Test, Uppercut test, Yergason test, O’Brien or active compression test, and acromioclavicular joint provocation tests (Ben Kibler et al., 2009; Cotter et al., 2018). Several of the clinical tests, used to diagnose LHBT tendinopathy, have been shown to have high sensitivity, poor to moderate specificity, poor predictive value, and low likelihood ratios (Ben Kibler et al., 2009; Holtby & Razmjou, 2004). Therefore, accurate diagnosis of LHBT pathology is challenging, however, tenderness over the intertubercular groove is considered one of the most important clinical tests for the diagnosis of biceps tendinopathy (Ahrens & Boileau, 2007; Ditsios et al., 2012; Gill et al., 2007). The goal of direct palpation over the patient's bicipital groove is to elicit a painful response which may be indicative of pathology (Ben Kibler et al., 2009). Therefore, precise palpation of the LHBT is critical for accurate diagnosis and subsequent intervention for LHBT pathology.

A number of shoulder positions for palpation of the LHBT have been recommended (Gazzillo et al., 2011; Gill et al., 2007; Mattingly & Mackarey, 1996), however, there is little consensus on the best position for palpation, and studies have included varying populations (symptomatics, asymptomatics, and cadavers). Recommended shoulder positions appear to be based on anatomical theory or personal preference as no evidence suggests whether one position is more effective for palpation than another. A study by Gazzillo et al. (2011) investigated the overall accuracy of physicians palpating the LHBT of (asymptomatics) in a position of 20-30° of shoulder abduction, 90° elbow flexion, and full forearm supination with examiners choice of rotation and found physicians had on average 5.4% agreement based on their definition of successful palpations (Gazzillo et al., 2011). Other positions that have been investigated in cadavers include the shoulder in adduction and 20° medial rotation with the shoulder in extension, "forearm behind the back" which is more typically used to palpate the supraspinatus tendon (Mattingly & Mackarey, 1996). From these studies (Gazzillo et al., 2011; Matsen & Kirby, 1982; Mattingly & Mackarey, 1996), it appears the positions with the most potential for accuracy might be the shoulder in adduction and 20° medial rotation or the shoulder in 20-30° degrees abduction, 90° elbow flexion, full supination, and examiner's choice of rotation. Although this information is useful in determining effective positions, none of the aforementioned studies used physical therapists as the palpating clinicians, thus it is difficult to generalize the results to physical therapists. Physical therapists may be a patient's first point of contact to examine and perform an evaluation of an individual's shoulder pain, therefore, it is important to determine physical therapists' ability to accurately locate and palpate the LHBT in any position. Subsequently, physical therapists provide interventions localized to the LHBT, and their accuracy with palpation is necessary to implement such treatments. Investigating physical therapists' ability to accurately palpate the LHBT will provide important information relevant to the examination and intervention of individuals with LHBT tendinopathy.

2.5 Expert Opinion on the Treatment of Long Head of Biceps Tendinopathy

PT for the conservative management of shoulder pain, including LHBT pathology, may involve a multifaceted approach addressing impairments of the shoulder, scapular region, and cervicothoracic spine (Krupp et al., 2009). This may include the use of exercises, joint and soft tissue mobilization, movement pattern retraining and therapeutic modalities. While the literature includes randomized controlled trials exploring the use of therapeutic modalities such as ultrasound, electrotherapy, extracorporeal shockwave therapy, and iontophoresis for the management of LHBT conditions, overall there are few studies of questionable quality on the conservative management of LHBT tendinopathy specifically (Alizadeh et al., 2018; Barbosa et al., 2008; Liu et al., 2012; Paynter, 2004; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007). Given that chronic biceps tendinopathy often leads to invasive surgical intervention, it is important for physical therapists to identify effective interventions for LHBT tendinopathy to potentially avoid such procedures. However, at present, there are no studies of high quality that have identified the most effective PT interventions for treating individuals with LHBT tendinopathy. The Delphi method (Powell, 2003), which involves obtaining expert consensus, may be a valuable tool for decision-making in the absence of strong evidence, and could be used to generate expert consensus on physical therapy interventions for LHBT tendinopathy, which could inform further research and guideline development.

2.6 Current Evidence on Eccentric-Concentric Exercise and Tendon Needling for Tendinopathy

Eccentric exercises are a well-documented and an effective component of an exercise program for treating individuals with tendinopathy (Andres & Murrell, 2008; Girgis & Duarte, 2020; Jayaseelan et al., 2017). Eccentric exercise has been shown to be beneficial in individuals with shoulder impingement, (Camargo et al., 2012; Jonsson et al., 2006) tendinopathy of the Achilles, (Alfredson et al., 1998), and patellar tendons (Rutland et al., 2010). Many research studies have shown that a combination of exercises including eccentric, concentric, and isometric contractions can be effective in treating tendinopathy. For example, one study (Coombes et al., 2015) found that a program comprising a combination of eccentric and concentric contractions was effective in reducing pain and improving function in patients with upper extremity tendinopathy. Similarly, another study (Kongsgaard et al., 2009) found that a program incorporating eccentric, concentric, and isometric contractions was effective in reducing pain and improving function in patients with patellar tendinopathy. These findings suggest that a multifaceted approach to exercise, including a variety of contraction types, may be more effective in treating tendinopathy than a single type of exercise. The optimal dosing parameters for loading programs in the treatment of tendinopathy are still uncertain, and it is important to tailor these programs to the individual patient to ensure adherence (Stubbs et al., 2020). Despite this, there is a lack of research on the use of mixed contraction types in loading programs for individuals with LHBT tendinopathy. Further studies are needed to examine the effectiveness of this approach in this population.

Dry needling is a treatment approach that involves the use of a a monofilament needles to stimulate specific points in the muscle, known as myofascial trigger points, in order to reduce muscle pain, restore normal movement and improve function (Clewley et al., 2014; Kietrys et al., 2013). It is a minimally-invasive technique that has been shown to be effective for a variety of musculoskeletal conditions, including shoulder pain and shoulder range of motion deficits (Clewley et al., 2014; Ingber, 2000; Osborne & Gatt, 2010). Some research studies have also found that dry needling can be helpful for relieving myofascial trigger point pain in the shoulder and neck region (Kietrys et al., 2013). However, it is important to note that dry needling is a technique that should be performed by a trained healthcare professional to minimize the risk of adverse effects.

Dry needling has been used by some healthcare professionals as a treatment for tendon pathologies including localized tendon pain. One technique that has been described in the literature is ultrasound-guided tendon fenestration, in which a needle is inserted through the skin and into the tendon under ultrasound guidance (Chiavaras & Jacobson, 2013; Housner et al., 2009, 2010); the tendon is then fenestrated which involves passing a needle through the abnormal tendon multiple times (20-25 times), (Chiavaras & Jacobson, 2013). This technique has been used to treat a variety of tendon pathologies, including patellar tendonitis, supraspinatus tendonitis, infraspinatus tendonitis, and gluteus medius tendonitis. Some research studies have suggested that ultrasound-guided tendon fenestration may be effective in reducing pain and improving function in individuals with these conditions (Chiavaras & Jacobson, 2013; Housner et al., 2010). However, more research is needed to fully understand the effectiveness and potential risks of this technique. The purpose of tendon fenestration is to induce a "healing response" which induces bleeding, inflammation and the release of local tissue factors resulting in the remodeling of chronic pathologic tendon changes (Chiavaras & Jacobson, 2013; Estévez-Loureiro et al., 2013). Dry needling has been utilized by physical therapists for the management of various tendinopathies (Jayaseelan et al., 2021) while physicians have also described tendon needling using fenestration for the management of tendinopathy (Chiavaras & Jacobson, 2013; Krey et al., 2015).

A systematic review on the use of tendon needling for the treatment of tendinopathy found that it may improve patient-reported outcomes (Krey et al., 2015). However, it is currently unclear whether this technique is effective for the treatment of LHBT tendinopathy. Similarly, loading exercises involving a combination of eccentric and concentric contractions have been shown to be beneficial in the treatment of various tendon pathologies (Coombes et al., 2015; Girgis & Duarte, 2020; Kongsgaard et al., 2009; Mellor et al., 2018; Silbernagel et al., 2007). However, the combined effects of these interventions on LHBT tendinopathy have not been studied. To date, there has been no research on the use of both tendon needling and loading exercises as a treatment for localized LHBT tendinopathy pain.

2.7 Summary

In summary, LHBT tendinopathy is a common condition that causes anterior shoulder pain and can be difficult to diagnose. If not properly treated, it can lead to unnecessary surgery. Despite being a known cause of anterior shoulder pain, there is a lack of research on the most effective interventions for individuals with LHBT tendinopathy. This is particularly concerning as surgery is often used to treat persistent pain associated with LHBT tendinopathy. To improve patient outcomes and avoid unnecessary surgical procedures, it is crucial to gain a better understanding of the various interventions used to treat LHBT tendinopathy, particularly in cases where it is a secondary shoulder pathology. This thesis aims to provide insight into the interventions used to treat LHBT tendinopathy and stimulate further research in this area.

CHAPTER 3. Physical Therapy Interventions used to Treat Individuals with Biceps Tendinopathy: A Scoping Review

3.1 Overview

As discussed in Chapters 1 and 2, there is a substantial amount of evidence for the use of PT management of shoulder pain and tendinopathy. Clinical practice guidelines (Gutkowski, 2021; Kelley et al., 2013a) and systematic reviews have investigated interventions for the management of SSP (Page et al., 2016; Pieters et al., 2020) and tendinopathy, (Desmeules et al., 2015; Girgis & Duarte, 2020; Jayaseelan et al., 2021) however, there has been limited evidence to determine the best practice for the management of LHBT. There have been no identified systematic reviews specifically focusing on LHBT tendinopathy. This may be due to its typical presence as a secondary shoulder pathology (Krupp et al., 2009; Nho et al., 2010). As a result, there is a lack of guidance on specific interventions that should be used to treat individuals with tendinopathy of the LHBT. This gap in literature is compounded by uncertainty surrounding the incidence of LHBT tendinopathy (due to it usually occurring as a secondary shoulder condition) and challenges related to identifying the source of shoulder pain in the LHBT as tendinopathy (Murthi et al., 2000; Nho et al., 2010). Therefore, patients who do not respond to conservative management including PT, often pursue surgical options including biceps tenodesis (Koh et al., 2010). Despite the reports of the existence of LHBT tendinopathy in the literature, there are currently only recommendations based on opinion for PT of the condition. As a first step in commencing to investigate the most effective treatments for LHBT tendinopathy, it is important to initially identify and summarize interventions that have been reported in the literature as potentially effective for treating proximal LHBT tendinopathy. The methodology of a scoping review, as outlined by Munn et al. (2018), provides an ideal framework for systematically identifying and mapping the available evidence on a given topic, allowing for a comprehensive evaluation of the breadth and depth of the existing literature. The purpose of this scoping review is to examine and describe the interventions that have been used in the treatment of proximal LHBT tendinopathy.

This review included 14 articles that met the inclusion criteria, data extracted included physical therapy recommendations, intervention type and dosing parameters (if available). Interventions utilized in the 7 research studies to treat LHBT included: extracorporeal shock wave therapy (ESW), polarized light, ultrasound (US), low-level laser (LLT), iontophoresis, general exercise, eccentric training, stretching, dry needling and joint mobilization (JM). Interventions recommended in literature reviews and clinical commentaries included: activity modification, strengthening, eccentrics, range of motion, stretching, and modalities. A better understanding of the most effective interventions for treating LHBT tendinopathy can lead to improved patient care and potentially reduce the need for surgical intervention. While this review provides some initial recommendations for PT based interventions for individuals with LHBT tendinopathy, further research is needed to fully understand the most effective treatment options.

3.2 Citation

The work presented in this chapter has been submitted to a peer-reviewed journal:

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This manuscript was submitted to the Brazilian Journal of Physiotherapy in June, 2022 with a revision submitted December 19, 2022. My roles in the manuscript were as the first author and included: concept/research design, acquisition of data, analysis and interpretation of the data, and writing/reviewing/editing of the manuscript. I take responsibility for the work from inception to publication.

3.3 Abstract

3.3.1 Background

Shoulder pain related to pathology of the long head of the biceps tendon (LHBT) can be debilitating and may interfere with an individual's activity and participation. Chronic LHBT tendinopathy is a common condition that is difficult to treat.

3.3.2 Objective

The purpose of this review was to systematically scope the literature to identify and describe the content of PT interventions used for the PT management of individuals with proximal LHBT tendinopathy.

3.3.3 Methods

A scoping review of PT interventions used to treat LHBT was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. A computer-assisted literature search was conducted of the CINAHL, Embase, Medline, and SportDiscus databases. We included two categories of literature: 1) quantitative research studies referred to as "research reports" and 2) qualitative peer-reviewed publications referred to as "articles." Full-text records reporting PT-based interventions in individuals with proximal LHBT pathology were included. Articles not written in English were excluded.

3.3.4 Results

Of the 3721 records identified, 14 (7 research reports; 7 articles) met the inclusion criteria. Interventions used to treat proximal LHBT identified in research reports included: extracorporeal shock wave therapy, polarized light, ultrasound, low-level laser, iontophoresis, general exercise, eccentric training, stretching, dry needling, and joint mobilization. Interventions recommended in articles (including a Delphi study) included: therapeutic modalities, manual therapy, exercise, dry needling, and patient education.

3.3.5 Conclusion

This scoping review reported interventions primarily based on therapeutic modalities in research reports while articles recommended the addition of manual therapy, patient education, exercise, and dry needling. Little consensus exists regarding the optimal approach to treating individuals with LHBT tendinopathy. Overall, there are few studies and articles detailing the non-surgical management of LHBT tendinopathy.

3.4 Introduction

Shoulder pain is a common orthopedic condition often associated with incomplete resolution of symptoms and continued pain (Hill et al., 2010). Shoulder pain resulting from the pathogenesis of the rotator cuff tendons and other subacromial tissues is referred to as subacromial shoulder pain (Beard et al., 2018; Pieters et al., 2020) and may be caused by overuse (Christiansen et al., 2016), capsular tightness (Tyler et al., 2000), rotator cuff and scapular dysfunction (Ludewig & Cook, 2000), and poor posture (J. S. Lewis et al., 2005). Proximal LHBT tendinopathy often presents as a secondary shoulder pathology with other primary shoulder pathologies including subacromial shoulder pain (Krupp et al., 2009; Nho et al., 2010), and injury to the LHBT is recognized as a significant independent source of pain when left untreated (Sethi et al., 1999). Discrete diagnosis of the pain generators in the shoulder joint can be difficult as it encompasses a variety of conditions and symptoms. Further, diagnosis of LHBT tendinopathy is difficult (Ejnisman et al., 2010; Krupp et al., 2009; R. B. Lewis et al., 2016) and often involves a combination of clinical tests including palpation of the LHBT tendon for pain. Clinical tests (i.e. Speed’s, Yergason’s) used for diagnosing LHBT lesions have been shown to have high sensitivity, poor to moderate specificity, and low likelihood ratios, (Holtby & Razmjou, 2004; Kibler et al., 2002; McFarland et al., 2010) which makes diagnosis without the use of imaging challenging (Gazzillo et al., 2011). Recent evidence suggests that pain is the key clinical feature and imaging may not helpful in diagnosing tendinopathy (Cardoso et al., 2019; Scott et al., 2020). Therefore, clinicians’ confidence in the diagnosis of the condition may be a barrier to selecting a treatment approach that effectively targets the condition.

PT management of individuals with suspected LHBT tendinopathy may involve a multimodal approach to remediate impairments of the shoulder, scapular region, and cervicothoracic spine through exercise, joint and soft tissue mobilization as well as retraining dysfunctional movement (Krupp et al., 2009). Contemporary research on tendinopathy describes the need for mechanical loading of the tendon, including eccentric exercise and heavy slow-load exercises, as an effective component of an exercise program with the overall intent of promoting tendon healing (Andres & Murrell, 2008; Girgis & Duarte, 2020; Jayaseelan et al., 2017; Martin et al., 2018). However, exercise delivery including intervention details and dosing specific to LHBT management is not widely reported in the literature.

In addition to exercise as a component of a multimodal approach, management may include the use of therapeutic modalities or biophysical agents. Based on a recent review of systematic reviews specific to tendinopathies, only moderate-quality evidence supports low-level laser for pain and disability in the short-term yet shockwave therapies showed a statistically significant improvement in pain and function at all follow-up periods (Girgis & Duarte, 2020). Contrary to these findings, evidence also exists stating therapeutic modalities are supported by weak evidence (Cardoso et al., 2019) with moderate evidence of no effect for interventions including low-level laser therapy, extracorporeal shockwave therapy, pulsed electromagnetic energy, and ultrasound (Pieters et al., 2020). Therefore, it is difficult to interpret best practices utilizing therapeutic modalities for treating tendinopathy specific to the shoulder region.

Younger, active patients who do not respond to non-surgical management or PT, often pursue surgical options including biceps tenodesis (Koh et al., 2010). Surgery may be an unnecessary option, creating an additional burden on the healthcare system especially if evidence to support PT exists. There is a lack of well-defined or adopted PT guidelines used to treat individuals with proximal LHBT tendinopathy yet there is a need to determine if evidence of interventions exists. Due to the paucity of available literature, a systematic review was not possible. Therefore, the purpose of this scoping review was to identify and describe the contents of PT interventions reported in the literature used to treat individuals with proximal LHBT tendinopathy. A scoping review allows the researcher to thoroughly canvas the literature and analyze knowledge gaps. Thus, this is the first step to identifying information that will support future research in this area.

3.5 Material and Methods

3.5.1 Protocol and Registration

A scoping review of the literature was performed to fully explore the research question (Colquhoun et al., 2014). The research team modified the review design from a systematic review to a scoping review after initial searches revealed a limited number of randomized controlled trials available. A systematic review was not possible yet it was deemed that initial, intervention-based information needed to be gathered. The review protocol was prospectively registered with PROSPERO (CRD42020193354) prior to changing the design. This scoping review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist (Christensen et al., 2020).

3.5.2 Eligibility Criteria

Two categories of literature included, research studies referred to throughout this paper as "research reports" and qualitative publications including literature reviews, clinical commentaries, and Delphi studies referred to throughout this paper as "articles." Research reports that met the following criteria were included: 1) patients of any age diagnosed with LHBT tendinopathy and/or pain 2) treatment included a description of PT-based interventions, and 3) were available in full text. Participants in randomized and nonrandomized trials, cohort trials, and case series were included of any age and sex if they had a proposed diagnosis of LHBT tendinopathy based on clinical examination findings and/or positive imaging and were treated with a PT intervention in either the experimental or control groups. PT interventions were defined as exercise, manual therapy, patient education, and therapeutic modalities (heat, cold, electricity, sound waves, radiation, and other interventions). PT interventions combined with corticosteroid injections were included as an intervention as injections are strongly related to PT rehabilitation, despite not being within the scope of PT (Pieters et al., 2020). Research reports that met the following criteria were not included: 1) diagnosis of biceps tear or labral tear 2) treatment, surgery, or post-surgery follow-up that was only medical in nature. Articles, including literature reviews, clinical commentaries, and Delphi studies, were included if PT intervention was described in the context of LHBT tendinopathy. We excluded publications that were not available or translated into the English language.

3.5.3 Information Sources and Search

The electronic databases CINAHL, Embase, Medline, and SportDiscus were searched from inception to September 12, 2021, and updated on November 30, 2022. The search was developed and performed with assistance from a research librarian. The terms “bicep” and “tendinopathy/tenosynovitis” or “tendinitis” or “tendonitis” or “tendon injuries” or “inflammation and tendons” or “tendon inflammation or pathology” or “tendinosis” and “physical therapy specialty” or “physical therapy modalities” or “intervention” or “rehabilitation” were used to search the electronic databases. Depending on the database used, MeSH terms or subheadings related to these terms were included. Results were limited to publications describing humans. To retrieve all records, including any form of PT rehabilitation, the search terminology was applied (Table 3.1). In addition, bibliographic reference lists from identified publications were hand-searched for any other publication not identified during the database searches.

Table 3.1 Medline Search Strategy Upon Which Other Searches Were Based

#	**Searches**
1	bicep*.mp.
2	tendinopathy/ or tenosynovitis/
3	Tendon Injuries/
4	paratenonitis.mp.
5	tendonitis.mp.
6	tendinitis.mp.
7	Inflammation/ and tendons.mp.
8	(tendon* adj5 (inflamm* or pathology)).mp.
9	tendinosis.mp.
10	2 or 3 or 4 or 5 or 6 or 7 or 8 or 9
11	Physical Therapy Specialty/ or Physical Therapy Modalities/ or Physical Therapists/ or physical therapist*.mp.
12	physiotherap*.mp.
13	(intervention* or treatment* or therap* or program*).mp.
14	Rehabilitation/ or rehab*.mp.
15	11 or 12 or 13 or 14
16	**1 and 10 and 15**

3.5.4 Study Selection

After records were retrieved from the databases, duplicates were removed. Two authors (A.M, J.Y) independently screened records to identify those meeting the inclusion criteria, initially by title and abstract, followed by a full-text review. If consensus could not be reached, disagreements between reviewers were resolved by a third author (J.C). Covidence systematic review software

(Veritas Health Innovation Ltd, Melbourne, Australia) was used to manage search results and the included publications throughout the review (Covidence, n.d.).

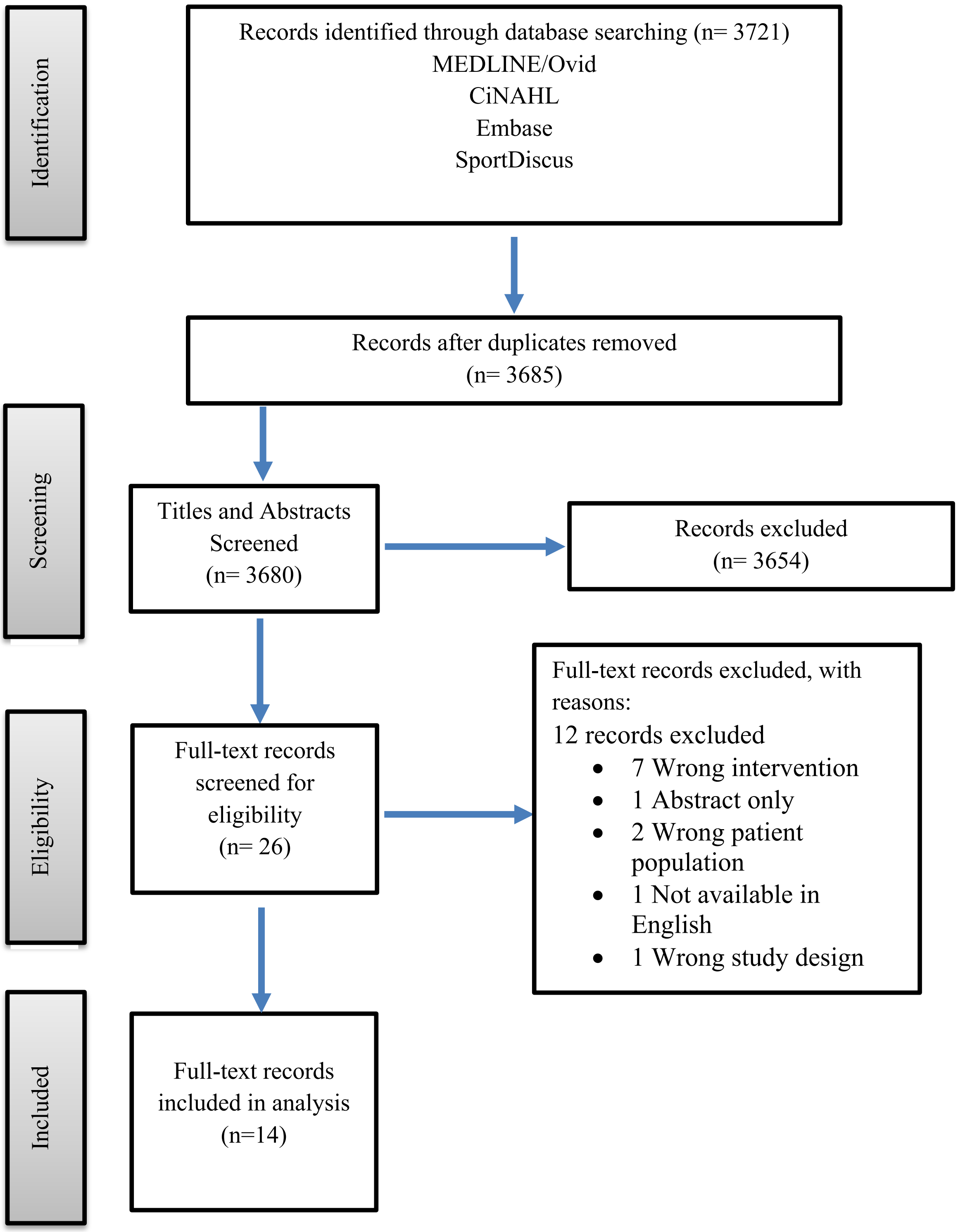
3.5.5 Data Extraction and Analysis

The data were extracted in Covidence with a standardized form based on the *Cochrane Handbook for Systematic Reviews of Interventions* (Version 5.1.0) (HIGGINS & JP, 2011). Two authors (A.M, P.H) independently extracted data, and inconsistencies between the reviewers were resolved by a third reviewer (J.Y). The extracted data included the research report study design or the article type, participant and treatment characteristics (if applicable), and research report results or article recommendations and/or conclusions. The following data were extracted from the research reports: author, study design, sample size, age, sex, criteria for diagnosis (if included), and a description of interventions and intervention groups. Specific descriptions of PT interventions including parameters, timing, and dosing were also extracted for each research report. A synthesis of the available evidence from articles (clinical commentaries, literature reviews, and a Delphi study) was undertaken and narrative summaries of the information were constructed. PT intervention details (eg, specific interventions, progression criteria, and interventions recommended according to the phase of healing) were extracted and categorized into themes and summarized into tables.

3.6 Results

The electronic database searches resulted in 3685 records. After duplicates were removed, 3680 unique records underwent title/abstract screening, and 3654 records were excluded for not meeting inclusion criteria. Twenty-five full-text articles were assessed for eligibility. Ultimately, 12 were excluded for various reasons (e.g., wrong intervention, abstract only; see Figure 3.1, PRISMA flow diagram) leaving 14 records (Alizadeh et al., 2018; Barbosa et al., 2008; R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; Liu et al., 2012; McDevitt, Snodgrass, et al., 2020; Paynter, 2004; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007) to be included in this scoping review.

Figure 3.1 PRISMA Flow Diagram



3.6.1. Study Characteristics

The 14 records included seven research reports [five randomized controlled trials, (Alizadeh et al., 2018; Barbosa et al., 2008; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021) one observational cohort study, (Živanović et al., 2007) one case series (McDevitt, Snodgrass, et al., 2020)] and seven articles [four literature reviews, (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; R. B. Lewis et al., 2016) two clinical commentaries, (Krupp et al., 2009; Paynter, 2004) and a Delphi study (McDevitt et al., 2022)]. The publication years ranged from January 2004 to June 2022. Specific PT interventions were provided to participants in all research reports, and PT interventions were described in the remaining seven articles. Diagnoses of study participants (n=513) included biceps tendonitis, (Alizadeh et al., 2018) tendinopathy of biceps brachii muscles, (Barbosa et al., 2008) tendinopathy of the long head of the biceps tendon, (McDevitt, Snodgrass, et al., 2020; Xiao et al., 2021) bicipital tenosynovitis (Liu et al., 2012) and proximal biceps tendon pathology (Taskaynatan et al., 2007). Study participants included males and females ranging in age from 19 to 69 years old from seven countries. Literature reviews, clinical commentaries, and a Delphi study had varying descriptions of recommended interventions for managing individuals with LHBT tendinopathy. Table 3.2 summarizes the research report characteristics including, the type of study, diagnoses criteria of included participants, and intervention descriptions (research reports and articles) for all interventions. Table 3.3 summarizes the frequency of the identified themes of the PT interventions among the research reports, literature reviews, clinical commentaries, and the Delphi study.

Table 3.2 Description of Physical Therapy Interventions for Long Head of the Biceps Tendinopathy

Author Year	**Study Type *n***	**Participant Characteristics and Criteria for Diagnosis**	**Description of Physical Therapy Intervention**
Alizadeh et al 2018	**Randomized Controlled Trial** *n=206*	Male=121, female=83; mean age not reported Shoulder pain (> 3 months); local tenderness in bicipital groove; at least one biceps positive test (Yergason's test or Speed's test); positive LHB tendonitis signs in IMRA (indirect magnetic resonance arthrography); lack of any evidence of complete or incomplete rupture of rotator cuff.	US: 10 sessions of US (3 per week) with frequency of 1MHz and intensity of 1W/cm^2 by the pulse mode duty cycle of 2:8 and the probe surface of 5cm^2 were applied for 5 minutes in each section. L/US: Type and frequency of US were same US group. In addition, LLLT was performed using gallium-arsenide-aluminum infrared laser 9 with a pencil probe. ISCI: In the supine position, forelimb of the injection site was bent as 90° from the elbow and it was put on the body; with the help of the linear probe at a range of 2-20 MHz and based on the depth of anatomical structure, LHB tendon was found in bicipital groove. One mL of 40 mg/mL methylprednisolone acetate solution and 1 mL of 2% lidocaine solution were mixed and intra tendon sheath injection under US guidance by 1.5-inch length gauge 25-needle was applied. ESCl: All steps and equipment were those used for ISCI however, extra tendon sheath injection of the solution was applied.
Barbosa et al 2008	**Randomized Controlled Trial** *n=14*	Male=5, female=9; mean age 46.14+/-7.62 Shoulder pain (> 6 months); did not have a diagnosis of a frozen shoulder; pain with palpation of the biceps brachii muscle tendons; positive in one or more special tests for biceps brachii	US: utilized frequency of 3MHz with dosage of 1.0W/cm^2 and pulsed exit of 1:1. US was applied for 4 minutes to the long head of the biceps brachii muscle. EMT: consisted of 3 sets of 20 reps each session. Patient performed either "empty can" movement when treating supraspinatus or "right curl" movement when treating biceps brachii dysfunctions. Movement resistance was offered manually, always by the same researcher and respecting the patient's pain limit.

		muscle tendon (Speed's test and Yergason's test)	JM: accessory movements of the shoulder were performed: front, back, lower longitudinal and lateral relaxations of the glenohumeral joint, anteroposterior movements of the acromioclavicular (squeeze) joint and anteroposterior, inferior to superior and superior to inferior movements of the sternoclavicular joint. The following series was applied twice every session: one minute of mobilization for each movement (two to three cycles per second), and one minute of active free abduction movement in the scapular plane, over the arc of movement without pain. * Both groups received treatment for 10 sessions (3 per week). Experimental group added JM in conjunction with US and EMT; control group only received US and EMT.
Liu et al 2012	**Randomized Controlled Trial** ***n=79***	Male=54, female=25; age 27-79 Bicipital groove point tenderness; pain confirmed through Yergason's test and Speed's test	rESWT: 1500 pressure pulses were irradiated at a repetition frequency of 8 Hz at the nominal peak pressure set on the rESWT device to 3 bar. Sham: treatment head was deflated to avoid forming pressure pulse in the pathological site, and no coupling gel was applied. The machine makes a noise ''bang bang'' when each pressure pulse is delivered to enhance the sham design. * All treatments were dosed once per week for 4 weeks.
McDevitt et al 2018	**Case Series** ***n=10***	Male=8, female=2; age 24-64 Anterior shoulder symptoms (> 3 months); pain with palpation of the LHBT; positive results on a combination of tests including active shoulder flexion, Speed's test, Hawkins Kennedy test, Neer test, and Yergason's test	DN: standard, disposable stainless-steel needles inserted into the skin over the most painful and/or thickened areas of the tendon. The technique utilized was a fast-in and fast-out (pistoning) technique for 20–30 repetitions per area in up to three areas. EE: emphasized the eccentric component of the movement and was performed after the DN intervention in two positions. In both positions, they would the eccentrically lower the arm for a count of 3–4 s. Then, the concentric component of the exercise was performed for a count of only 1 s. 3 sets of 15 were performed of each exercise.

			Stretching: Stretching of the biceps muscle/tendon was performed following the EE for 2x30 seconds.
Taskaynatan et al 2007	**Randomized Controlled Trial** ***n=47***	Male=19, female=28; mean age 56 +/- 9.96 Shoulder pain >4 weeks; soft tissue ultrasound examination that revealed biceps tendon pathology	SI: SI [0.5 percent hydrocortisone acetate with the negative electrode placed anterior side of the shoulder, 3-4 mA galvanic current, 15 minutes] was applied ET: ET [interferential current, 0-100 Hz, 15 minutes] was applied in the second group for 15 sessions. * Both groups received hot pack [15 minutes], US [1.5 watts per square centimeter, continuous mode, five minutes], and a standard exercise program including pendulum, strengthening, and ROM exercises in pain-free range.
Zivanovic et al 2007	**Observational Cohort Study** ***n=65***	Male=25, female=40; age 19-69 Tenderness of the biceps brachi tendon; positive Yergason's test	Control group: provided with anti-rheumatic: diclofenac natrijum 2x100 mg or nimesulid 2x50 mg depending on the gastrointestinal tolerance and diazepam 2x5 mg as a miorelaxant and anxiolytic. Experimental group: provided with corticosteroid injection (combination of the betametasone, Na-phosphate and betametasone dipropionate) periarticular and anti-rheumatic, and for the following 10 days the disease localization was treated with polarized light.
Xiao et al 2021	**Randomized Controlled Trial** ***n=93***	Male=54, female=39; age 34-68 Diagnosed with TLHBBT based on relevant examinations; unilateral lesion; the tendon sheath of the LHBBT was not completely torn	Control group: received extracorporeal shock wave treatment with standard therapeutic gun head (15mm). This was performed in concert with MSUS. Treatment was performed once every week, with continuous treatment of 5 applications as a course of treatment. Observation group (CI, PL): received injections consisting of 2 ml of water for injection + 0.5 ml of compound betamethasone injection (CBI) + 0.5 ml of 2% lignocaine injection. During treatment, upper limb of the affected shoulder joint was kept with palm facing upwards and close to the body side, the forearm was kept bent at 90° after rotation, and the site to be

			operated was positioned. Once the injured site was identified, the probe was rotated at a right angle, and kept parallel to the long axis of the biceps brachii. Drugs were injected using long axis needle insertion technique. Full treatment was course of 1 treatment.
Chen and Voloshin 2018	**Literature Review**	N/A	Conservative management includes activity modification, nonsteroidal anti-inflammatory drugs, ice, gradual strengthening exercises and corticosteroid injections (into the biceps tendon sheath and/or subacromial).
Ejnisman et al 2010	**Literature Review**	N/A	Conservative treatment is indicated for primary tendinopathy and in older and/or inactive patients with secondary pathology. Conservative treatment includes rest, medication, physical therapy, strengthening of periscapular muscles.
Harwood and Smith 2004	**Literature Review**	N/A	Conservative management is more favorable for middle aged to older patients due to minimal strength loss and a 30% failure rate with surgical intervention. Treatment options include restoration of strength and function, physical therapy, rotator cuff strengthening and surrounding structures to minimize stress on the bicep tendon.
Krupp et al 2009	**Clinical Commentary**	N/A	The initial approach to both primary and secondary bicipital tendinopathy is nonoperative, beginning with rest and withdrawal from aggravating activities. Additional treatment includes ice, a course of anti-inflammatory medication, and formal physical rehabilitation. Establishing a causal relationship between physical impairments and biceps pathology is important as the treatment plan needs to address impairments. The individual should be advanced through a four-phase rehabilitation protocol while monitoring response to treatment, including pain, swelling and motion. A four-phase approach to rehabilitation is recommended. Phase 1: Acute Phase-Pain management, restoration of PROM and restoration of accessory motion; treatment includes clinical

			modalities, ROM, joint mobilization, stretching, and early scapular strengthening including lower trapezius facilitation. Phase 2: Subacute Phase, Early Strengthening-AROM and early strengthening; treatment includes: active shoulder ROM, rotator cuff strengthening (sport cord), scapular strengthening (sport cord) and clinical modalities as necessary. Phase 3: Advanced Strengthening-consists of rotator cuff and periscapular strengthening as well as a focus on improving dynamic stability; treatment includes: PNF, push up progressions, plyometric exercise, resisted training (sport cord) and weight training. Phase 4: Return to Activities-consists of return to sport exercises focused on improving power and speed; treatments include return to sport and re-evaluation, plyometric training, rhythmic stabilization and PNF plyometrics.
Lewis et al 2016	**Literature Review**	N/A	Conservative therapy includes rest, NSAIDs, ice, activity modification, corticosteroid injection and physical therapy. Mechanical stimulation using dry needles have been shown to increase blood flow to the area in animal studies. Once the acute phase has passed physical therapy may include stretching of anterior shoulder and pectoralis minor, mechanical stimulation with dry needling, ROM, core and scapular strengthening, stretching of the low back and hamstring, rotator cuff strengthening of progressive difficulty. If the individual is a thrower, they would begin a more rigorous throwing regimen once the rotator cuff is strengthened sufficiently.

McDevitt et al 2022	**Delphi Study**	Consensus based on Delphi survey (over 3 rounds) from 31 identified experts in the management of shoulder pain.	Consensus (based on agreement) for interventions was established across six themes after three rounds of surveys. 1. Resistance exercise/muscle performance (subthemes: tendon loading, progressive resistance exercise, open/closed kinetic chain, task specific functional activities) to the rotator cuff, scapular stabilizers, biceps brachii etc. 2. Stretching/flexibility of the biceps brachii, pectoralis major and minor, rotator cuff, latissimus dorsi, and upper trapezius. 3. Manual therapy (subthemes: non-thrust manipulation by region, thrust manipulation by region, thrust and non-thrust manipulation by technique, and soft tissue techniques). 4. Patient education (interventions: activity and occupational modification, load modification, pain neuroscience, pathoanatomy, plan of care, and posture) 5. Dry needling (intervention: dry needling to the biceps brachii muscle) 6. Other (intervention: cognitive behavioral therapy)
Paynter 2004	**Clinical Commentary**	N/A	Most cases of biceps tendinitis are secondary to a primary impingement syndrome. Conservative treatment is warranted for primary or secondary bicipital tendonitis including rest, ice, NSAIDs, steroid injections and physical therapy. In the acute stage, aggressive physical therapy should be avoided. Initially, physical therapy should include gentle ROM, pulley, wand, wall walking, and towel aided stretches followed by PROM, AROM, stretching of posterior capsule, strengthening of rotator cuff and scapular stabilizers with isometrics progressing to isotonic exercises or stretch band exercises. It is important to avoid positions of impingement including overhead exercises and shoulder abduction.

Abbreviations: US, ultrasound; L/US, low level laser treatment and ultrasound; MHZ, megahertz; W/cm, watts/centimeter; LLLT, low level laser therapy; ISCl, intrasheath ultrasound guided corticosteroid injection; LHB, long head of the biceps; ESCl, extrasheath ultrasound guided

corticosteroid injection; EMT, eccentric muscle training with manual resistance; JM, joint mobilization; rESWT, radial extracorporeal shock wave therapy; DN, dry needling; EE, eccentric exercise; SI, steroid iontophoresis; ET, electrotherapy; MSUS, musculoskeletal ultrasonography; CI, corticosteroid injection; PL, polarized light; ROM, range of motion; PROM, passive range of motion; AROM, active range of motion; PNF, proprioceptive neuromuscular facilitation; NSAIDS, non-steroidal anti-inflammatory drugs
Symbols: +/-=standard deviation

Table 3.3 Key Themes for Physical Therapy Interventions (n=14)

Theme	Intervention Mentioned by Research Report/Articles	Research Report[a] (Article)[a]
Therapeutic Modalities	Acute modalities	0(1)
	Ultrasound with a frequency of 1MHz or 3MHz and intensity of 1.0W/cm^2 -1.5W/cm^2 the LHBT tendon and/or biceps brachii muscle	3(0)
	ESWT to the most seriously affected tendon and sheath areas (visualized by ultrasound)	2(0)
	Electrotherapy (interferential current) to anterior shoulder region	1(0)
	Polarized light	1(0)
	Low level laser therapy	1(0)
	Heat to anterior shoulder region	1(0)
	Ice	0(4)
Manual Therapy	Joint mobilization or non-thrust manipulation (glenohumeral joint, acromioclavicular and sternoclavicular joints)	1(3)
	Joint mobilization or non-thrust manipulation (cervical and thoracic spine)	0(1)
	Thrust manipulation (thoracic spine and cervicothoracic junction)	0(1)
	Soft tissue techniques (biceps brachii, rotator cuff, periscapular, scapular muscles and the cervical region)	0(1)
Dry Needling	Dry needling to painful or thickened areas of the tendon based on palpation or the biceps brachii muscle	1(2)
Exercise	Eccentric muscle training using manual or mechanical resistance (biceps brachii muscle)	2(3)
	Stretching (biceps brachii muscle/tendon)	1(3)

	Stretching (pectoralis major, pectoralis minor, upper trapezius, latissimus dorsi, posterior rotator cuff and glenohumeral medial rotator muscles)	0(3)
	Strengthening exercises (shoulder and/or scapular region)	1(6)
	Progressive resistance exercises (latissimus dorsi, deltoid, biceps brachii, middle and lower trapezius, serratus anterior, rhomboid major and minor, rotator cuff medial and lateral rotator muscles)	0(3)
	Open/closed kinetic chain exercises (rotator cuff muscles, scapular stabilizers, biceps brachii muscles)	0(1)
	Task specific functional activities (reaching, lifting, overhead activity, occupation specific, sport specific)	0(3)
	Range of motion exercises in pain-free range	1(3)
Education	General advice on activity modification	0(6)
	Patient education (occupation modification, training/loading modification, medication, PT treatment plan, pain neuroscience education, LHBT pathoanatomy, postural control)	0(1)
	Cognitive behavioral therapy	0(1)
Physical Therapy	General recommendation for "physical therapy" as an approach to treatment	0(5)

[a]*Values are n*

Abbreviations: rESWT, radial extracorporeal shock wave therapy; PT, physical therapy; LHBT, long head of the biceps tendon

3.6.2 Intervention Themes and Descriptions

3.6.2.1 Therapeutic Modalities

Therapeutic modalities are defined as thermal, mechanical, electromagnetic, and light energies administered for therapeutic purposes (Bellew, n.d.). Two research reports (Alizadeh et al., 2018; Barbosa et al., 2008) evaluated the use of US on proximal biceps tendinopathy. Alizadeh et al. (2018) compared four groups: ultrasound, plus ultrasound low-level laser, intrasheath or extrasheath ultrasound-guided corticosteroid injection. The ultrasound group received five minutes of ultrasound for 10 sessions over three weeks. Barbosa et al. (2008)compared ultrasound and EE to the combined interventions of ultrasound, EE, and joint mobilization for 10 sessions, with four minutes of ultrasound applied to the LHBT (Barbosa et al., 2008). One report (Taskaynatan et al., 2007) had both the experimental and control group receive ultrasound for five minutes over 15 sessions.

Two RCTs assessed the effects of extracorporeal shockwave therapy on tenosynovitis of the LHBT (Liu et al., 2012; Xiao et al., 2021). Liu et al. (2012) assessed the effects of extracorporeal shockwave therapy versus sham and Xiao et al. (2021) assessed extracorporeal shockwave therapy versus corticosteroid injection. One report (Taskaynatan et al., 2007) described the use of electrotherapy; one group received hydrocortisone acetate through iontophoresis (3-4 milliamp, galvanic current, 15 minutes), and the other received electrotherapy (interferential current, 0-100 hertz, 15 minutes). Both groups received hot packs, ultrasound, and a standard exercise program over 15 sessions. Zivanovic et al. (2007) compared polarized light therapy (for 10 days) combined with a corticosteroid injection to a control group who were prescribed oral anti-inflammatories.

3.6.2.2 Manual Therapy

Manual therapy is defined as skilled passive movements of joints and soft tissue intended to improve tissue extensibility and range of motion, induce relaxation, mobilize or manipulate soft tissue and joints, modulate pain, and reduce soft tissue swelling, inflammation, or restriction (*Guide to Physical Therapist Practice 3.0*, 2014). Techniques may include manual lymphatic drainage, manual traction, massage, joint mobilization/manipulation, and passive range of motion (*Guide to Physical Therapist Practice 3.0*, 2014). One research report (Barbosa et al., 2008) described joint mobilization combined with ultrasound and eccentric exercise muscle training over 10 sessions. Joint mobilization included several accessory movements to the shoulder, acromioclavicular joint, and sternoclavicular joint followed by one minute of passive shoulder abduction in the scapular plane (Barbosa et al., 2008). The Delphi study described grades of techniques recommended and regions treated (glenohumeral, cervical and thoracic spine, and shoulder) with thrust and non-thrust manipulation and soft tissue techniques (McDevitt et al., 2022). A literature review (Paynter, 2004) described stretching of the posterior capsule of the shoulder and range of motion while a clinical commentary (Krupp et al., 2009) recommended the restoration of accessory motion and joint mobilization.

3.6.2.3 Dry Needling

The case series by McDevitt et al. (2020) described the utilization of dry needling to the LHBT for up to six visits followed by eccentric exercise (heavy slow load exercises) and stretching of the biceps muscle. The dry needling technique involved the pistoning of the needle in and out of the most painful areas of the tendon (based on palpation) for 20-30 repetitions in up to three areas. The Delphi study (McDevitt et al., 2022) reported consensus (based on expert input) on dry needling of the biceps brachii muscle while Lewis et al. recommended mechanical stimulation with dry needling to increase blood flow and growth factors (R. B. Lewis et al., 2016).

3.6.2.4 Exercise

Three research reports (Barbosa et al., 2008; McDevitt, Snodgrass, et al., 2020; Taskaynatan et al., 2007) and all seven articles (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004) described exercise as a component of PT management of individuals with LHBT tendinopathy. Stretching of the biceps brachii muscle (Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; McDevitt, Snodgrass, et al., 2020) and other associated muscle groups (R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004) was also frequently recommended. Strengthening exercises were included in two research reports (McDevitt, Snodgrass, et al., 2020; Taskaynatan et al., 2007) and recommended in all seven articles (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004). Additional exercise recommendations included progressive resistance exercise (Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022), open and closed chain exercise (McDevitt et al., 2022), task-specific or functional activities (Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt, Snodgrass, et al., 2020), and eccentric exercise (Barbosa et al., 2008; Krupp et al., 2009; McDevitt et al., 2022; McDevitt, Snodgrass, et al., 2020).

A randomized controlled trial (Barbosa et al., 2008) and a case series (McDevitt, Snodgrass, et al., 2020) included eccentric exercise as an intervention to treat LHBT. The randomized controlled trial (Barbosa et al., 2008) included eccentric exercise muscle training in the experimental (ultrasound+eccentric exercise+joint mobilization) and control (ultrasound+eccentric exercise) groups (Barbosa et al., 2008). The eccentric exercise muscle training exercise had participants perform a “bicep curl” movement (patient flexes their elbow) with manual resistance (Kisner et al., 2017) provided by the researcher for three sets of 20 repetitions per treatment session for 10 sessions over three weeks (Barbosa et al., 2008). The case series described combining dry needling with eccentric exercise and stretching of the biceps muscle (McDevitt, Snodgrass, et al., 2020). Heavy slow load exercises, including eccentric exercise, targeting the LHBT were dosed, as described by Alfredson (Alfredson et al., 1998; McDevitt, Snodgrass, et al., 2020), at three sets of 15 repetitions with 4-6 pounds (or until perceived patient discomfort) in two positions. The Delphi study (McDevitt et al., 2022) described consensus on the use of isometrics, concentrics, and eccentric biceps brachii contractions with resistance.

3.6.2.5 Education

Several articles included the general recommendation to provide advice on activity modification and/or rest (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004) while the Delphi study (McDevitt et al., 2022) and the clinical commentary by Krupp et al. (2009) included more specific recommendations for patient education including return to sport and occupational advice.

3.7 Discussion

LHBT is responsible for considerable pain and disability in individuals with shoulder pain (Krupp et al., 2009; Nho et al., 2010; Sethi et al., 1999). Little consensus exists on the ideal management of LHBT (Ahrens & Boileau, 2007; Becker & Cofield, 1989). The primary purpose of this scoping review was to categorize publications and identify and describe the content of PT interventions used for the management of individuals with LHBT tendinopathy. The findings of this scoping review suggest that preliminary evidence on the PT management of LHBT tendinopathy is not robust enough to draw strong conclusions (Ahrens & Boileau, 2007; Barbosa et al., 2008; R. B. Lewis et al., 2016; McDevitt, Snodgrass, et al., 2020; Nho et al., 2010; Taskaynatan et al., 2007; Xiao et al., 2021).

It is important to understand the pathophysiology of LHBT to appropriately target effective therapeutic interventions. LHBT often begins as an inflammatory condition or tenosynovitis which may develop into a degenerative tendinopathy including the presence of tendon thickening, disorganization, adhesions, and scarring (Ahrens & Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). Therapeutic modalities have historically been utilized by physical therapists to treat musculoskeletal conditions, including tendon pathology, (Lindsay et al., 1995; Watson, 2000). It is unsurprising that therapeutic modalities would be studied and utilized clinically to treat pain associated with LHBT. However, contemporary opinion persists that many available therapeutic modalities (specifically ultrasound, electrotherapy, extracorporeal shockwave therapy, and low-level laser) are only supported by weak evidence (Cardoso et al., 2019), and for some therapeutic modality-based interventions, there is moderate evidence of no effect (Pieters et al., 2020). Nearly all of the research reports included in this review investigated the use of therapeutic modalities as an intervention used to treat patients with LHBT (Alizadeh et al., 2018; Barbosa et al., 2008; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007).

A recent review of systematic reviews on interventions specific to various tendinopathies reported moderate-quality evidence to support the use of low-level laser therapy for pain and disability in the short term. Extracorporeal shockwave therapies showed a statistically significant improvement in pain and disability at all follow-up periods (Girgis & Duarte, 2020). In contrast, a systematic review on the efficacy of ultrasound in individuals with rotator cuff tendinopathy found that ultrasound was not superior to placebo (Desmeules et al., 2015). Evidence also exists for exercise therapy, as a component of a multimodal approach, specifically eccentric exercise in treating individuals with tendinopathy (Andres & Murrell, 2008; Girgis & Duarte, 2020; Jayaseelan et al., 2017). In fact, according to Pieters et al. (2020), exercise therapy is strongly recommended as a first-line treatment to improve pain, mobility, and function in individuals with subacromial shoulder pain.

In this review, only three of seven research reports focused on a multimodal approach, which is recommended by clinical practice guidelines focusing on the management of shoulder pain (Diercks et al., 2014; Kelley et al., 2013b). The randomized controlled trial by Barbosa et al. (2008) added joint mobilization to eccentric exercise and ultrasound. Similarly, the case series by McDevitt et al. (2020) utilized a multimodal approach of dry needling, eccentric exercise, and stretching. Taskaynatan et al. (2007) included the combined therapy of iontophoresis with a standard exercise program. In contrast, recommendations provided by seven of seven articles described a multimodal approach including the use of exercise.

Interestingly, the inclusion of a multimodal approach (including exercise) was described by the literature reviews, clinical commentaries and Delphi study (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004). According to Krupp et al., (2009) PT management of LHBT tendinopathy should involve a multimodal approach addressing impairments of the shoulder, scapular region and cervicothoracic spine with the application of exercise, joint and soft tissue mobilization as well as retraining dysfunctional movement patterns (Krupp et al., 2009). Further, in addition to addressing associated impairments, Krupp et al. (2009) recommended patients with LHBT pathology progress through a four-phase exercise program (pain management, restoration of range of motion, active range of motion, early strengthening, rotator cuff and periscapular strengthening, and return to sport). Two additional commentaries recommended a multimodal approach including education on activity modification, stretching (muscles and capsular tissue), joint mobilization, dry needling, and various forms of strengthening including isometrics, isotonics, core, rotator cuff, and scapular strengthening (R. B. Lewis et al., 2016; Paynter, 2004).

The commentaries and Delphi study suggest experts in the field may be recommending a multimodal approach and this approach may be emerging in clinical practices; however, further research is needed to formally recommend treatment guidelines for managing individuals with LHBT pathology.

Seven research reports specific to PT interventions describe the treatment of LHBT to include ultrasound, extracorporeal shockwave therapy, electrotherapy, strengthening, joint mobilization, EE, dry needling, and polarized light therapy. Articles (literature reviews, clinical commentaries, and a Delphi study) recommended "physical therapy" which included therapeutic modalities, various forms of exercise (stretching and strengthening), manual therapy (soft tissue mobilization, thrust, and non-thrust manipulation), dry needling, and patient education (advice on activity modification). Few of the research reports specific to the treatment of LHBT describe a multimodal approach including the addition of exercise; however, clinical commentaries, literature reviews, and the Delphi study recommend PT to include a multimodal approach to treatment including exercise. A disconnect in the literature exists, therefore, clear guidance on optimal clinical management of LHBT tendinopathy is lacking.

3.7.1 Knowledge Gaps and Future Research

Future quantitative investigations should report on intervention in sufficient detail to assure reproducibility including information on dosing and time-based interventions. Further, there is a need for consistent use of reporting guidelines for interventions such as the Template for Intervention Description and Replication (TIDierR) and the Consensus on Exercise Reporting Template (CERT) to improve reporting on exercise-based interventions (Grandeo et al., 2022; MacPherson et al., 2022) and manual therapy based interventions (Leech et al., 2022) in individuals with musculoskeletal pain. Overall, a standardized approach to describing "physical therapy" based interventions is needed to better understand how to manage individuals with LHBT tendinopathy. Further research including improved consistency of reporting PT-based interventions is required to evaluate the effectiveness of interventions.

3.7.2 Limitations

Despite a systematic search strategy, it is possible that not all relevant studies were identified and it is possible that other sources of information (blogs, conference proceedings), which were excluded, may have contributed additional information to this topic. A considerable limitation was that the research reports included in this review were heterogeneous in design and content which precluded the use of conclusive summative statements thus limiting the generalizability of our findings. Further, this scoping review included qualitative information from clinical commentaries, literature reviews, and a Delphi study due to the overall lack of literature reporting on interventions for LHBT. This impacts the quality of the reported information and limits generalizability. Further, we reported the frequency of intervention themes which does not necessarily reflect the importance of identified themes. Lastly, only English-language articles were included which increases the risk of language bias.

3.8 Conclusions

Limited evidence suggested PT interventions may be effective for treating individuals with LHBT tendinopathy. Only six randomized controlled trials were identified that primarily reported on the use of therapeutic modalities to treat LHBT tendinopathy. Expert commentary on the treatment of tendinopathy recommends a multimodal approach (including exercise) yet PT interventions recommended were variable and did not provide sufficient detail to guide practicing clinicians. Future research is needed due to the overall lack of evidence and literature available.

CHAPTER 4: Physical Therapy Utilization Prior to Biceps Tenodesis or Tenotomy for Biceps Tendinopathy

4.1 Overview

The results of the scoping review (Chapter 3) contextualized the knowledge gained from Chapters 4 and 5 in this thesis. The paucity of literature to guide clinical decision-making in the treatment of individuals with LHBT tendinopathy is evidenced by the lack randomized controlled trials identified in the scoping review. Further, diagnosis of the condition is often challenging and involves a combination of clinical tests and patient report, therefore, it is hard to definitively identify individuals with the condition. Chapters 1 and 2, highlight the presence of substantial evidence for the use of PT in the management of shoulder pain and tendinopathy, yet weak level 1 evidence exists for the management of LHBT tendinopathy is clearly lacking. When non-operative management, including PT, is unsuccessful and LHBT pain persists, surgical intervention (biceps tenotomy or tenodesis) is commonly used to treat individuals with increased pain or disability (Krupp et al., 2009). Therefore, physical therapists need to recognize interventions that could be potentially effective in treating LHBT tendinopathy to avoid such procedures. This chapter sought to elucidate what physical therapists do for treatment of this condition is in a large hospital-based system through a retrospective chart review.

This retrospective cohort study used data from the electronic medical records of individuals diagnosed with anterior shoulder pain due to LHBT tendinopathy who had biceps tenodesis or tenotomy surgery between March 16, 2016, and March 16, 2020, and who were receiving care in a large hospital system including outpatient physical therapy clinics. This review sought to describe current practices by collecting and assessing data to better understand PT interventions for LHBT. Further, this review collected data on overall attendance to physical therapy, the number of PT visits, the number of active and passive billing codes utilized, and a summary of PT-related interventions received within 2 years prior to surgery to understand the population of interest more fully. Identifying individuals with a definitive diagnosis of LHBT was challenging, therefore, this review identified individuals who had tenotomy or tenodesis surgery and presented to PT prior to their surgery. This review served as a foundation for future research in exploring "what" physical therapists actually do clinically when treating this population prior to surgery.

4.2 Citation

The work presented in this chapter has been submitted to a peer reviewed journal:

McDevitt A, Cleland J, Hiefield P, Bravman J, Snodgrass S. Physical Therapy Utilization Prior to Biceps Tenodesis or Tenotomy for Biceps Tendinopathy. (In Review: Journal of Orthopaedic Research; submitted December 22, 2022)

This manuscript was submitted to Journal of Orthopaedic Research, December 22, 2022. My roles in the manuscript were as the first author and included: concept/research design, acquisition of data, analysis, and interpretation of the data, and writing/reviewing/editing of the manuscript. I take responsibility for the work from inception to publication.

4.3 Abstract

4.3.1 Introduction

Surgery for the management of individuals with long head of the biceps tendon (LHBT) tendinopathy is common. Little is known about PT utilization prior to surgery. The purpose of this review was to investigate the use of PT prior to biceps tenodesis and tenotomy surgeries by assessing the number of visits and the types of interventions. A secondary objective was to report on themes of PT interventions.

4.3.2 Methods

A retrospective observational cohort study design was used to analyze medical records in a large hospital-based system database (Epic) and report on patient visits, procedure codes based on active or passive interventions, and themes of interventions utilized by PT.

4.3.3 Results

Patient records (n=308) were screened for eligibility, n=62 (20.1%) patients attended PT prior to surgery. The median number of PT visits was 4 (IQR=3.5), and 39/62 (63%) patients had 4 or more visits to PT. Active interventions were used in 54.5% (533/978) of the codes billed; passive interventions were used in 45.5% (445/978) of the codes. There was high utilization of therapeutic exercise [93.4% (498/533) of active procedure codes] including muscle performance/resistance, functional activity, motor control and stretching. Manual therapy [84.3% (375/445) of passive procedure codes] included soft tissue mobilization, non-thrust manipulation (glenohumeral joint and cervical spine) and thrust manipulation (thoracic spine).

4.3.4 Conclusions

PT was not commonly utilized prior to undergoing biceps tenodesis and tenotomy surgery. Further research is needed to understand the reasons for low utilization.

4.4 Introduction

Shoulder pain related to pathology of the LHBT can be debilitating. The LHBT is a known pain generator of the shoulder and can interfere with an individual's activity and participation (Ahrens & Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). Tendinopathy of the LHBT may start as an inflammatory condition or tenosynovitis (Ahrens & Boileau, 2007; Krupp et al., 2009; Nho et al., 2010) and may progress to degenerative tendinopathy (characterized by tendon thickening, disorganization, and irregularity of the tissue including the presence of hemorrhagic adhesions and scarring), (Krupp et al., 2009). The overall incidence of LHBT tendinopathy remains uncertain due to its presence as a secondary shoulder condition associated with other shoulder pathology including rotator cuff disease and subacromial impingement (Murthi et al., 2000; Nho et al., 2010). Overall, there remains a paucity of literature regarding the diagnosis, and appropriate management of disorders related to the LHBT, including PT management and surgical intervention (Griffin et al., 2019; Murthi et al., 2000; Nho et al., 2010; Pogorzelski et al., 2018).

There is little consensus regarding the optimal approach to treating chronic anterior shoulder pain due to LHBT tendinopathy (Ahrens & Boileau, 2007; Krupp et al., 2009). Conservative management including PT, activity modification, nonsteroidal anti-inflammatory drugs, and steroid injections in the biceps sheath are often recommended prior to more invasive interventions (Krupp et al., 2009; R. B. Lewis et al., 2016; Paynter, 2004; Schickendantz & King, 2016). However, conservative management may be suboptimal and provide only partial/temporary relief of symptoms and many individuals go on to seek more invasive surgical procedures including biceps tendon reattachment (tenodesis) or release (tenotomy), (Becker & Cofield, 1989; Nho et al., 2010).

Physical therapy management of anterior shoulder pain (including LHBT tendinopathy) may involve a multimodal approach addressing impairments of the shoulder, scapular region, and cervicothoracic spine. Further, interventions may include therapeutic exercise, joint and soft tissue mobilization as well as retraining of dysfunctional movement patterns (Krupp et al., 2009). Information on the management of subacromial shoulder pain is robust (Christiansen et al., 2016; Diercks et al., 2014; Page et al., 2016; Pieters et al., 2020), however, there remains a lack of high-quality literature describing PT management of individuals with LHBT tendinopathy in isolation (Alizadeh et al., 2018; Barbosa et al., 2008; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007). Most randomized controlled trials exploring PT management for LHBT pain involve the utilization of biophysical agents (ultrasound, electrotherapy, extracorporeal shockwave therapy, and iontophoresis) and are of questionable study quality (Alizadeh et al., 2018; Barbosa et al., 2008; Diercks et al., 2014; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007). Invasive surgical intervention is one approach to managing chronic biceps tendinopathy pain, therefore, to potentially avoid such procedures it is essential for physical therapists to recognize other interventions that may be effective in treating LHBT tendinopathy (McDevitt, Snodgrass, et al., 2020). A retrospective chart review is the first step in determining the typical PT interventions utilized in this population to support the next steps, which may include the development of randomized intervention trials. The purpose of this retrospective chart review was to investigate the use of PT prior to biceps tenodesis and tenotomy surgeries by assessing the number of visits and use of different interventions and whether they were active or passive. A secondary objective was to report on the themes of PT interventions used in treatment.

4.5 Methods

4.5.1 Study Design

This was a retrospective observational cohort study of patients who underwent biceps tenodesis or tenotomy for biceps tendinopathy in a large healthcare system from March 15, 2016, through March 15, 2020, with presurgical physical therapy utilization (active and passive billing codes) extracted for each individual up to 24 months prior to surgery. To guide study reporting, the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD),(Benchimol et al., 2015) statement was utilized, an extension of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2014).

4.5.2 Data Source

Data were extracted from electronic medical records in the Epic database of the University of Colorado Health system. These data include person-level data for all outpatient physical therapy visits. They also included information about physical therapy procedures and subsequent biceps tenodesis or tenotomy surgery.

4.5.3 Data Collection Procedures

This retrospective medical chart review study was approved by the Colorado Multiple Institutional Review Board (Protocol 20-2235) and the Human Research Ethics Committee at the University of Newcastle (H-2021-0009).

4.5.4 Eligibility Criteria

The medical records of eligible patients between the ages of 18 and 85 years of age who underwent biceps tenotomy or tenodesis surgery at the University of Colorado Sports Medicine between March 15, 2016 and March 15, 2020 in the University of Colorado Health hospital-based system were included in the cohort. The study cohort was identified using Current Procedural Terminology (CPT) codes most used for biceps tenodesis (23430) and biceps tenotomy (23405) within a four-year period while excluding patients who underwent concomitant procedures such as rotator cuff repair (29827), distal clavicle excision (29824), and labral repair (23455 and 29807).

Arthroscopic biceps tenodesis (29828) was also excluded since this surgery is typically performed in conjunction with another surgery listed above. Subacromial decompression (29826) was not excluded since it is presumed not to interfere with the outcomes of biceps tenodesis or tenotomy. Patients who saw a physical therapist within two years prior to surgery for shoulder pain related to LHBT tendinopathy were included in the analysis. Data were initially filtered by an orthopedic research administrative staff by surgical CPT codes to track which patients had the surgery of interest (23430 and 23405) and dates of surgery to determine preliminary eligibility and determine patients who had the surgery of interest without other associated surgeries. March 15, 2020 served as the cut-off date as all ambulatory services and elective surgeries in the hospital system were significantly impacted by the COVID pandemic after this time period.

Two investigators (A.M, P.H) completed the next phase of detailed chart reviews on all patient records meeting inclusion criteria based on filtering of CPT codes and dates. Individual charts were reviewed to verify further inclusion based on rehabilitation billing codes, operative reports and rehabilitation notes.

4.5.5 Billing Code Data

Billing code data in the Epic database was initially used to screen which patients had the surgery of interest (23430 and 23405). Following the screening of surgery codes, CPT codes for rehabilitation informed the research team to which patients engaged with physical therapy prior to surgery (within 2-years of surgery). The use of PT prior to surgery was of interest including the number of individual rehabilitation visits. To satisfy the criteria for physical therapy utilization, patients needed to have at least 1 PT evaluation (97161-97163) specifically for a shoulder diagnosis (on the same side as the operative side) within 24 months prior to surgery. We also identified all rehabilitation visits based on physical therapy procedure codes, (Table 4.1). The research team did not record or analyze codes related to PT evaluation or assessment of the patient as the research question involved active and passive intervention codes.

Table 4.1 Description of Surgical and Rehabilitation Procedure Codes

Description of Surgical Procedure		**CPT Codes**
Biceps tenodesis		23430
Biceps tenotomy		23405
Subacromial decompression		29826
Description of Rehabilitation Procedure		**CPT Codes**
Physical Therapy Visit		97010-97799
Physical Therapy Evaluation-low complexity		97161
Physical Therapy Evaluation-moderate complexity		97162
Physical Therapy Evaluation-high complexity		97163
Physical Therapy Re-evaluation		97164
Active Physical Therapy Codes	Therapeutic exercise	97110 054299
	Therapeutic activity	97530 054301
	Neuromuscular Re-ed	97112
	Self-care home management	97535 54303
Passive Physical Therapy Codes	Manual Therapy	997140 054329
	Dry Needling	97799 600245 570629
	Ultrasound/Phono	97035 054282
	Hot/cold	97010
	Iontophoresis	97033
	Electrical stimulation	97014 97032
	TENS/ES	054311
Other	Vasopneumatic Device	97016
	Mechanical Traction	054309
	Physical Performance Test	054305

Abbreviations: CPT, Current Procedural Terminology; Re-ed, Re-education; TENS, Transcutaneous Electrical Nerve Stimulation; ES, Electrical Stimulation.

4.5.6 Qualitative Patient Data

Data obtained from a general chart review of the Epic database included patients' age, sex, procedural side (right or left) and baselines scores for patient-reported outcome measures including the numeric pain rating scale (NPRS) and The Shortened Disabilities of the Arm, Shoulder and Hand Questionnaire (QuickDASH). Surgical data collected included procedure(s) performed, date of surgery, and relevant perioperative and operative notes. Chart review of the treating physical therapists' notes included the date of PT episode relative to the surgery date, PT problem list (to determine if the patient had anterior shoulder pain vs low back pain or other complaints), shoulder physical examination findings (pain localization, palpation, range of motion, Speed's and Yergason's tests), and all PT notes in the episode of care (to document specific interventions related to the active and passive codes). Information from PT chart notes included examination and all follow-up treatments which were recorded. Data were extracted using a data collection template created in an excel spreadsheet.

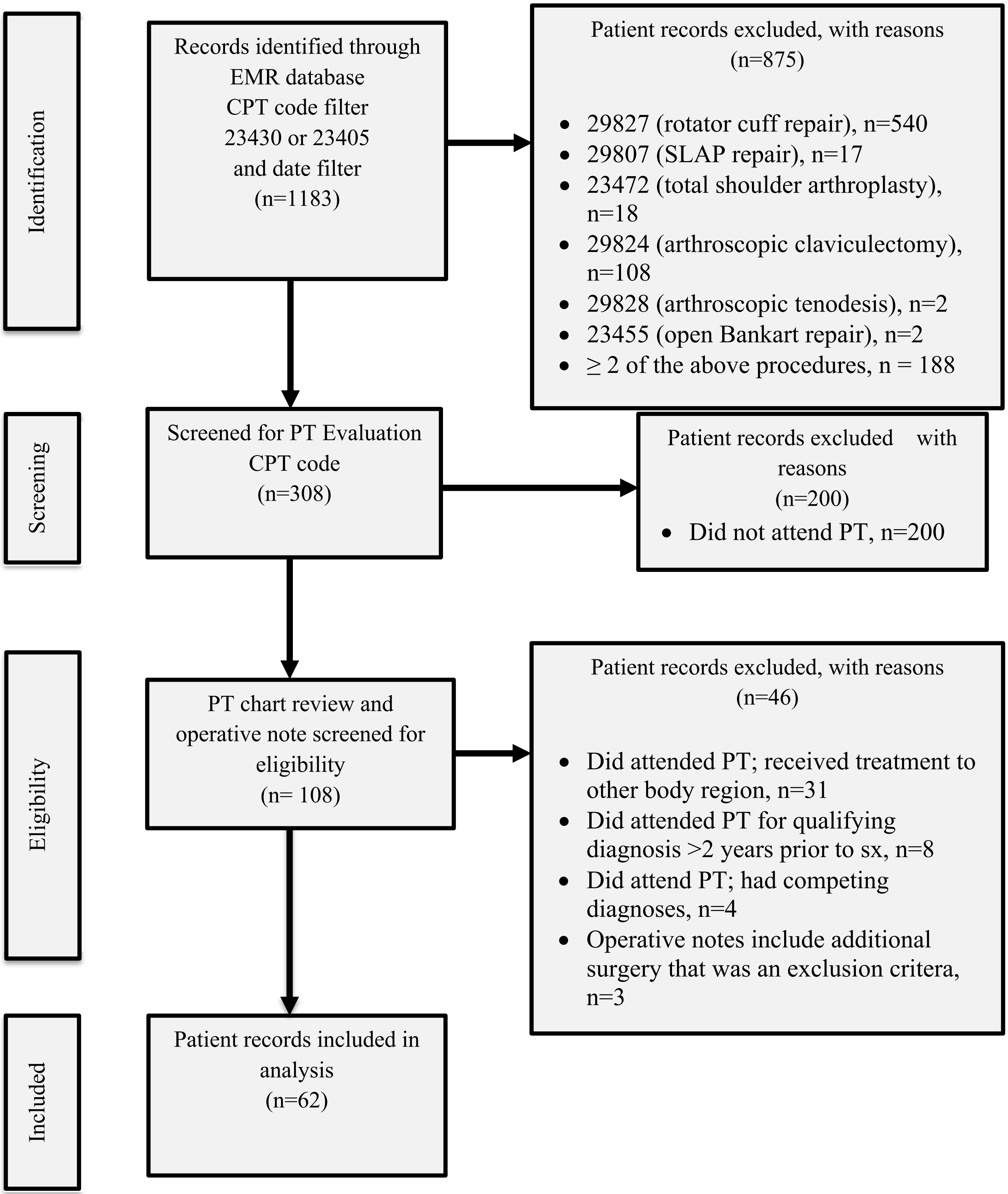
4.5.7 Data Analysis

The aim of the data analysis was to describe the frequency of patients who attended PT prior to surgery, therefore, the total number of visits patients attended physical therapy was calculated. A secondary aim was to describe the PT interventions received. Active and passive procedure codes were identified from the chart review. Active procedure codes were procedure codes used when the patient is actively participating as a component of the PT intervention; these included therapeutic exercise, therapeutic activity, neuromuscular re-education, and self-care home management. Passive procedure codes are codes used when the patient is passively receiving an intervention void of patient participation; these included manual therapy, therapeutic modalities, dry needling and other. The percentage of active and passive codes was calculated. Further, thematic analysis of the interventions within each code, based on a chart review of rehabilitation notes, was performed for both active and passive procedure codes. Two investigators individually categorized them to organize the qualitative, intervention data into themes. The 2 investigators (A.M, P.H) then came together to reach a consensus. Inconsistencies between the reviewers were resolved by discussion, and, if needed, a third reviewer was consulted (S.S). The types of interventions performed within each theme were tabulated. Due to the heterogeneous nature of the physical therapy interventions, a quantitative analysis of PT interventions was not feasible.

4.6 Results

Of 308 eligible patients who underwent biceps tenodesis or tenotomy surgery 79.9% (246/308) of the total cohort did not receive PT prior to surgery; 20.1% (62/308) patients attended PT for LHBT pain within 2 years of surgery and met the inclusion criteria for further analysis (Figure 4.1). Demographics of the cohort are described in (Table 4.2). The 62 patients who attended physical therapy had a total of 355 visits for their reported shoulder pain. Of the 62 patients who initiated physical therapy, 11.3% (7/61) received no additional care beyond the initial evaluation. The median number of PT visits for patients was 4 (IQR=3.5), 22 patients had 3 visits or less and 64.5% (40/62) participants had 4 or more visits of PT (Figure 4.2). After tabulation of active and passive procedure codes, 54.5% (533/978) of the codes were active and 45.5% (445/978) of the codes were passive. There was high utilization of the active codes for therapeutic exercise and activity [96.4% (514/533)] and the passive procedure code of manual therapy [84.3% (375/445)]. Among the remaining 3.6% (19/445) of active codes, interventions included neuromuscular re-education [2.3% (12/533)] and self-care home management [1.3% (7/533)]. Among the remaining 15.7% (70/445) of passive codes, interventions included therapeutic modalities [10.6% (47/445)], dry needling [3.4% (15/445)] to the shoulder region, and other [1.8% (8/445)] (Figure 4.3).

Figure 4.1 Flow Diagram of Eligibility



Abbreviations: CPT, current procedural terminology; EMR, electronic medical records; PT, physical therapy; SLAP, superior labrum anterior and posterior; sx, surgery.

Table 4.2 Descriptive Characteristics of Patient Sample (n=62)

Variable	**Data**
Age	43.32 (+/- 13.73)
Sex	30 (male), 32 (female)
Days prior to surgery†	250.74 (+/- 195.87)
Biceps sheath injection prior to PT	11/62 (17.7%)
Surgical procedure information	
Side of surgery	38 (right), 24 (left)
Biceps tenodesis	61/62 (98.4%)
Biceps tenotomy	1/62 (1.6%)
Patient reported outcome	
NPRS maximum (0-10)[a]	6.02 (+/- 2.48)
NPRS minimum (0-10)[a]	2.10 (+/- 2.15)
NPRS current (0-10)[a]	3.02 (+/- 2.32)
NPRS average (0-10)[a]	3.76 (+/- 2.37)
QuickDASH (0-100)[a]	42.78 (+/- 21.67)

Figure 4.2 Number of Physical Therapy Visits Attended

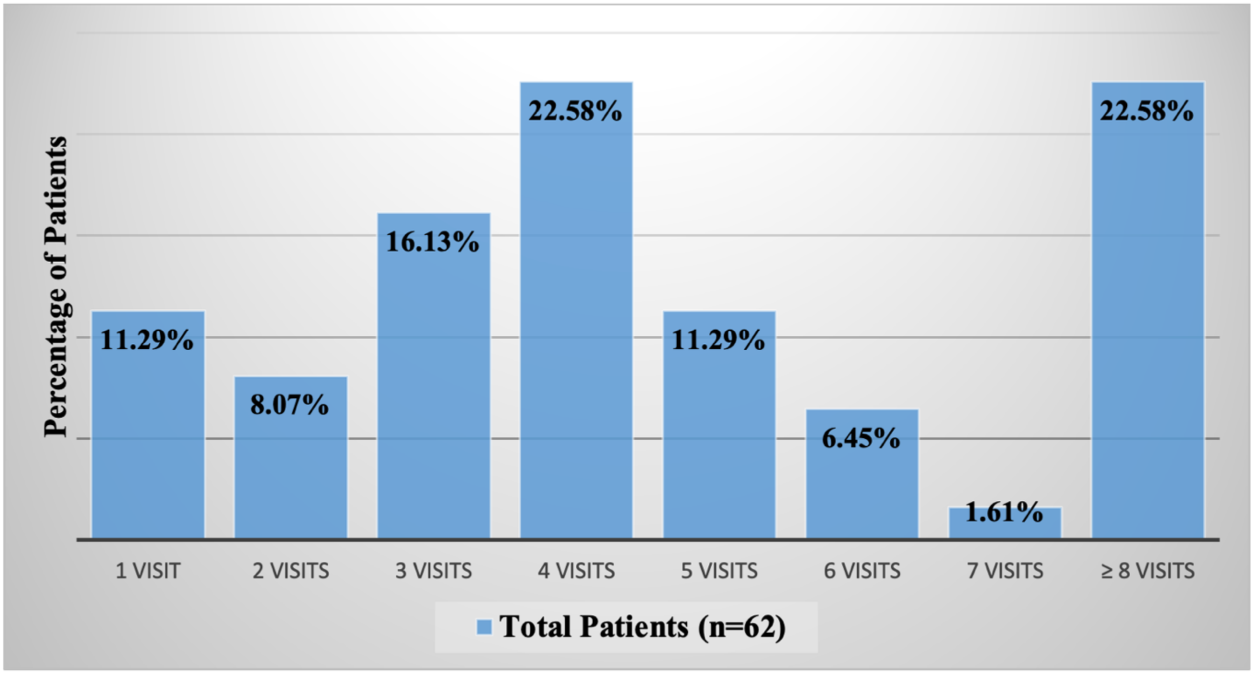
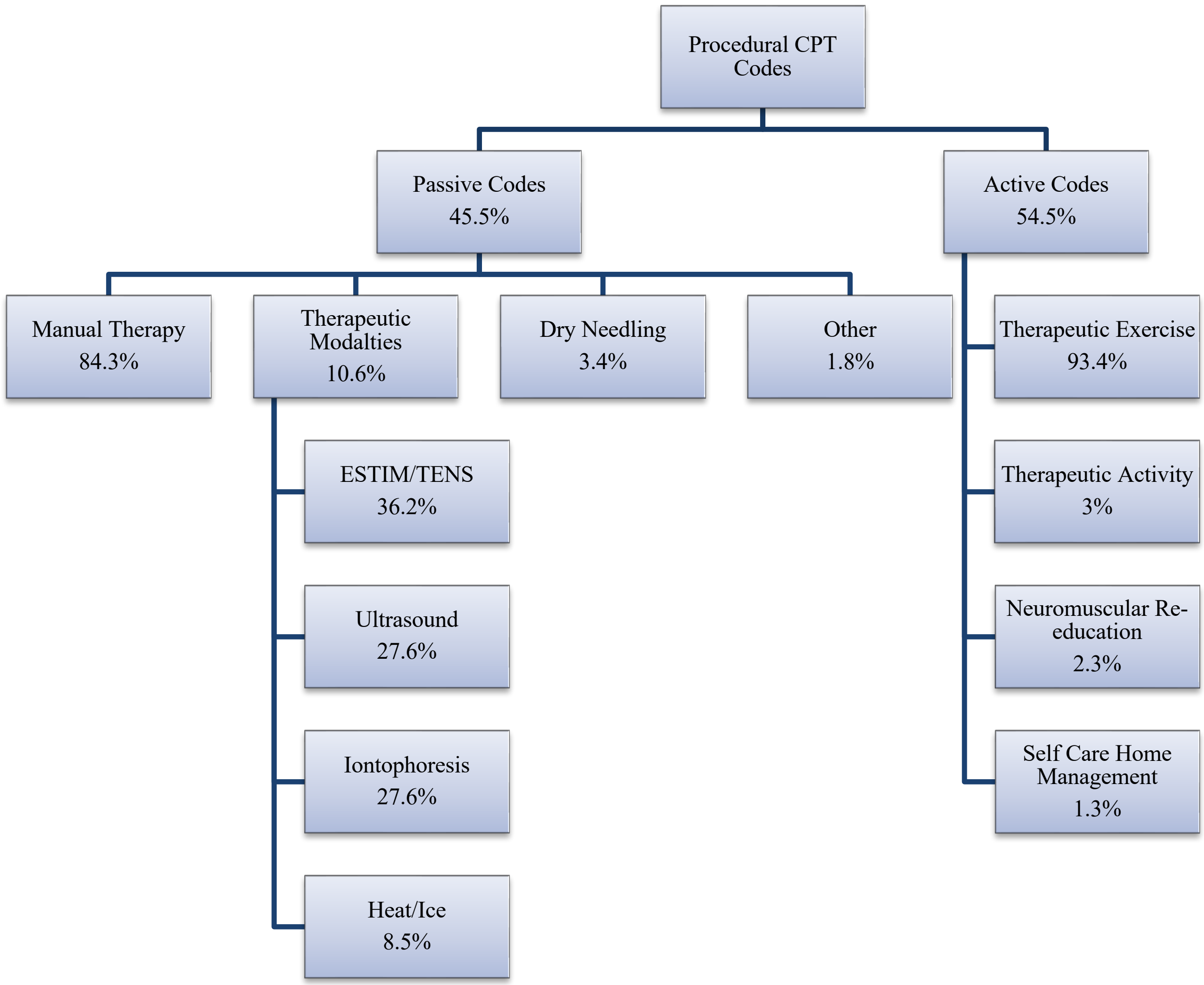


Figure 4.3 Description of Commonly Used Procedural Codes



Abbreviations: CPT=current procedural terminology; ESTIM=electrical stimulation; TENS=transcutaneous electrical nerve stimulation; Re-ed=re-education

Theme and coding synthesis of the chart notes within the active code of therapeutic exercise, revealed themes of resistance exercise/muscle performance (subthemes: tendon loading techniques and progressive resistance exercise) and muscle length/mobility (subthemes: stretching and flexibility and range of motion). Theme and coding synthesis of the chart notes within the active code of therapeutic activity included the theme of functional activity. The active code of neuromuscular re-education revealed the theme of motor control training (subthemes: stabilization and muscle re-education). The active code of self-care home management revealed the theme of motor control training (subthemes: stabilization and muscle re-education). Interventions specific to identified themes and subthemes of chart notes based on active codes can be found in Table 4.3.

Theme and coding synthesis of the chart notes within the passive code of manual therapy included themes of joint mobility (subthemes: non-thrust manipulation and thrust manipulation), soft tissue mobilization (subthemes: general techniques and specific techniques) to the shoulder region and LHBT and range of motion (subthemes: passive range of motion and active assisted range of motion). Among the other passive codes, theme analysis of chart notes included the use of biophysical agents which was the theme for the following billing codes (electrical stimulation, transcutaneous electrical nerve stimulation, iontophoresis, ultrasound/phonophoresis, and hot/cold therapy) typically applied to the shoulder region and/or LHBT. Synthesis of chart notes within the passive code of dry needling revealed the themes of dry needling without electrical stimulation and with electrical stimulation to LHBT, glenohumeral and scapular muscles in the shoulder region. Additional themes, subthemes and interventions derived from chart notes of passive codes can be found in Table 4.4.

Table 4.3 Themes and Subthemes from Active Procedural Codes

Procedure Code	Theme	Subthemes and Interventions
Therapeutic Exercise	**Resistance Exercise/ Muscle Performance**	**Tendon Loading Techniques (target tissue and/or action)**
		Isometric tendon loading (biceps brachii muscle)
		Concentric tendon loading (biceps brachii muscle/shoulder flexion)
		Concentric tendon loading (biceps brachii muscle/elbow flexion)
		Eccentric tendon loading (biceps brachii muscle/shoulder flexion)
		Eccentric tendon loading (biceps brachii muscle/elbow flexion)
		Progressive Resistance Exercise (target tissue or action)
		Elbow flexion and shoulder flexion (biceps brachii muscle)
		Scapular muscles (upper/middle/lower trapezius, serratus anterior, rhomboid major/minor muscles)
		Rotator cuff internal (medial) rotation
		Rotator cuff external (lateral) rotation
	Muscle Length/Mobility	**Stretching and Flexibility (target tissue)**
		Pectoralis major and minor muscles
		Upper trapezius muscle
		Biceps brachii muscle
		Posterior rotator cuff muscles
		Glenohumeral medial (internal) rotators
		Latissimus dorsi muscle
		Range of Motion (region or joint)
		Active range of motion (shoulder)
		Active assisted range of motion with equipment (shoulder)
		Passive range of motion (shoulder)
		Active range of motion (thoracic spine)
Therapeutic Activity	**Functional Activity**	**Functional Activities**
		Reaching, lifting and overhead activity
		Occupation specific
		Sport specific
Neuromuscular Re-education	**Motor Control Training**	**Stabilization**
		Lumbar, hip, and abdominal stabilization
		Scapular stabilization

		Muscle Re-education
		Shoulder re-education (unspecified)
		Scapular re-education (unspecified)
		Proprioceptive neuromuscular re-education to scapula
		Kinesio® Taping techniques
Self-Care Home Management	**Patient Education**	**Posture Education**
		Postural control (static) activity
		Postural control (with movement) activity
		Activity Related Education
		Activity modification
		Avoid aggravating activities
		Active recovery
		Rest
		Load modification
		Pain Education
		Shoulder positioning for decreased pain (with activity and at rest)
		Expectations anticipating and following surgery

Table 4.4 Themes and Subthemes from Passive Procedure Codes

Procedure Code	Theme	Subthemes and Interventions
Manual Therapy	Joint Mobility	**Non-thrust Manipulation (grade I-IV) Region**
		Glenohumeral joint
		Thoracic spine
		Cervical spine
		Acromioclavicular joint
		Thrust Manipulation (grade V) Region
		Thoracic spine
		Cervical spine
	Soft Tissue Mobilization	**Specific Techniques (target tissue)**
		Deep transverse friction (biceps brachii muscle, LHBT)
		Trigger point therapy (biceps brachii muscle)
		Instrument-assisted soft tissue mobilization (biceps brachii muscle, shoulder)
		General Techniques (target tissue)
		Soft tissue techniques (biceps brachii muscle)
		Soft tissue mobilization (periscapular muscles)
		Soft tissue mobilization (scapular muscles)
		Soft tissue mobilization (rotator cuff muscles)
		Soft tissue mobilization (cervical region)
	Range of Motion	**Passive Range of Motion (region or joint)**
		Passive range of motion (shoulder)
		Passive range of motion (scapula)
		Active Assisted Range of Motion (region or joint)
		Active assisted range of motion (shoulder)
Electrical Stimulation	Therapeutic Modalities	**Electrical Stimulation (target tissue)**
		Shoulder and anterior shoulder (with heat or ice and without heat or ice)
TENS		**TENS (target tissue)**
		Shoulder
Iontophoresis		**Iontophoresis (target tissue)**
		Iontophoresis with dexamethasone (anterior shoulder/LHBT)
Ultrasound/ Phonophoresis		**Ultrasound/Phonophoresis (target tissue)**
		Ultrasound (long head of biceps tendon and anterior shoulder)

Hot/Cold		**Thermal Agents (target tissue)**
		Moist heat (shoulder or cervical region)
		Cold pack (shoulder)
		Ice massage (anterior shoulder)
Dry Needling	**Dry Needling without Electrical Stimulation**	**Dry Needling without Electrical Stimulation (target tissue)**
		Dry needling (long head of the biceps tendon)
		Dry needling (biceps brachii muscle)
		Dry needling (rotator cuff muscles)
		Dry needling (upper trapezius)
		Dry needling (deltoid)
	Dry Needling with Electrical Stimulation	**Dry Needling with Electrical Stimulation Location (target tissue)**
		Dry needling (deltoid)
		Dry needling (rotator cuff muscles)
		Dry needling (upper trapezius)
		Dry needling (biceps brachii muscle)
		Dry needling (pectoralis major)
		Dry needling (latissimus dorsi)

Abbreviations: LHBT=long head of the biceps tendon; TENS=transcutaneous electrical nerve stimulation

4.7 Discussion

The purpose of this retrospective review was to report on the use of PT for the treatment of LHBT tendinopathy by describing the number of visits and the use of active and passive interventions as defined by procedure codes. A secondary objective was to report on the interventions utilized as described in the PT chart notes. Our results indicate overall low utilization of PT prior to surgery for individuals with LHBT (62 patients over two years in a large hospital system). Treating therapists utilized active interventions slightly more than passive interventions, as defined by the procedural codes they selected. The most common interventions were therapeutic exercise (progressive resistance exercise, tendon loading techniques, and stretching) and manual therapy (joint mobility, soft tissue mobilization, and range of motion), suggesting that a multi-modal approach is being utilized. However, there is a lack of evidence for the treatment of LHBT tendinopathy in isolation, therefore these findings provide a first step in understanding how physical therapists manage patients with LHBT tendinopathy.

The following sections aim to better explain these findings, interpret the findings in the context of PT care for shoulder pain including LHBT tendinopathy, and highlight clinical implications, limitations, and future directions for research.

4.7.1 Physical Therapy Utilization and Visits

Of patient records meeting eligibility criteria, only 20.1% of patients attended PT for LHBT pain within 2 years prior to biceps tenodesis or tenotomy surgery. Similarly, in a study of patients who had arthroscopic rotator cuff repair, only 21% of patients received some form of PT in the year prior to their surgery (Malik et al., 2020) which is consistent with our results. The combined results of the current medical records review and the study by Malik et al. (2020) are surprising, given contemporary evidence has shown PT is effective for the management of shoulder pain (Diercks et al., 2014; Pieters et al., 2020). Patients may lack knowledge of the benefits of PT management for shoulder pain, and patients may have barriers to attending PT or may not want to attend due to unknown reasons. According to a recent article on patient expectations, one factor that may affect patients seeking PT care may be that patients lack understanding of PT care including the role of PT (Subialka et al., 2022). Further, patients may not be referred for PT by their general practitioner or specialist, or patients may have had prior PT for LHBT with limited success. In addition, LHBT tendinopathy is difficult to diagnose (Ejnisman et al., 2010; Krupp et al., 2009; R. B. Lewis et al., 2016) which may further complicate management pathways.

The median number of PT visits for participants was 4 (IQR=3.5), and 40 (64.5%) patients had 4 or more visits to PT. In a study of Medicare beneficiaries with just under 2000 episodes of care for low back, shoulder, or knee pain, patients attended PT for 6.8 visits (SD=4.7) on average over a median of 27 days (Fritz et al., 2011). The results of this medical records review demonstrated a lower number of visits per patient for LHBT which may relate to 1) access issues in a large hospital-based system, 2) other patient-specific reasons stated above, 3) patients in the sample are active, and younger (mean age was 43 years +/-13.7), 4) patients may feel equipped to manage their care independently through a home program or other avenues.

4.7.2 Procedure Codes and Intervention Themes

The results of this review demonstrate high utilization of active interventions (54.5% of procedure codes) with therapeutic exercise and activity (96.4%) being the most utilized intervention codes. Therapeutic exercises are activities that include specific muscles at specific joints while therapeutic activities are dynamic activities used to increase functional performance. A recent update of systematic reviews made a strong recommendation for "exercise therapy" as the first-line treatment to improve pain, mobility, and function in patients with subacromial pain syndrome (Pieters et al., 2020), however, it is difficult to determine if these recommendations extend to managing pain specific to LHBT tendinopathy. These conditions of the shoulder have some symptoms in common, and in some patients present concurrently. Therefore exercise-based interventions recommended for patients with subacromial pain syndrome such as strengthening, flexibility, and range of motion may also have benefits for LHBT pathology. Intervention themes related to therapeutic exercise included resistance exercise/muscle performance, progressive resistance exercise, and stretching. Several interventions were utilized in the exercise subtheme of tendon loading techniques such as heavy slow load activities which are well supported in the literature for the treatment of tendinopathy (Cardoso et al., 2019; Mascaró et al., 2018) therefore, therapists may be practicing in alignment with guidelines for managing tendinopathies. The main interventions related to the procedural code of therapeutic activity were functional activities (such as reaching, lifting, occupation, and sport-specific activities). Overall, the utilization of therapeutic exercise and activity by the clinicians who treated this sample, is in alignment with current recommendations for subacromial pain syndrome (Diercks et al., 2014; Kelley et al., 2013a; Pieters et al., 2020).

Passive interventions represented 45.5% of the procedure codes, with high utilization of manual therapy (86.2%) among the passive codes. In an update of systematic reviews specific to patients with shoulder pain, manual therapy (joint mobilization and manipulation, soft tissue techniques, neurodynamic mobilizations, and mobilizations with movement) was an intervention with a strong recommendation, especially when combined with exercise (Pieters et al., 2020). Manual therapy interventions utilized by PTs in this medical chart review included soft tissue mobilization, non-thrust and thrust manipulation of the glenohumeral joint, thoracic spine, and cervical spine which are consistent with contemporary evidence for managing subacromial pain syndrome (Diercks et al., 2014; Mintken et al., 2016; Pieters et al., 2020). While it is encouraging that PT interventions were consistent with contemporary evidence for the treatment of shoulder pain, it is unknown if these evidence-based recommendations are applicable to LHBT tendinopathy. A recent Delphi study on PT interventions for treating individuals with LHBT tendinopathy included the following themes within the manual therapy recommendation: soft tissue mobilization (including deep transverse friction and trigger point release), and thrust and non-thrust manipulation to the glenohumeral joint, thoracic spine and cervical spine (McDevitt et al., 2022) which do align with the findings of this medical records review. Additional Delphi study recommendations included the use of a multimodal approach including exercise combined with manual therapy which again, is consistent with our current findings (McDevitt et al., 2022).

Among the 20% of passive codes in the current study not attributed to manual therapy, interventions included therapeutic modalities (10.5%) and dry needling (3.4%) to the shoulder region and LHBT. Several studies have investigated the use of therapeutic modalities to treat pain specific to the LHBT including iontophoresis, ultrasound, low-level laser, and extracorporeal shock wave therapy, with reported improvements in pain or function (Alizadeh et al., 2018; Liu et al., 2012; Taskaynatan et al., 2007; Xiao et al., 2021). A case series of ten individuals with LHBT tendinopathy reported reduced pain and disability and avoided surgery after dry needling, stretching, and tendon loading techniques (McDevitt, Snodgrass, et al., 2020). Passive interventions utilizing therapeutic modalities including iontophoresis, electrical stimulation, and ultrasound, therefore, appear to be consistent with the available evidence.

4.7.3 Limitations

A limitation of this study was that we were unable to identify patients with LHBT tendinopathy who did not have biceps tenodesis or tenotomy surgery. We did not use the ICD-10 diagnosis codes M75.21 and M75.22 for bicipital tendinitis of the right and left shoulder respectively because, in the medical records system analyzed in this study, diagnoses of the shoulder are often coded more broadly using the ICD-10 code for shoulder pain M25.51. There are a number of reasons clinicians may use this code, one of which is that LHBT pathology often accompanies other primary shoulder pathologies and LHBT is difficult to definitively diagnose (Ahrens & Boileau, 2007) and may not be diagnosed at an initial visit. However, this makes it difficult to track patients with a specific diagnosis in electronic medical records. Our only mechanism to track patients with the pathology of interest (LHBT tendinopathy) was to follow them retrospectively from their date of surgery. As a result, another related limitation is the inability to report on patients who went to PT prior to surgery and improved and therefore did not elect to have surgery. Again, the use of ICD-10 codes that are more general such as “shoulder pain” creates a barrier to identifying patients with a specific diagnosis. This retrospective chart review would have been more comprehensive if LHBT tendinopathy was more explicitly diagnosed; this would have afforded us the ability to track patients who went through a course of PT regardless of whether they had surgery. We are therefore unable to determine if the number of visits and PT-based interventions provided would have been different for those who did not have surgery and we are unable to determine if our studied sample is more inclusive of those who “failed” conservative management. Further, it is possible that patients excluded from our sample received physical therapy care outside of the healthcare system which is challenging to track due to a lack of documentation including billing codes.

4.7.4 Clinical Implications

Physical therapy is underutilized prior to biceps tendon surgeries and few guidelines exist to guide clinical care for LHBT tendinopathy. Guidelines exist for the management of subacromial pain syndrome and for tendinopathy, including tendinopathies of the rotator cuff, which may serve as a guide due to the paucity of recommendations specific to LHBT tendinopathy. Based on this review, when PT was utilized, active interventions were utilized more often than passive interventions, and the common themes from clinician records of exercise, manual therapy, and therapeutic modalities were all consistent with evidence-based recommended interventions used to treat subacromial pain syndrome and tendinopathy. Further research in the form of randomized controlled trials is needed to determine if these intervention approaches provide optimal effective care for patients with LHBT tendinopathy.

4.8 Conclusion

Physical therapy was not commonly utilized prior to undergoing biceps tenodesis and tenotomy surgery by patients seeking care in a large hospital-based health system. Further research is needed to understand the reasons for poor utilization and whether the PT interventions commonly utilized provide optimal care for patients with LHBT tendinopathy.

CHAPTER 5. Accuracy of Long Head of the Biceps Tendon Palpation by Physical Therapists; an Ultrasonographic Study

5.1 Overview

Chapter 3 reported on interventions described in the literature to treat LHBT tendinopathy, some of which are reliant on locating the LHBT by manual palpation in order to effectively implement the intervention. In Chapter 4 we described interventions used to treat patients with LHBT tendinopathy who elected to have surgery, followed retrospectively in their course of PT 24 months prior to surgery. Patients were not able to be identified at baseline possibly due to difficulty in accurately identifying patients with LHBT pathology. Accurate diagnosis of LHBT typically involves a combination of clinical tests (referred to as special tests) including palpation of the LHBT tendon for pain. Clinical tests (Speed's, Yergason's) used for diagnosing LHBT lesions have been shown to have high sensitivity, poor to moderate specificity, poor predictive value and low likelihood ratios (Holtby & Razmjou, 2004; Kibler et al., 2002; McFarland et al., 2010) which makes diagnosis without the use of imaging difficult (Gazzillo et al., 2011). Also, recent evidence suggests that tendon pain is the key clinical feature and imaging may not be helpful in diagnosing tendinopathy (Cardoso et al., 2019; Scott et al., 2020). Accurate palpation of the LHBT may be an important skill to properly diagnose LHBT tendinopathy, yet physical therapists may not feel equipped to effectively palpate the LHBT. In addition, physical therapy-based interventions specific to the tendon including soft tissue mobilization techniques and dry needling (described in Chapters 3 and 4) also require accuracy in identifying the LHBT with palpation. Therefore, further investigation of the ability to accurately and reliably palpate the LHBT is warranted to guide examination and treatment. As a result, it is crucial to initiate a more accurate diagnosis of individuals with LHBT tendinopathy through a combination of clinical assessments (excluding imaging) in order to determine the eligibility of participants for a randomized controlled trial or a cohort study. This chapter reports on a reliability study, included in this thesis, which explores if physical therapists can palpate the LHBT (accurately and reliably) with the use of ultrasound as the gold standard.

The reliability study included asymptomatic male and female volunteers ages 18-65. Physical therapists palpated the LHBT of all participants using two evidence-based positions. The goal was to determine if physical therapists could accurately and reliably perform the palpation which will inform challenges with identifying the condition. Further, this study sought to determine if palpation can be used as a useful clinical test in diagnosing individuals with LHBT tendinopathy, or if reliance on other clinical tests is more important. The results of this study were that physical therapists exhibited poor inter-rater reliability palpating the LHBT in 2 positions with a reported accuracy to be just under 50% in asymptomatic participants in 2 positions. However, due to the lack of evidence on the 2 identified positions used to palpate, it is possible that other palpation positions may be more accurate or, there needs to be an increased reliance on other clinical tests. Further, the palpation of a pathological and/or painful tendon, often used to accurately diagnose LHBT tendinopathy clinically, may be an important factor in accurate palpation and subsequent diagnosis. This study provided an understanding of the challenges associated with palpation of the LHBT, especially in a non-symptomatic population. Due to the high prevalence of LHBT injuries, accurate palpation of this tendon is important when considering its importance to diagnosis and in the implementation of interventions such as injections, dry needling and other therapeutic modalities targeting the LHBT. Further research may be necessary to determine the best position to optimally palpate and examine the LHBT.

5.2 Citation

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Original Article

Accuracy of long head of the biceps tendon palpation by physical therapists; an ultrasonographic study

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Abstract. [Purpose] Examination and treatment of the long head of the biceps tendon (LHBT) requires accurate palpation. The purpose of this study was to determine physical therapists' reliability and ability to accurately palpate the LHBT in two arm positions with ultrasound as the gold standard. [Participants and Methods] Examiners palpated the LHBT within the intertubercular groove (ITG) of the humerus on the bilateral shoulders of 32 asymptomatic (21 female; 24.3 ± 1.9 years) participants in 2 arm positions. The magnitude of distance between a marker and the border of the ITG was compared between 2 positions using an independent t-test. Percent accuracy was calculated. [Results] Inter-rater reliability was poor (position 1, k=1.04; position 2, k=0.016). Overall accuracy rate was 45.7% (117/256). Accuracy was 49.2% (63/128) and 42.2% (54/128) for testing position 1 and position 2 respectively. Mean distance palpated from the groove was M=2.58 mm (± 6.2 mm) for position 1 and M=3.77 mm (± 6.6 mm) for position 2. Inaccurate palpation occurred medially 72.3% (47/65) and 93.2% (69/74) in position 1 and position 2 respectively. [Conclusion] Results of this study did not support one arm position being more accurate over another for LHBT palpation.
Key words: Palpation, Accuracy, Long head of biceps tendon

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INTRODUCTION

Shoulder pain is common with a reported incidence ranging from 7–26% in the general population[1)], up to 53% in certain working populations[2)] and a reported lifetime prevalence of up to 67%[1)]. Additionally, studies have reported low rates of perceived recovery for individuals with a primary complaint of shoulder pain[3, 4)]. The prognosis is generally poor, and Rekola and colleagues[5)] reported that over 50% of individuals with neck or shoulder pain are likely to experience a recurrence of their symptoms and pursue additional episodes of care within 12 months. Several authors have reported a high economic burden of shoulder pain on the medical system[6–9)]. The financial burden associated with the evaluation and management of shoulder pain has been estimated at 3 billion dollars annually in the United States[10, 11)].

Pathology of the long head of the biceps tendon (LHBT) has long been recognized as a source of shoulder pain[12, 13)]. The condition can be debilitating and often impacts an individual's quality of life due to persistent pain with activity[14–16)]. The overall incidence of bicipital tendinopathy remains unclear[14, 17)] as it is commonly associated with other pathologies of the

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shoulder including anterior glenohumeral instability, rotator cuff disease and subacromial impingement[15–17].

LHBT pathology is difficult to identify and is therefore diagnosed through a combination of patient identified pain location, clinical palpation, and other clinical findings including clinical tests involving specific movements of the shoulder designed to reproduce the patient's pain[18]. Many of the clinical tests (Speed's, Yergason's) for diagnosing LHBT lesions have been shown to have high sensitivity, poor to moderate specificity, poor predictive value and low likelihood ratios[19–21]. Accurate diagnosis of LHBT pathology can be difficult without the use of imaging due to the relatively poor psychometric properties associated with clinical tests used to diagnose the condition[18]. Moreover, tenderness over the bicipital groove is still considered one of the most common clinical tests for diagnosing biceps tendinopathty[12, 15, 22]. Therefore, accurate palpation of the LHBT is critical for accurate diagnosis and subsequent management for LHBT pathology.

Recommended shoulder positions to palpate the LHBT appear to be based on anatomical theory or personal preference as no evidence exists to suggest whether one position is more effective for palpation than another. One study found that 65% of patients with chronic anterior shoulder pain with clinical findings consistent with biceps tendinopathy, also had concomitant anatomic findings of variability in the anatomy of the bicipital groove (acute angle, flat groove, small medial groove)[23] thus making accurate palpation challenging. A study by Gazzillo et al.[18] investigated the overall accuracy of physicians palpating the LHBT of asymptomatic individuals in a position of 20–30° of shoulder abduction, 90° elbow flexion and full forearm supination. The examiners could rotate the humerus to fine-tune their palpation. They reported that physicians had, on average, only 5.4% agreement based on their definition of successful palpations[18]. Other positions that have been investigated in cadavers include the shoulder in adduction and 20° medial rotation and a position of shoulder extension with the "forearm behind the back", which is more typically used to palpate the supraspinatus tendon[24]. From these studies, it appears the positions with the most potential for accuracy might be with the shoulder in adduction and 20° medial rotation or the shoulder in 20–30° degrees abduction, 90° elbow flexion, full supination with the examiner's choice of rotation. However, few studies have used physical therapists as the palpating clinicians, and thus it is difficult to generalize the results of other palpation studies involving other healthcare providers to physical therapists due to differences in education related to training in the area of palpation. Physical therapists may be a patient's first point of contact to evaluate an individual's shoulder pain, therefore, it is important to determine physical therapists' ability to reliably and accurately locate and palpate the LHBT in any position. The purpose of this study was 1) to determine the inter-rater reliability and accuracy of physical therapists in palpating the LHBT and 2) to examine the accuracy of physical therapists palpation of the LHBT in two different shoulder positions.

PARTICIPANTS AND METHODS

A prospective single-blind validity study was performed to investigate the reliability and accuracy of physical therapists palpating the LHBT as compared to the location of the tendon as observed on ultrasound (US) images. A total of 32 asymptomatic male and female (21) volunteers were recruited. Participants were included if they were between the age of 18 and 65 years and were able to attend the data collection site for two hours on a specified day. Exclusion criteria included: any previous history of biceps tenotomy or tenodesis, history of shoulder surgery, shoulder pain, known bicipital tendon pathology or anatomic deformity of the shoulder. The study was approved through the Colorado Multiple Institutional Review Board (No. 17-1161) and all participants provided informed written consent before their participation. Two practicing physical therapists working full time in an outpatient orthopedic practice with 19 and 22 years of experience participated as palpating therapists. The palpating therapists did not receive any education or advanced training on how to palpate the LHBT, as we were interested in the clinical reliability and accuracy of physical therapists palpating the LHBT as they normally would in the clinical setting.

All US scans were performed on a Phillips iU22 US machine using a 12 MHz linear transducer (Philips Ultrasound Systems, Bothell, WA, USA). Short axis (transverse orientation to biceps tendon) grey scale images were taken for each palpated position and were saved for later analysis and measurement. An electronic digital inclinometer (Floureon DXL360S) was zeroed to be parallel to the surface of the examination table and was secured to the US transducer using elastic bands. The inclinometer calibration of 0° facilitated a standardized transducer position that would parallel the table for all measurements to control for consistency with how the images were taken. A standard goniometer was used to measure the two palpating positions.

All palpations occurred on the bilateral shoulders of each participant, in two positions. Therapists attempted to palpate the LHBT within the intertubercular groove (ITG) of the humerus in two test positions which were measured and stabilized before and after palpation by study investigators: position 1 was supine, with 90° elbow flexion, 0° shoulder abduction, 20° medial rotation[24]; position 2 was supine with 90° elbow flexion, 30° shoulder abduction and neutral (0°) rotation to allow examiner preference for the desired rotation[18]. The two positions were randomized for each participant to eliminate the potential for within-session practice effect. Additionally, the radiologist and palpating therapist were blinded to the exact degree of shoulder rotation, flexion and abduction for the above two positions.

Study investigator 1 prepared the participants in each of the two test positions, depending on randomization, using a goniometer to measure joint angles before the palpating therapist entered the room. Study investigator 2 stabilized the humerus before the palpating therapist entered the room. Once the palpating therapists entered the room, they were given instructions to: "palpate the LHBT in the ITG and attempt to position the LHBT parallel to the surface of the examination table". They then attempted to palpate the LHBT without moving the extremity (position 1) or palpated the LHBT after medially and laterally rotating the shoulder to their preference (position 2). Once the palpating therapist determined they had their palpating finger on the LHBT, they marked the position by using transpore clear surgical tape to secure a disposable, blunt stainless steel needle on top of the skin with the assumption that the needle was superficial to the biceps tendon over the ITG (Fig. 1a). Using a black marker they also drew a horizontal line on the tape bisecting the needle to verify the exact location of their palpation (in the caudad-cephalad direction) of the LHBT in the ITG (Fig. 1b). Study investigator 2 measured the therapist's preferred medial/lateral rotation position with a standard long-arm goniometer (Fig. 2). The palpating therapist would then leave the room. The radiologist would use real-time US to sonographically assess the magnitude and direction of the marker from the underlying LHBT and ITG (Fig. 3). The same procedure was repeated with two palpating therapists for both test positions (position 1 and position 2) on the right and left shoulder of each participant for a total of 128 total palpations per therapist.

All examinations were performed by a radiologist with 8 years of experience. The radiologist placed the transducer transversely over the blunt needle at the marked point superficial to the humerus with ample gel on the skin and with minimal pressure over the needle so as not to depress the underlying soft-tissue structures. This process assured standardization of the transducer position for each measurement. The transducer was placed on the black marker point and the needle was identified sonographically by its echogenic appearance, superficial location, and posterior reverberation artifact. When the needle, the LHBT, and the tuberosities were all visualized, an image was saved. Later, images were analyzed, and distances were measured between the needle and the medial or lateral borders of the ITG were recorded (Fig. 4). Measurements were taken based on the placement of a blunted stainless-steel 18-gauge needle which was used to mark and verify the palpation site for each therapists' palpation.

The primary aim was to determine both inter-rater reliability and the accuracy of palpation of the LHBT by physical therapists as compared to the actual position of the LHBT as viewed under US. The secondary aim was to determine which shoulder position was most ideal for LHBT palpation based on successful LHBT palpation accuracy rate. Successful palpation rate was defined as the therapists' palpation location being within the ITG as identified by US, or if outside of the groove, then within at least 2 mm from its medial or lateral border. The distance of 2 mm was utilized to account for the varying ITG widths along the length of the groove from superior to inferior combined with difficulty identifying clear medial ITG margins on ultrasonographic imaging due to natural variability in medial wall inclination[25]. Thus, needle placement relative to the groove was graded as being inside (inside or within 2 mm of either medial or lateral borders) or outside of the groove. The binary outcome was therefore: successful palpation or not. The accuracy of this binary outcome for each test position (position 1 and position 2) was determined by calculating the percent accuracy. The palpation location measurements within and <2 mm outside the ITG (our threshold for success) were negative numbers, and palpations occurring greater than 2 mm outside of the ITG were recorded as positive values. This variable was used to determine if there were significant differences between the two test positions, such that one position was more accurate for palpating than the other.

a b

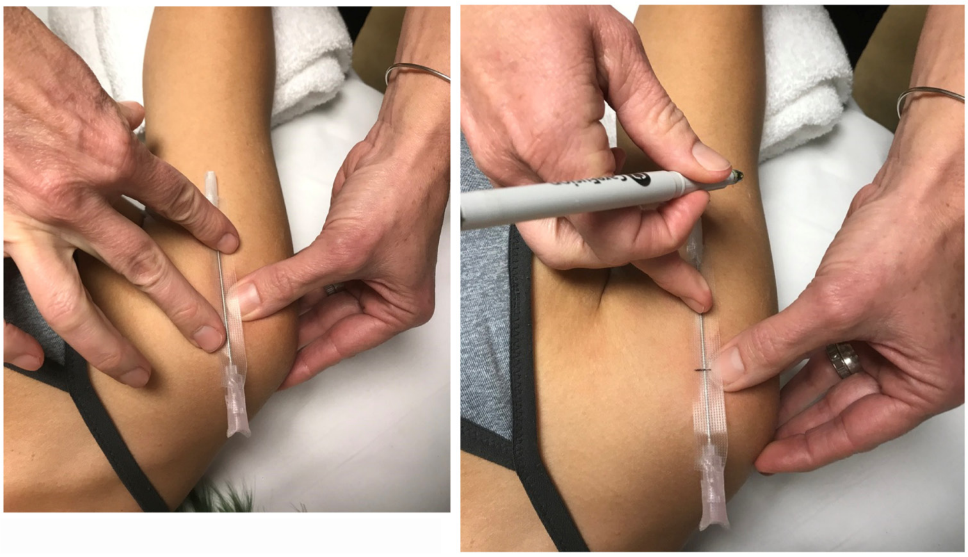

Fig. 1. a) Once the therapist determined they were on the LHBT, the position was marked by using clear surgical tape to secure a disposable, blunt stainless steel needle on top of the skin running parallel to the biceps tendon over the intertubercular groove. b) The palpating therapist drew a horizontal line on the tape with a black pen to verify the exact location of their palpation of the LHBT in the intertubercular groove.

Fig. 2. A study investigator used a goniometer to measure and record the medial/lateral rotation of the shoulder which was utilized in palpation position 2 while a study investigator stabilized the arm prior to the palpation.

Fig. 3. A digital inclinometer was attached to the transducer in order to standardize how the ultrasonographic images were taken. The radiologist used real time ultrasound to sonographically assess the magnitude and direction of the marker in relation to the underlying LHBT and borders of the intertubercular groove with the transducer head in a 0° position (parallel to the examination table).

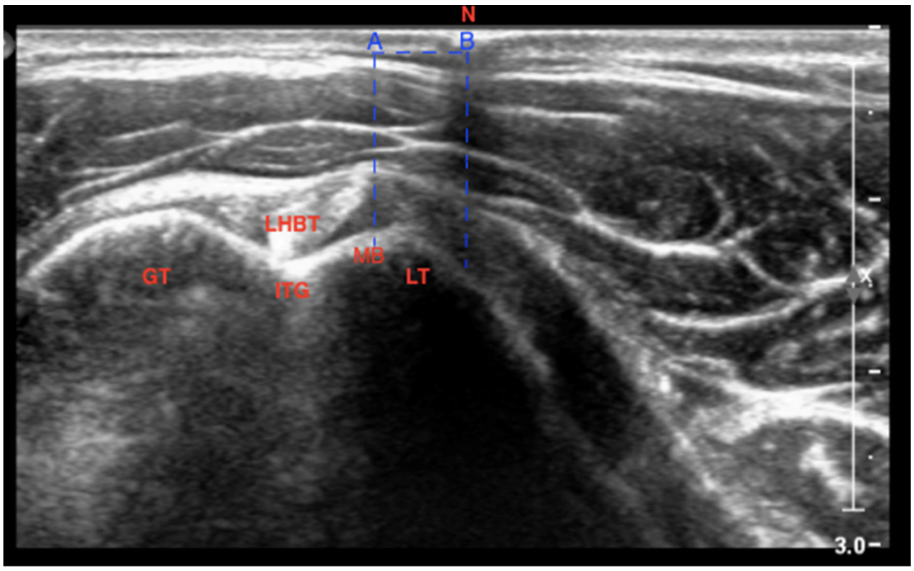

Fig. 4. When the needle, the LHBT, and the tuberosities were all visualized, an image was saved to be further analyzed at a later time. Distances from a line perpendicular to the medial (A) or lateral border of the intertubercular groove to the needle (B) were recorded. Abbreviations: GT, greater tuberosity; LT, lesser tuberosity; ITG, intertubercular groove; LHBT, long head of the biceps tendon; MB, medial border of ITG; N, needle.

To determine which shoulder position was best for achieving the highest palpation accuracy, the distance (mm) between the location palpated by the therapists (based on needle placement) and the location of the LHBT in the ITG as identified by US was measured in order to determine a magnitude of accuracy or inaccuracy. This was recorded as a continuous variable, in mm. An independent t-test was used to determine the difference between the mean distances (palpation location to location identified with US) for each test position. If there was a difference between test positions, then the position with the smallest mean distance would be considered the most accurate.

Sample size calculation was based on determining inter-rater reliability and accuracy (as a binary outcome) between two test positions however, the measure of accuracy was percent accuracy versus utilizing sensitivity and specificity as the participants were healthy individuals. Based on a prior study investigating the accuracy of LHBT palpation in physicians with a sample size of 25[18], a determination was made to exceed that sample size and include 32 participants to account for missing data or US image failure in order to assure adequate power. Descriptive data were reported for participants characteristics. Inter-rater reliability was calculated using Cohen's Kappa (k) coefficient. The overall accuracy and magnitudes of accuracy for each position were reported using percent accuracy and independent t tests respectively. A chi-square (χ^2) test was performed to determine the difference between the magnitudes of accuracy of the two palpation positions.

RESULTS

Participants consisted of 32 asymptomatic individuals (21 female) with a mean age of 24.3 (± 1.9 years) and a body mass index mean of 23.5 (± 1.9 kg/m^2). An alpha level of 0.05 was used as an indication of significance for all statistical tests. The calculated Cohen's Kappa to determine inter-rater reliability was $k=0.04$ for position 1 and $k=0.016$ for position 2. The overall accuracy rate was 45.7% (117/256). Accuracy with position 1 was 49.2% (63/128) and position 2 was 42.2% (54/128). The overall accuracy of therapist 1 was 52.3% (67/128) and therapist 2 was 39.1% (50/128). A chi-square test of independence was performed to determine if one position was more accurate over the other. The chi-square value demonstrated no difference between the two positions, χ^2 (2, N=256)=1.275, p=0.259. Overall, palpations were localized by a mean (M)=2.58 mm (± 6.17 mm) outside the defined border of success (within 2 mm of the ITG) in position 1 and M=3.72 mm (± 6.56 mm) in position 2. Missed palpations occurred, more commonly, medial to the ITG rather than lateral: 72.3% (47/65) of misses occurring medially in position 1 and 93.3% (69/74) of misses occurring medially in position 2 (Table 1).

DISCUSSION

The present study found that therapists exhibited poor inter-rater reliability palpating the LHBT in both tested positions based on the low Cohen's Kappa value. Additionally, the present study reported accuracy to be just under 50% in asymptomatic participants in 2 positions (position 1 was supine, with 90° elbow flexion, 0° shoulder abduction, 20° medial rotation[24]; position 2 was supine with 90° elbow flexion, 30° shoulder abduction and neutral (0°) rotation to allow examiner preference for the desired rotation[18]. The palpation accuracy rate in the current study was higher than that previously reported for physicians palpating the LHBT[18] (5.3%), using the presented methods and positions. In the present study, both study positions for palpation of the LHBT had similar accuracy rates (49.2% (63/128) for position 1 and 42.2% (54/128) for position 2) and magnitude of accuracy (no difference between positions), with the majority of missed palpations occurring medially in both positions. These results suggest neither of the chosen supine positions can be highly recommended for clinical practice, and due to a lack of additional evidence on the most ideal position, either may be appropriate for palpating the biceps tendon. It remains plausible that palpation in positions other than supine may be more accurate. Additionally, it is unknown if palpation accuracy would have been higher if therapists had been trained on the two study positions.

A number of measurement factors may have influenced the results of palpation accuracy including the prescriptive nature of the US transducer head and subsequent images and the difficulty in clearly identifying the ITG margins via ultrasonographic imaging due to the inter-subject variability in medial wall inclination of the ITG. Therefore, it is difficult to determine the potential magnitude of measurement error versus therapists' palpation error. Nevertheless, the reported palpation methods

Table 1. Accuracy in palpating the LHBT in the intertubercular groove

Position	Therapist 1	Therapist 2	Medial misses	Overall accuracy	Average distance*	Average difference**
Position 1 (n=128)	51.6% (33/64)	46.9% (30/64)	72.3% (47/65)	49.2% (63/128)	2.58 mm (± 6.2)	p=0.1514
Position 2 (n=128)	53.1% (34/64)	31.3% (20/64)	93.2% (69/74)	42.2% (54/128)	3.77 mm (± 6.6)	CI (−2.17 to 0.422)
Position 1 and Position 2	52.3% (67/128)	39.1% (50/128)	83.4% (116/139)	45.7% (117/256)		χ^2 (2, N=256) =1.275, p=0.259

SD: Standard deviation; mm: millimeters; CI: confidence interval (95%); χ^2: chi-square; p: p value corresponding to the difference between average distances of positions.
*Average distance from needle to edge of the groove, mm (± SD).
**Difference in 'average distance' between Position 1 and Position 2.

resulted in higher palpation accuracy rates as compared to a previous study[18] however, study population and methodologies between studies differed. There are additional factors that may influence palpation accuracy including clinician experience, participant body mass index, participant age, and US methodology.

Examination of musculoskeletal pathology relies heavily on accurate palpation of musculoskeletal structures. The LHBT originates at the supraglenoid tubercle and superior glenoid labrum and is extra synovial despite its intra-articular origin[14]. The LHBT becomes extra-articular when it enters the bicipital groove by way of the contours of the tuberosities[15]. The groove has been defined as the area between the greater and lesser tuberosities extending superiorly from the margin and the greater tuberosity of the humerus inferiorly to where the depth was less than 2 mm[26]. The tendon itself is approximately 9 cm long with a diameter of 5–6 mm[15]. The mean diameter of the biceps tendon sheath has been shown to range from 4.1 mm[27] to 4.3 mm[23], and may increase in size when inflammation is present. Based on the reported variability in the size of the tendon diameter combined with the relatively small size of the ITG and LHBT, the authors would argue that accuracy with manual palpation would be expected to be challenging. We believe that an accuracy rate of just under 50% combined with palpations localized at 2.58 mm (position 1) and 3.72 mm (position 2) may be acceptable in an asymptomatic population, however, higher accuracy rates would be necessary to provide targeted interventions. Physical therapists rely on both their knowledge of anatomical structures and digital palpation to examine and treat individuals with shoulder pain, however, the most ideal position to palpate the biceps tendon remains unknown.

Inconsistency exists regarding the most optimal position to palpate the biceps tendon. The position used in a palpation accuracy study of the LHBT was supine with 20–30° degrees of shoulder abduction, 90° elbow flexion, and full forearm supination with the examiners' preference for medial and lateral rotation in supine[18]. Conversely, Mattingly and Mackerey found that the best position to expose and access the LHBT in cadavers was 0° of shoulder abduction/adduction with 20° degrees of medial rotation[24]. We found that neutral shoulder rotation places the LHBT under the middle anterior deltoid and lateral shoulder rotation places the LHBT under the lateral aspect of the deltoid muscle[24]. However it is difficult to generalize recommendations based on this study as it was performed on cadavers[24]. While the patient is positioned in sitting, Matsen and Kirby recommend palpating the tendon 3 to 6 cm below the anterior acromion with the shoulder in 10° of medial rotation; while Gill and colleagues also suggest 10° shoulder medial rotation with the shoulder in adduction[12]. As a result of this variability, we sought to determine the palpation accuracy of two previously described positions. Position 1 was supine, with 90° elbow flexion, 0° shoulder abduction, 20° medial rotation as reported by Mattingly and Mackery[24]; position 2 was supine with 90° elbow flexion, 30° shoulder abduction and neutral (0°) rotation to allow the examiner preference for desired rotation as studied by Gazzillo et al[18].

The overall accuracy of palpating the LHBT in healthy individuals by a sports medicine board-certified staff physician, a sports medicine fellow, and a physical medicine and rehabilitation resident was reported to be 5.3%[18]. According to Gazzillo et al.[18], inaccurate palpations occurred medial to the ITG with a mean distance of 1.4 cm (14mm) away from the border of the ITG. Based on the results of our study, the overall accuracy of physical therapists palpating the LHBT in the same position reported by Gazzillo et al.[18] was higher than that of physicians[18] with most of the inaccurate palpations also occurring medial to the ITG with a mean distance of 2.58 mm away from the border. The study by Gazzillo et al.[18] did not include <2 mm outside the medial or lateral border as being accurate palpation, therefore, the accuracy results are difficult to compare due to differences in methodology.

In a study by Woods et al.[28], the accuracy of LHBT palpation using the same position labeled position 2 in the current study, increased from 20% to 51.7% after medical residents went through real-time US training with palpation[28]. Overall accuracy rates in the current study were 46–49% without specific training, however our therapists were experienced clinicians rather than clinicians in training which may have contributed to their increased accuracy. The use of US or other mechanisms of training may improve the accuracy of correctly palpating the LHBT or other musculoskeletal structures. The current study did not include a training component and examiners were not informed of the two LHBT palpation positions, before the study. The goal of the current study was to emulate the palpation abilities of physical therapists in clinical practice, consequently a training period or the use of US guidance was not utilized in the methodology. Therefore, it is hypothesized that accuracy rates may have increased if we had included intentional training. The literature supports increased accuracy with US-guided palpation over surface palpation alone with guided interventions of lateral joint line palpation of the knee[29] acromioclavicular joint palpation[30] and palpation of the sinus tarsi[31]. Less experienced clinicians may have decreased accuracy with palpation guided injections according to Curtiss et al.[32], however our accuracy rates (therapist 1: 52.3% (67/128); therapist 2: 39.1% (50/128) were not significantly different between 2 practicing physical therapists with similar years of experience (22 year and 19 years respectively).

Due to the high prevalence of LHBT injuries, it is important to have a better understanding of the accuracy of a health care provider's ability to palpate the potentially pathological structure. Palpation over the bicipital groove, which elicits tenderness, is a common provocation maneuver used to differentially diagnose LHBT pathology[12, 15] over other sources of anterior shoulder pain. Additionally, inaccurate palpation may result in incorrect placement of potentially therapeutic bicipital tendon sheath injections or dry needles[18].

There were limitations to our study. First, all of the participants were healthy, young individuals with a relatively low BMI. Results may have been different in older individuals with a higher BMI, or in individuals with painful LHBTs. Accuracy of LHBT palpation may be decreased or increased in individuals with suspected LHBT pathology. Palpation as an examination finding in individuals with LHBT pathology typically includes the presence of point tenderness of the tendon within the bicipital groove[14] which may potentially enhance the palpation accuracy, however conversely, broad referral patterns associated with shoulder pain may make accurate palpation more difficult.

A second limitation is that the therapist positioned the participants' shoulder so the LHBT was pointing directly towards the ceiling to standardize the ultrasonographic transducer position. The ultrasonographic scan was saved when the needle was identified based on its hyperechoic appearance and the transducer was positioned at 0° and parallel to the table for every palpation. Attempting to standardize a transducer position can present a number of challenges, and radiologists usually prefer to manually position a transducer for visualization rather than be restricted to a particular position. In a study investigating methods to increase the reliability of lumbar multifidus measures by US, a transducer position template did not enhance or increase the reliability[33] and the authors recommended that transducer position templates are used. A third limitation of our study is that we recorded all measurements based on the use of a single ultrasonographic image per palpation. An ultrasonographic reliability study concluded that optimal US measurement reliability requires the use of a single rater using an average score based on three images[33].

Additional limitations include difficulty identifying clear medial ITG margins on ultrasonographic imaging due to natural variability in medial ITG wall inclination. This may have led to an error in the overall measurement of the images. Further limitations may include: the possibility of participant movement after palpation and before imaging, errors in the therapist placing the needle on the skin after palpation, or errors in goniometric measurement. We attempted to carefully control these using procedures designed to minimize error, such as having a separate therapist stabilize the shoulder and arm of the participant throughout palpation and imaging.

In conclusion, the results of this study suggest that the inter-rater reliability of LHBT palpation by physical therapists are poor. Additionally, we did not find therapists to be significantly more accurate palpating the LHBT in either of the two tested positions. The vision of this study was to determine if physical therapists could accurately palpate the LHBT prior to performing other manual physical therapy interventions including soft tissue techniques, deep friction massage and dry needling. Due to the high prevalence of LHBT injuries, accurate palpation of this tendon is important when considering invasive interventions such as injections and dry needling and as such, the authors believe that reliability and accuracy studies of this nature are important to serve as a foundation for future research. Further research may be necessary to determine the best position to optimally palpate and examine the LHBT.

Presentation at a Conference

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Conflict of interest

We affirm that we have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript. We do not declare conflicts of interest.

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CHAPTER 6: Physical Therapy Interventions for the Management of Biceps Tendinopathy: An International Delphi Study

6.1 Overview

The results of Chapters 3 (scoping review) and Chapter 4 (retrospective review) inform the remaining studies in this thesis and provide direction for identifying interventions used to treat individuals with LHBT tendinopathy. The scoping review in Chapter 3 acknowledged that there is a lack of guidance for clinicians on effective interventions for LHBT tendinopathy. Several research studies have examined different treatment approaches with predominant focus on the effects of using therapeutic modalities to treat individuals with LHBT tendinopathy. Literature reviews and clinical commentaries recommend a multimodal approach. Chapter 4 reveals that clinicians are using a combination of active and passive exercise interventions to treat LHBT tendinopathy. This aligns with the findings in Chapter 1 and 2, which suggest that a multimodal approach (that includes exercise) is effective for treating subacromial pain syndrome and tendinopathy. However, there was very little evidence to guide the overall question of this thesis: what are the recommended physical therapy interventions used to treat individuals with LHBT tendinopathy. Challenges with diagnosis of the condition (Chapter 5) makes identification of individuals with LHBT tendinopathy difficult. Despite this challenge, recommendations for intervention must be established for future research to continue. When evidence is incomplete, yet guidance is needed to inform decision making, expert opinion may be used to determine direction for further research (Dawson & Barker, 2010; Powell, 2003).

The Delphi method is commonly used to elicit opinions and determine consensus from targeted content experts (Jünger et al., 2017). This design allows for the recruitment of international content experts without constraints of geography, affords anonymity, and avoids the dominance of opinion by a minority. To execute this technique, a research group surveys a group of identified experts with experience in a particular content area using a list of predetermined questions. The goal of the survey is to determine a consensus from the experts on a particular topic (Hasson et al., 2000;

Jünger et al., 2017). This method was deemed necessary to generate ideas regarding interventions used to treat individuals with LHBT tendinopathy.

In Chapter 6 of this thesis, a Delphi survey was used to query experts about their views on physical therapy-based interventions they commonly use or recommend for treating individuals with LHBT tendinopathy. The web-based Delphi method used consisted of three rounds of surveys with both a panelist (respondent) group and a workgroup (investigators) to answer the following question: *Which conservative interventions are effective in treating individuals with long head of the biceps tendon tendinopathy?* Information reported in Chapter 3 (scoping review) and Chapter 4 (retrospective review) of this thesis, was used to guide the development of general themes presented in the Round I Delphi survey. At the conclusion of the study 61 interventions were designated as recommended based on consensus amongst experts and 9 interventions were not recommended based on the same criteria, 15 interventions did not achieve consensus. The results of this Delphi study serve as a first step in identifying treatments deemed appropriate for treating individuals with LHBT tendinopathy.

6.2 Citation

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Original Research

Physical Therapy Interventions for the Management of Biceps Tendinopathy: An International Delphi Study

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Background

Shoulder pain related to the long head of the biceps tendon (LHBT) tendinopathy can be debilitating and difficult to treat especially in athletes who often elect for surgical intervention. Conservative management is recommended but there are limited established guidelines on the physical therapy (PT) management of the condition.

Hypothesis/Purpose

The purpose of this study was to establish consensus on conservative, non-surgical physical therapy interventions for individuals with LHBT tendinopathy using the Delphi method approach.

Study Design

Delphi Study

Methods

Through an iterative process, experts in the PT field rated their agreement with a list of proposed treatment interventions and suggested additional interventions during each round. Agreement was measured using a four-point Likert scale. Descriptive statistics including median and percentage agreement were used to measure agreement. Data analysis at the end of Round III produced, by consensus, a list of PT interventions recommended for the management of individuals with LHBT tendinopathy. Consensus was defined as an a priori cutoff of $\geq$75% agreement.

Results

The respondent group included 29 international experts in the PT management of individuals with shoulder pain. At the conclusion of the study 61 interventions were designated as recommended based on consensus amongst experts and 9 interventions were not recommended based on the same criteria, 15 interventions did not achieve consensus.

Conclusion

There is a lack of well-defined, PT interventions used to treat LHBT tendinopathy. Expert respondents reached consensus on multimodal interventions including exercise, manual therapy and patient education to manage LHBT tendinopathy.

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Level of Evidence

5

INTRODUCTION

Shoulder pain related to pathology of the long head of the biceps tendon (LHBT) can be debilitating and often interferes with an individual's activity and participation.[1–3] The biceps tendon and labral complex is a potential pain generator in overhead throwing athletes.[4–6] Anterior shoulder pain caused by tenosynovitis of the LHBT in athletes can lead to decreased performance and persistent pain.[4,7,8] LHBT "tendinopathy" may start as an inflammatory condition or tenosynovitis of the LHBT[1–3] and progress to a degenerative tendinopathy of the LHBT (characterized by tendon thickening, disorganization and irregularity of the tissue including the presence of hemorrhagic adhesions and scarring).[3] The incidence of LHBT tendinopathy remains unclear as it is often considered a secondary shoulder condition associated with other conditions including rotator cuff disease and subacromial impingement.[1,8] However, the reported incidence of tendinopathies in sports appears to be rising due to increased participation and training frequency.[9] Overall, the literature regarding diagnosis, appropriate management of disorders related to the LHBT, including physical therapy (PT) management and surgical intervention, especially in the younger, athletic population remains controversial.[1,4,8,10]

Management of LHBT tendinopathy may include rest, activity modification, non-steroidal anti-inflammatory drugs, corticosteroid injections and tendon fenestration.[1,8,11] More invasive, surgical interventions include biceps tendon distal reattachment (tenodesis) or release (tenotomy).[1,12] However, there is little consensus regarding the ideal approach to treating chronic pain related to the LHBT.[2,3] Conservative management including PT is often recommended prior to more invasive interventions,[3,13,14] yet conservative management may be suboptimal in relieving symptoms and many individuals go on to seek more invasive treatment alternatives including surgical intervention.

Conservative PT management of shoulder pain including LHBT pathology may involve a multimodal approach addressing associated impairments of the shoulder, scapular region and cervicothoracic spine with the application of exercise, joint and soft tissue mobilization as well as retraining dysfunctional movement patterns.[3] A search of the literature revealed that most randomized controlled trials exploring PT management for LHBT conditions involved the utilization of biophysical agents including ultrasound, electrotherapy, extracorporeal shockwave therapy and iontophoresis however, there remains a paucity of high quality literature outlining the conservative management of LHBT tendinopathy in isolation.[15–20] Considering chronic biceps tendinopathy often leads to invasive surgical intervention it is essential for physical therapists to recognize interventions that can be potentially effective in treating LHBT tendinopathy to avoid such procedures.[21] Currently no quality studies have identified the most effective interventions for treating individuals with LHBT tendinopathy. Expert opinion in the form of the Delphi method is an important tool in fostering decision making when evidence is lacking.[22] Therefore, the purpose of this study was to perform a Delphi study on common PT interventions utilized to treat individuals with biceps tendinopathy in order to generate expert consensus on recommended PT interventions.

MATERIALS AND METHODS

STUDY DESIGN

This study used a Delphi method to elicit opinions and determine consensus from targeted content experts.[23] This design allowed for the recruitment of international content experts without constraints of geography, offered anonymity, and avoided the dominance of opinion by a minority. The web-based Delphi consists of three rounds of surveys with both a panelist (respondent) group and a work group (investigators) in order to answer the following question: *Which conservative interventions are effective in treating individuals with long head of the biceps tendon tendinopathy?* The three-step Delphi method took place between February and June of 2021. This research received exempt status by the University of Colorado Multiple Institutional Review Board (COMIRB) and was approved by the Human Research Ethics Committee (HREC) at the University of Newcastle; all participants provided informed consent prior to participation. The study was performed in line with the Conducting and Reporting Delphi Studies (CREDES) recommendations to assure study rigor.[23]

PARTICIPANTS AND RECRUITMENT

In line with CREDES recommendations, experts were sought globally[23] and were defined and agreed upon by the work group. Experts on shoulder pain were systematically identified using three methods. First, experts were identified as clinicians and/or researchers who had international and nationally recognized training and experience in the PT management of shoulder pathology or experience in research related to specific PT interventions utilized to treat individuals with shoulder pain and/or pathology. Relevant manuscripts and abstracts were collected utilizing electronic libraries including PubMed, CINAHL and Google Scholar. Investigators composed a list of potential panelists consisting of physical therapists and researchers listed as first/last authors of peer-reviewed publications on the PT management of individuals with shoulder pathology. Second, experts were identified through presentation abstracts and records of conference programming specifically, individuals who had presented on shoulder pathology at the 2019 and 2020 American Physical Therapy Association (APTA) Combined Sections Meeting (CSM) specifically in the Orthopedics, Research, and Sports Sections. Third, experts were identified by searching the grey literature through Google to include additional conference proceedings, textbooks and non-peer-reviewed nationally or internationally published material. Experts were invited via email to participate in the study.

WORK GROUP

The work group consisted of the five authors of the study: the lead investigator (AM, a board-certified orthopedic specialist and a fellow in the American Academy of Orthopaedic and Manual Physical Therapists), two senior academics (SS and JC), with experience in the Delphi technique, quantitative research methods and 50 years of combined experience in musculoskeletal medicine, and two research assistants (SA, LC) completing doctoral training in PT. The work group was responsible for study design, recruiting content experts, and circulation and analysis of the questionnaire data. Additionally, the work group made decisions regarding methodology, data analysis and quality assurance.

SYSTEMATIC REVIEW OF THE LITERATURE

A systematic review of the literature was performed prior to questionnaire development to identify best practice for the PT management of LHBT tendinopathy. The electronic databases MEDLINE, CINAHL, Cochrane Library, PubMed and Physiotherapy Evidence Database (PEDro) were searched from inception to June 20, 2020. The search was developed and performed with assistance from a research librarian. The search strategy combined headings and keywords for "biceps tendinopathy" or "biceps tendinitis" and "physical therapy" or "management" or "rehabilitation." Individuals from the work group screened titles and abstracts to discard irrelevant ones. Articles from the literature search were included if they described or recommended PT interventions. Articles discussing medical or surgical interventions were excluded. Full-text publications were searched for information relevant to PT interventions used to treat individuals with LHBT tendinopathy. Data extracted from the full-text publications were then used to guide development of general themes presented in the Round I Delphi survey.

PROCEDURE

This Delphi consisted of a preparatory phase by the work group and three rounds of electronic surveys conducted via the Qualtrics (Qualtrics, Provo, UT) online platform. An email was sent to 136 potential panelists inviting them to participate in the Delphi survey, including a link with information about the study, informed consent, privacy, and a link to complete the Round 1 survey online. Email invitations generated from Qualtrics with links for Rounds II and III were sent to all respondents who completed Round I. Each Delphi round was conducted over a four-week period with three reminder emails to ensure survey completion. Between each round, investigators performed data management, analysis, subsequent survey creation, and survey testing for two weeks. An introductory invitation containing the link to the consent and Round I questionnaire was sent to the list of identified experts to inform them of the study and request their participation via email. Two weeks later, the invitation to participate was sent again to all experts who did not decline participation. Three follow up emails were sent to non-responders at intervals of one week. Throughout the entire Delphi process, all participants were blinded to the identity of the other participants in the respondent group. Details of participant recruitment can be found in Figure 1.

INSTRUMENT

ROUND I OF DELPHI

The first instrument consisted of an information statement describing the study, informed consent, demographic questions, and nine open-ended questions on the conservative management strategies that the participants believe are most common and effective for the physical therapy treatment of individuals with LHBT tendinopathy (Appendix 1). The first two open-ended questions inquired about general interventions followed by six open-ended questions on interventions including exercise-based interventions, manual therapy, and biophysical agents. The last question asked for further comments on PT interventions used to treat individuals with LHBT tendinopathy. The purpose of Round I was to gather information and inform investigators of the most common and effective interventions utilized, or believed to be utilized, to treat individuals with LHBT tendinopathy. The use of open-ended questions was intentional to reduce the potential for bias and allow individuals to describe interventions openly.

Definitions of all terms were provided upon initiation of the survey to assure familiarity and congruence with the terms. The definition of LHBT tendinopathy used for the purpose of the study was: an inflammatory condition or tenosynovitis, occurring in the path of the LHBT as it courses in the intertubercular or bicipital groove of the humerus.[1,2] The continuum of clinical pathology ranges from acute inflammatory tendonitis to degenerative tendinopathy.[1,2] Without the use of imaging, LHBT pathology is typically diagnosed through a combination of patient identified location, palpation, special tests and other provocative maneuvers.[24] The term manual therapy was defined as skilled hand movements and skilled passive movements of joints and soft tissue intended to improve tissue extensibility; increase range of motion; induce relaxation; mobilize or manipulate soft tissue and joints; modulate pain; and reduce soft tissue swelling, inflammation, or restriction. Techniques may include manual lymphatic drainage, manual traction, massage, mobilization/manipulation, and passive range of motion.[25] Manual therapy was also defined in terms of non-thrust manipulation (mobilization) or thrust manipulation. Non-thrust manipulation was defined as a passive procedure which involves a low velocity, low to high amplitude force to a targeted region which is modified based on clinician assessment and patient feedback; thrust manipulation was defined as a passive procedure which involves a high velocity, low amplitude force to a targeted region which is modified based on clinician assessment and patient feedback.[25] The term intervention was defined as the purposeful interaction of the physical therapist with an individual to produce changes in the condi-

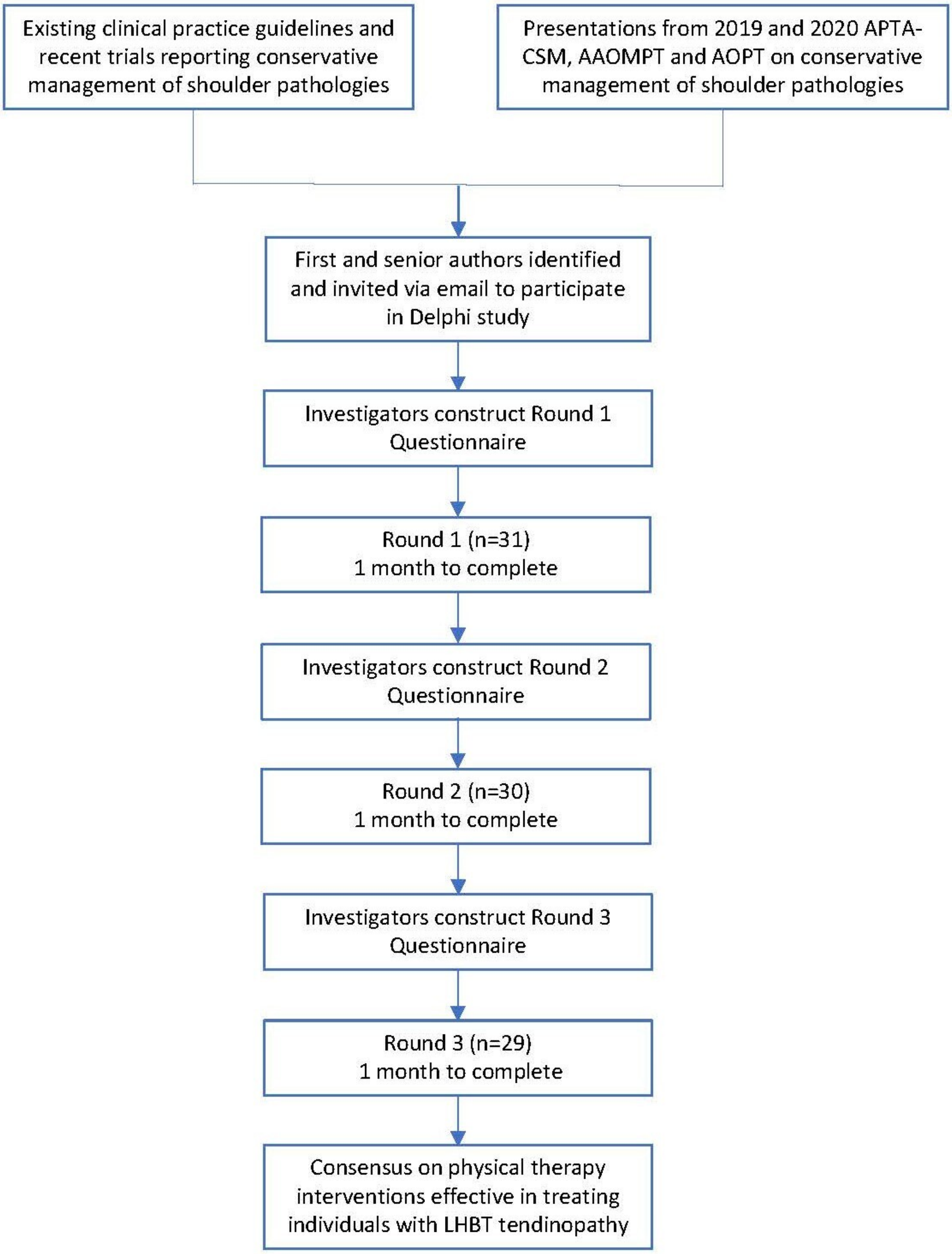

Figure 1. Flow recruitment and study respondents.

(Abbreviations: APTA=American Physical Therapy Association; CSM=Combined Sections Meeting; AAOMPT=American Academy of Orthopaedic Manual Physical Therapists; AOPT=Academy of Orthopedic Physical Therapy; LHBT=Long Head of Biceps Tendon) tion that are consistent with the diagnosis and prognosis.[25] Lastly, the term biophysical agents was defined as a broad group of agents that use various forms of energy and are intended to assist muscle force generation and contraction; decrease unwanted muscular activity; increase the rate of healing of open wounds and soft tissue; maintain strength after injury or surgery; modulate or decrease pain; reduce or eliminate edema; improve circulation; decrease inflammation, connective tissue extensibility, or restriction associated with musculoskeletal injury or circulatory dysfunction; increase joint mobility, muscle performance, and neuromuscular performance; increase tissue perfusion and remodel scar tissue; and treat skin conditions.[25] Subsequent rounds were used to reach a consensus among reported recommendations while incorporating modifications and inclusion of new items.

ROUND II OF DELPHI

From the qualitative analysis of responses from Round I, themes were identified and subsequently coded to present themes in Round II. A qualitative, thematic analysis approach was used to interpret, construct, and develop themes summarizing the participants' recommended interventions.[26,27] Using this approach, thematic interpretations remain close to participants' words. Themes and subthemes were identified and subsequently coded by A.M. and L.C. and disputes were settled by S.A. The purpose of Round II was to achieve consensus on intervention strategies identified in Round I. Additionally, Round II included questions regarding the stage of healing (acuity) in which each intervention would be utilized. Identified themes and subthemes included: Resistance Exercise/Muscle Performance (subthemes: tendon loading techniques, progressive resistance exercises, open/closed kinetic chain exercises, task specific/functional activities), Stretching and Flexibility, Manual Therapy (subthemes: non-thrust manipulation, thrust manipulation, soft tissue techniques), Patient Education, Biophysical Agents, Dry Needling, Other and Treatment Statements. Questions were organized using a 4-point Likert scale ranging from 1 ("strongly agree") to 4 ("strongly disagree"). Participants were also asked to rate through multiple choice questions, the stage(s) of tissue healing they would recommend each intervention be used with options of "acute", "subacute", "chronic", or "I would not use or recommend this intervention". Common definitions of the stages of healing were included again for standardization.[28] Finally, respondents were asked to report their level of agreement with statements regarding clinical decision making (which resulted from Round 1 open ended statements) pertaining to treating individuals with LHBT tendinopathy using the Likert scale described above.

ROUND III OF DELPHI

The questionnaire for Round III contained the same questions that were presented in Round II, including all definitions, intervention techniques, and stages of acuity. Each question was accompanied by tables and figures illustrating the results of Round II. The respondents were asked to review the feedback from Round II and rescore each intervention.

DATA ANALYSIS

The survey instrument was built on Qualtrics survey software (Qualtrics, Provo, UT). After Round I was complete, data were exported from Qualtrics to an excel sheet for analysis. Three investigators completed the theme and coding synthesis process individually. The 3 investigators (A.M., L.C., and S.A.) then came together to reach consensus for themes to advance into Round II. After the completion of Round III, data were exported from Qualtrics to an excel sheet for further analysis by the workgroup. For Round III, a benchmark of ⩾75% agreement as an a priori cutoff was utilized, as seen in similar study designs.[23,29] Recommendations rated as 3 (disagree) or 4 (strongly disagree) by ⩾75% of the panelists were collapsed into "disagree" and not considered recommended interventions. Intervention recommendations rated as a 1 (strongly agree) or 2 (agree) by ⩾75% of the panelists were collapsed into "agree" and included as recommended in the final consensus. Scores were tallied for each intervention including the frequency of respondents and corresponding percentages.

RESULTS

RESPONDENT CHARACTERISTICS

A total of 136 potential participants were contacted via email. Ten potential participants had email addresses that were currently not active, leaving 126 eligible participants. One expert declined to participate due to a disagreement in the definition of biceps tendinopathy utilized in our study. One hundred and five experts did not respond to the invitation to participate or the reminders. Thirty-one (24.6%) participants completed the consent form and responded to Round I (Figure 1). The respondent group consisted of experts from the United States (n = 19), United Kingdom (n=2), Australia (n=2), Sweden (n=2) and one from each of the following countries: Spain, New Zealand, Turkey, Canada, Italy, and the Netherlands. Thirteen respondents were female (41.9%), eighteen were male (58.1%), and 0% responded as non-binary. Respondents had a variety of degrees, including Masters, Doctorate, Doctor of Science (DSc), and Doctor of Philosophy (PhD), in addition to other specialty certifications. Twenty-six of 31 (83.9%) of the respondents in Round I were clinicians. Of those clinicians, fifteen (48.4%) had 20 or more years of clinical practice. Twenty-seven of 31 respondents (87.1%) consented to be acknowledged for their participation (Table 1).

ROUND I

Comments from Round 1 were summarized and statements containing similar constructs were grouped and reduced for each theme. For example, the following five items were originally included in the list of statements for Round 1: 1) common and effective interventions used to treat LHBT tendinopathy 2) common and effective exercise-based interventions used to treat LHBT tendinopathy 3) common and effective manual therapy-based interventions used to

Table 1. Descriptive characteristics of the Delphi expert panel

Demographic characteristics	Value	Percentage
Age (years)		
20-30	0	0.00%
30-40	10	31.30%
40-50	11	34.40%
50-60	8	25.00%
60-70	3	9.40%
70+	0	0.00%
Total	32	100%
Gender		
Male	19	59.40%
Female	13	40.60%
Non-binary	0	0.00%
Prefer not to say	0	0.00%
Total	32	100.00%
In what country do you currently reside?		
United Kingdom	2	6.30%
Spain	1	3.10%
Australia	2	6.30%
New Zealand	1	3.10%
United States	20	62.50%
Turkey	1	3.10%
Canada	1	3.10%
Sweden	2	6.30%
Italy	1	3.10%
Netherlands	1	3.10%
Total:	32	100.00%
If you reside in the US, in which region do you currently reside?		
South Atlantic (DE, DC, FL, GA, MD, NC, SC, VA, WV)	3	15.00%
Middle Atlantic (NJ, NY, PA)	2	10.00%
East North central (IL, IN, MI, OH, WI)	3	15.00%
West North Central (IA, KS, MN, MO, NE, ND, SD)	1	5.00%
New England (CT, ME, MA, NH, RI, VT)	1	5.00%
Pacific (AK, CA, HI, OR, WA)	1	5.00%
East South Central (AL, KY, MS, TN)	0	0.00%
Mountain (AZ, CO, ID, MT, NV, NM, UT, WY)	9	45.00%
Total:	20	100.00%
Describe your current role?		
None	0	0.00%
Clinician	27	84.40%
Researcher	13	40.60%
Academic	18	56.30%
Management	4	12.50%
How many total years have you been in clinical practice?		
None	0	0.00%
0-5	2	6.30%

Demographic characteristics	Value	Percentage
5-10	2	6.30%
10-15	9	28.10%
16-20	4	12.50%
20+	15	46.90%
Total	32	100.00%
How many total years have you been involved in research?		
None	2	6.30%
0-5	9	28.10%
5-10	7	21.90%
10-15	7	21.90%
15-20	3	9.40%
20+	4	12.50%
Total	32	100.00%
Degrees and/or certifications		
MSPT/MPT	12	37.50%
DPT	15	46.90%
ATC	1	3.10%
DSc	2	6.30%
PhD	8	25.00%
OCS	17	53.10%
SCS	4	12.50%
Other: FAAOMPT, TDN, PhD(c), OMPT, DSc student, BSc	21	65.60%
In what country did you receive your degree(s)?		
United Kingdom	2	6.30%
Spain	1	3.10%
Australia	1	3.10%
New Zealand	1	3.10%
United States	19	59.40%
Turkey	1	3.10%
Canada	1	3.10%
Sweden	2	6.30%
Morocco	1	3.10%
Italy	1	3.10%
Netherlands	1	3.10%
Wales	1	3.10%
Total	32	100.00%
Have you completed a residency in physical therapy?		
No	24	75.00%
Yes	8	25.00%
Total	32	100.00%
Have you completed a fellowship in physical therapy?		
No	17	53.10%
Yes	15	46.90%
Total	32	100.00%

Abbreviations: US=United States, DE=Delaware, DC=District of Columbia, FL=Florida, GA=Georgia, MD=Maryland NC=North Carolina, SC=South Carolina, VA=Virginia, WV=West Virginia, NJ=New Jersey, NY=New York, PA=Pennsylvania, IL=Illinois, IN=Indiana, MI=Michigan, OH=Ohio, WI=Wisconsin, IA=Iowa, KS=Kansas, MN=Minnesota, MO=Missouri, NE=Nebraska, ND=North Dakota, SD=South Dakota, CT=Connecticut, ME=Maine, MA=Massachusetts, NH=New Hampshire, RI=Rhode Island, VT=Vermont, AK=Arkansas, CA=California, HI=Hawaii, OR=Oregon, WA=Washington, AL=Alabama, KY=Kentucky, MS=Mississippi, TN=Tennessee, AZ=Arizona, CO=Colorado, ID=Idaho, MT=Montana, NV=Nevada, NM=New Mexico, UT=Utah, WY=Wyoming, MSPT=Master of Science in Physical Therapy, MPT=Master of Physical Therapy, DPT=Doctor of Physical Therapy, ATC=Certified Athletic Trainer, DSc=Doctor of Science, PhD=Doctor of Philosophy, OCS=Orthopedic Certified Specialist, SCS=Sports Certified Specialist, FAAOMPT=Fellow of the American Academy of Orthopaedic Manual Physical Therapists, TDN=Trigger point Dry Needling, PhD(c)=Candidate Doctor of Philosophy, OMPT=Orthopedic Manual Physical Therapist, BSc=Bachelor of Science

treat LHBT tendinopathy 4) common and effective biophysical agents used to treat LHBT tendinopathy 5) other common and effective interventions used to treat LHBT tendinopathy. Across all five item categories, 217 initial statements from the open-ended responses specific to physical therapy interventions were provided in Round 1 and condensed into 47 intervention-based statements across eight newly formed themes (resistance exercise/muscle performance, stretching and flexibility, manual therapy, patient education, biophysical agents, other, dry needling, and treatment statements).

ROUNDS II AND III

One respondent did not complete the survey from Round II despite weekly reminders; therefore 30 of 31 of the respondents participated in Round II (96.7% retention rate between Round I and Round II; Figure 1). Retention rates for respondents were reduced from 30 to 29 from Round II to Round III (96.6% retention rate between Round II and Round III); (Figure 1). Twenty-nine respondents completed Round III (93.5% retention rate between Round I and Round III). A detailed description of consensus for "agree" and "disagree" per intervention category for Round III is reported beginning with Table 2.

INTERVENTION THEMES

RESISTANCE EXERCISE/MUSCLE PERFORMANCE

Among respondents there was strong consensus in favor of *tendon loading techniques* as an effective intervention for treating individuals with LHBT tendinopathy. Consensus "agree" was reached for five of five tendon loading techniques in Round II and Round III (Table 2). Respondents reached consensus "agree" that *progressive resistance exercises* would be prescribed for nine of 11 muscles/muscle groups not including upper trapezius and pectoralis major muscles. Consensus "agree" was also established across six of six *open and closed chain kinetic chain exercises* including minimal change in consensus between Rounds II and III. *Task specific functional activities* (reaching, lifting, overhead activity, and occupation and sport specific tasks) reached consensus "agree" with all respondents in Round II and III (Table 2).

STRETCHING/FLEXIBILITY

Respondents demonstrated consensus "agree" in favor of stretching/flexibility for five of seven identified muscles/muscle groups in Round II increasing to seven of seven muscles/muscle groups in Round III with four participants changing to agree in Round III to include upper trapezius as a target muscle for stretching (Table 2).

MANUAL THERAPY

Non-thrust manipulation techniques (five of five) achieved consensus "agree" by respondents in Round III with techniques to the acromioclavicular joint and scapulothoracic joints not reaching the threshold for agreement by respondents in Round II. Four *thrust manipulation* techniques were included in the questionnaire with only two of four regions (thoracic spine and cervicothoracic junction) achieving overall consensus "agree" by respondents in Round III (Table 3 and Figure 2). Intervention to the thoracic spine region received the highest level of consensus "agree" in both non-thrust and thrust manipulation techniques; 89.65% and 83.34% respectively in Round III. Specific *thrust and non-thrust manipulation* techniques included Grade I-II and Grade III-IV non-thrust, Grade V thrust and mobilization with movement (MWM) all of which achieved consensus "agree" in Round II and III. *Soft tissue techniques* were included in the manual therapy category and two of 11 techniques (soft tissue mobilization of the biceps brachii and trigger point therapy to the rotator cuff muscles) achieved consensus "agree" in Round II compared to seven of 11 techniques in Round III. All other *soft tissue techniques* to specified regions (six of 11) did not reach consensus for "agree" or "disagree" (Table 3 and Figure 3).

PATIENT EDUCATION

Patient education concepts related to advice achieved eight of eight consensus "agree" in Round III. Concepts that achieved 100% consensus included: activity and occupational modification, training/loading modification and education surrounding the PT treatment plan and pain neuroscience education (Table 4).

BIOPHYSICAL AGENTS

Respondents reached consensus "disagree" on seven of nine biophysical agents including iontophoresis, phonophoresis, three forms of electrical stimulation, ultrasound and low-level laser therapy (LLLT), (Table 4 and Figure 4). Therefore, thermal agents including cryotherapy and moist heat did not reach consensus agree or disagree. Additionally, there was no change in consensus "agree" in the seven of nine categories between Round II and Round III.

DRY NEEDLING

Among respondents there was consensus "agree" on dry needling to the biceps brachii muscle in Round II and Round III. In Round II respondents reached consensus "agree" on needling the rotator cuff muscles but consensus "agree" was not achieved in Round III (Table 4).

Table 2. Results from Round III, Themes: Resistance Exercise/Muscle Performance, Stretching/Flexibility

Theme Resistance Exercise/Muscle Performance	Agree, n (%)	Disagree, n (%)	Consensus
Subtheme: Tendon Loading Techniques			
Isometric tendon loading - Biceps brachii muscle	26 (89.66%)	3 (10.35%)	CA
Concentric tendon loading - Biceps brachii muscle (shoulder flexion)	29 (100%)	0 (0%)	CA
Concentric tendon loading - Biceps brachii muscle (elbow flexion)	29 (100%)	0 (0%)	CA
Eccentric tendon loading- Biceps brachii muscle (shoulder flexion)	28 (96.55%)	1 (3.45%)	CA
Eccentric tendon loading - Biceps brachii muscle (elbow flexion)	29 (100%)	0 (0%)	CA
Subtheme: Progressive Resistance Exercise (PRE)			
Pectoralis major muscle	19 (65.52%)	10 (34.48%)	NC
Latissimus dorsi muscle	22 (75.86%)	7 (24.14%)	CA
Deltoid muscle	28 (96.55%)	1 (3.45%)	CA
Biceps brachii muscle	29 (100%)	0 (0%)	CA
Upper trapezius muscle	15 (51.72%)	14 (48.28%)	NC
Middle trapezius muscle	27 (93.10%)	2 (6.90%)	CA
Lower trapezius muscle	27 (93.10%)	2 (6.90%)	CA
Serratus anterior muscle	29 (100%)	0 (0%)	CA
Rhomboid major/minor muscles	23 (79.31%)	6 (20.69%)	CA
Rotator cuff internal (medial) rotation muscles	28 (96.55%)	1 (3.45%)	CA
Rotator cuff external (lateral) rotation muscles	28 (96.55%)	1 (3.45%)	CA
Subtheme: Open/Closed Kinetic Chain Exercises			
Rotator cuff muscles-open chain	29 (100%)	0 (0%)	CA
Rotator cuff muscles-closed chain	28 (96.55%)	1 (3.45%)	CA
Scapular stabilizers-open chain	29 (100%)	0 (0%)	CA
Scapular stabilizers-closed chain	29 (100%)	0 (0%)	CA
Biceps brachii muscle-open chain	29 (100%)	0 (0%)	CA
Biceps brachii muscle-closed chain	28 (96.55%)	1 (3.45%)	CA
Subtheme: Task-specific Functional Activities			
Reaching	29 (100%)	0 (0%)	CA
Lifting	29 (100%)	0 (0%)	CA
Overhead activity	29 (100%)	0 (0%)	CA
Occupation specific	29 (100%)	0 (0%)	CA
Sport specific	28 (96.55%)	0 (0%)	CA
Theme: Stretching/Flexibility			
Pectoralis major muscle	28 (96.55%)	1 (3.45%)	CA
Pectoralis minor muscle	28 (96.55%)	1 (3.45%)	CA
Upper trapezius muscle	25 (86.20%)	4 (13.79%)	CA
Biceps brachii muscle	23 (79.31%)	6 (20.69%)	CA
Latissimus dorsi muscle	26 (89.66%)	3 (10.35%)	CA
Posterior rotator cuff muscles	27 (93.10%)	2 (6.90%)	CA
Glenohumeral medial/internal rotators	25 (86.20%)	4 (13.79%)	CA

Abbreviations: CA=consensus agree; NC=non consensus; n=number of participants

OTHER

The other category included additional interventions that respondents commented on by providing free text answers to open-ended questions in Round I. Respondents reached consensus "agree" on two of five items to include cognitive behavioral therapy and non-steroidal anti-inflammatory drugs (NSAIDs) and consensus "disagree" on two of five items including extracorporeal shock wave therapy (ESWT) and dry cupping therapy (Table 4).

Table 3. Results from Round III, Theme: Manual Therapy

Theme: Manual Therapy	Agree, n (%)	Disagree, n (%)	Consensus
Subtheme: Non-thrust Manipulation (Region)			
Glenohumeral joint	24 (82.76%)	5 (17.24%)	CA
Thoracic spine	26 (89.66%)	3 (10.35%)	CA
Cervical spine	24 (82.76%)	5 (17.24%)	CA
Scapulothoracic "joint"	22 (75.86%)	7 (24.14%)	CA
Acromioclavicular joint	22 (75.86%)	7 (24.14%)	CA
Subtheme: Thrust Manipulation (Region)			
Thoracic spine	25 (86.20%)	4 (13.79%)	CA
Cervical spine	21 (72.41%)	8 (27.58%)	NC
Cervicothoracic junction	23 (79.31%)	6 (20.69%)	CA
Glenohumeral joint	11 (37.93%)	18 (62.07%)	NC
Subtheme: Thrust & Non-thrust Manipulation (Techniques)			
Grade I-II non-thrust	23 (79.31%)	6 (20.69%)	CA
Grade III-IV non-thrust	25 (86.20%)	4 (13.79%)	CA
Grade V thrust	22 (75.86%)	7 (24.14%)	CA
Mobilization with movement (MWM)	27 (93.10%)	2 (6.90%)	CA
Subtheme: Soft-Tissue Techniques			
Deep transverse friction (long head of the biceps tendon)	9 (31.03%)	20 (68.96%)	NC
Deep transverse friction (biceps brachii muscle belly)	9 (31.03%)	20 (68.96%)	NC
Deep transverse friction (bicipital groove)	9 (31.03%)	20 (68.96%)	NC
Trigger point therapy (biceps brachii muscle)	22 (75.86%)	7 (24.14%)	CA
Trigger point therapy (rotator cuff muscles)	22 (75.86%)	7 (24.14%)	CA
Soft Tissue Mobilization (biceps brachii muscle)	25 (86.20%)	4 (13.79%)	CA
Soft tissue mobilization (periscapular muscles)	22 (75.86%)	7 (24.14%)	CA
Soft tissue mobilization (scapular muscles)	23 (79.31%)	6 (20.69%)	CA
Soft tissue mobilization (rotator cuff muscles)	26 (89.66%)	3 (10.35%)	CA
Soft tissue mobilization (cervical region)	24 (82.76%)	5 (17.24%)	CA
Instrument-assisted soft tissue mobilization	16 (55.17%)	13 (44.82%)	NC

Abbreviations: C=consensus; CA=consensus agree; NC=non consensus; n=number of participants

TREATMENT STATEMENTS

Respondents reported their level of agreement with treatment-based statements in terms of intervention (which resulted from Round 1 open ended questions) and consensus “agree” was reached in six of eight statements with one statement (clinical decision making should be prescriptive) reaching consensus “disagree” and the other reaching non consensus (Table 5). Statements that were consensus “agree” included utilization of a pragmatic and multimodal approach to intervention following clinical practice guidelines when available. Additional statements are included in Table 5.

DISCUSSION

The primary purpose of this Delphi study was to identify experts in the PT management of shoulder pain and utilize their experience and expertise to identify interventions that are common and effective in treating individuals with LHBT tendinopathy. For the 29 expert respondents who contributed to the final results, findings demonstrated that 61/86 interventions across seven intervention themes met the criteria of 75% consensus of being effective for the treatment of LHBT tendinopathy; conversely, 9/86 interventions across seven themes reached a 75% consensus of being ineffective for the treatment of LHBT tendinopathy. These findings suggest there are several physical therapy interventions across multiple intervention themes (with high consensus) including resistance exercise, stretching and flexibility, manual therapy, and patient education that are recommended by experts to treat individuals with LHBT tendinopathy. These interventions may serve as a proposed guideline of interventions to be investigated in clinical trials and trialed with patients clinically due to a lack of additional evidence to guide optimal management.

One noteworthy finding was the overall high consensus with the intervention of exercise including the themes of *resistance exercise/muscle performance* and *stretching/flexibility* and subthemes of *tendon loading techniques* (including

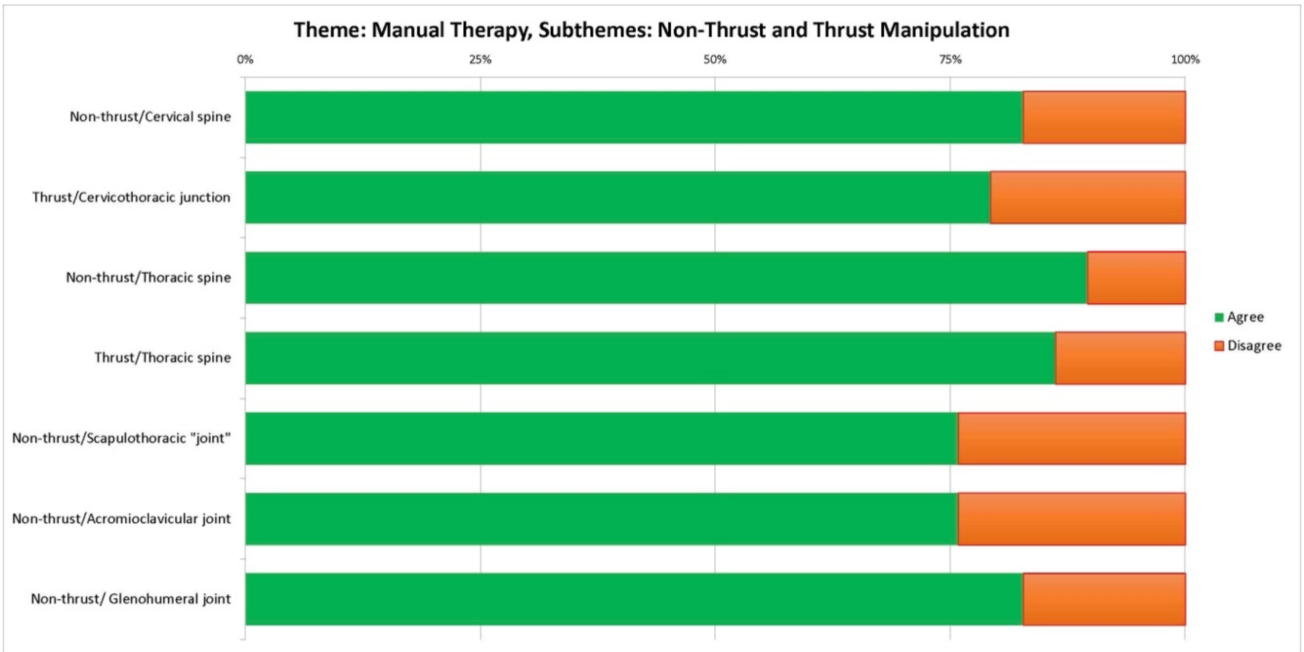

Figure 2. Consensus agree (⩾75%) for interventions in the theme manual therapy and subthemes of non-thrust and thrust manipulation by region.

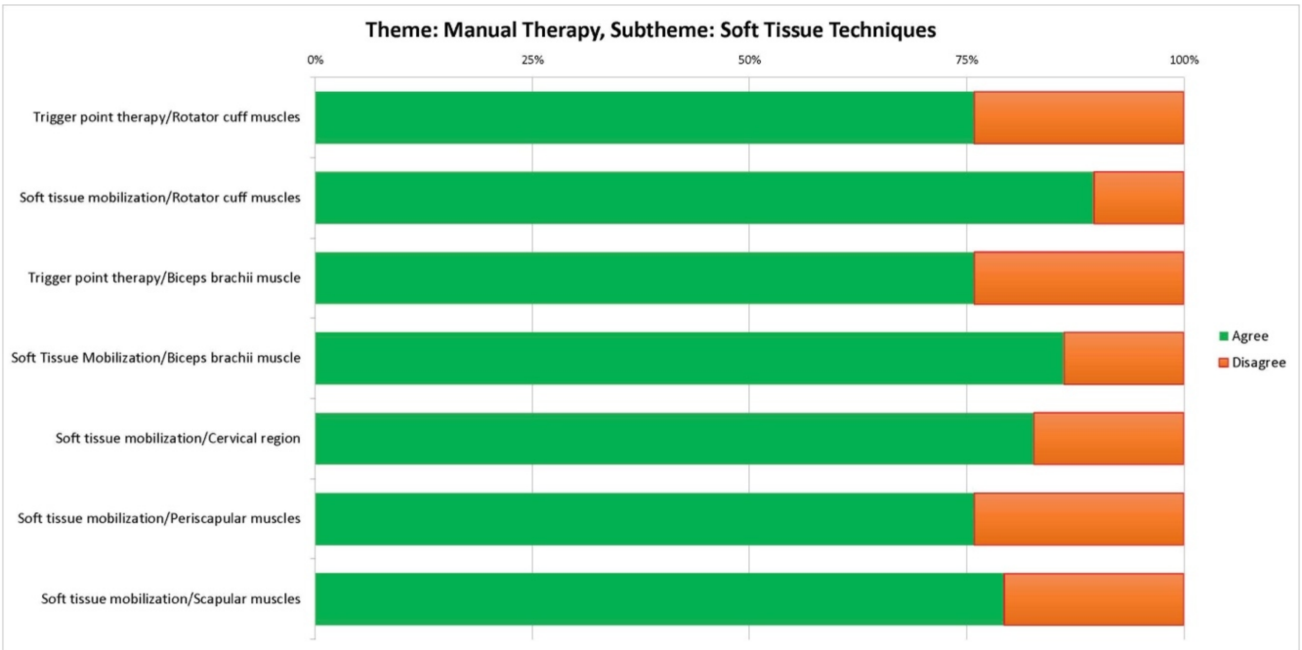

Figure 3. Consensus agree (⩾75%) for interventions in the theme manual therapy and subtheme of soft tissue techniques by region or muscle.

isometrics, concentric and eccentrics), *progressive resistance exercises*, *open/closed kinetic chain exercises* and *task-specific functional activities* (Table 2). These findings are not surprising considering strong recommendations in the literature for including exercise therapy as the first-line treatment to improve pain, mobility, and function in patients with subacromial shoulder pain.[30] Studies specific to tendinopathies describe exercise therapy, specifically eccentric exercise, as an effective component of an exercise program in treating individuals with tendinopathy.[31–33] Respondents agreed that "progressive loading of the LHBT should be matched to tissue capacity and pain severity/irritability" based on consensus with those *treatment statements,* combined with a consensus on the recommendation of five of five *tendon loading techniques*. Respondents also demonstrated consensus on nine of 11 *progressive resistance exercises,* and consensus on all interventions in the theme of *stretching/flexibility and* subthemes of *open/closed kinetic chain exercises* and *task-specific functional activities.* Krupp and colleagues[3] state that a comprehensive rehabilitation program should

Table 4. Results from Round III, Theme: Patient Education, Biophysical Agents, Dry Needling, Other

Theme: Patient Education	Agree, n (%)	Disagree, n (%)	Consensus
Activity modification	29 (100%)	0 (0%)	CA
Occupation modification	29 (100%)	0 (0%)	CA
Training/loading modification	29 (100%)	0 (0%)	CA
Medication	25 (86.20%)	4 (13.79%)	CA
Physical therapy treatment plan	29 (100%)	0 (0%)	CA
Pain neuroscience education	29 (100%)	0 (0%)	CA
Long head of the biceps tendon (LHBT) pathoanatomy	28 (96.55%)	1 (3.45%)	CA
Postural control	24 (82.76%)	5 (17.24%)	CA
Theme: Biophysical Agents			
Iontophoresis	2 (6.90%)	27 (93.10%)	CD
Phonophoresis	1 (3.45%)	28 (96.55%)	CD
Interferential current (IFC)	1 (3.45%)	28 (96.55%)	CD
Neuromuscular electrical stimulation (NMES)	3 (10.34%)	26 (89.65%)	CD
Transcutaneous electrical nerve stimulation (TENS)	3 (10.34%)	26 (89.65%)	CD
Ultrasound	3 (10.34%)	26 (89.65%)	CD
Laser Therapy	5 (17.24%)	24 (82.76%)	CD
Cryotherapy	17 (58.62%)	12 (41.38%)	NC
Moist Heat	13 (44.83%)	16 (55.17%)	NC
Theme: Dry Needling			
Dry Needling (long head of the biceps tendon)	15 (51.72%)	14 (48.28%)	NC
Dry Needling (biceps brachii muscle)	22 (75.86%)	7 (24.14%)	CA
Dry Needling (upper trapezius)	19 (65.52%)	10 (34.48%)	NC
Dry Needling (rotator cuff muscles)	21 (72.41%)	8 (27.58%)	NC
Dry Needling with electrical stimulation	15 (51.72%)	14 (48.28%)	NC
Theme: Other			
Taping	20 (68.96%)	9 (31.04%)	NC
Non-steroidal anti-inflammatory drugs (NSAIDs)	24 (82.76%)	5 (17.24%)	CA
Extracorporeal shock wave therapy (ESWT)	4 (13.79%)	25 (86.21%)	CD
Dry cupping therapy	5 (17.24%)	24 (82.76%)	CD
Cognitive behavioral therapy	22 (75.86%)	7 (24.14%)	CA

Abbreviations: CA=consensus agree; NC=non consensus; CD=consensus disagree; n=number of participants

focus on restoring dynamic stability to the shoulder and rehabilitation may vary depending on clinical presentation. Further, according to Krupp et al.[3] patients may progress through four phases (pain management and restoration of range of motion (ROM), active range of motion (AROM) and early strengthening, rotator cuff and periscapular strengthening, return to sport) which may explain why respondents recommended 32 of 34 exercise interventions and included the use of exercise interventions across all stages of tissue healing (acute, subacute, chronic).

A second noteworthy finding was the lack of agreement among respondents on interventions within the dry needling theme and the manual therapy subthemes of *thrust manipulation and soft tissue techniques* (Table 3). Respondents reached consensus on *non-thrust manipulation* interventions to the glenohumeral joint, cervical and thoracic spines, scapulothoracic and acromioclavicular joints and *thrust manipulation interventions* to the cervicothoracic regions (Figure 2) but did not meet the a priori consensus of 75% for *thrust manipulation* of the glenohumeral joint or cervical spine. Therefore, it is possible the respondents were familiar with literature surrounding manual therapy interventions known to be more effective in treating individuals with shoulder pain. Well described in the literature are the effects of cervicothoracic and thoracic manipulation in individuals with shoulder pain[34,35] demonstrating findings of reduced pain and disability immediately and up to 52 weeks.[36,37] However, there is overall less evidence to support thrust manipulation to the cervical spine and glenohumeral joint for the management of shoulder pain. Respondents did not reach consensus on instrumented soft tissue mobilization or deep transverse friction techniques (Table 3). Deep transverse friction techniques have been recommended for the treatment of various tendinopathies,[38,39] however, evidence is anecdotal[40] and the authors are not aware of studies investigating these

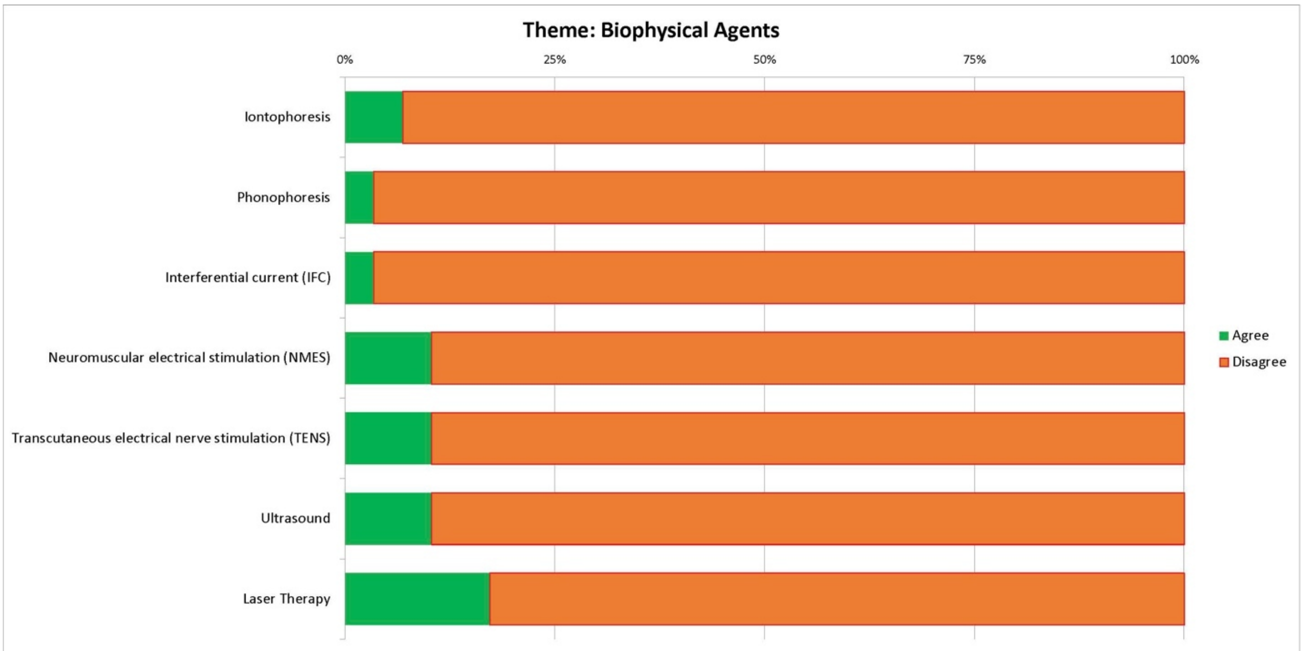

Figure 4. Consensus disagree (⩾75%) for interventions in the theme biophysical agents.

Table 5. Results from Round III, Theme: Treatment Statements

Theme: Treatment Statements	Agree, n (%)	Disagree, n (%)	Consensus
Interventions selected should be multimodal in nature.	28 (96.55%)	1 (3.45%)	CA
Clinical decision making should be based on a pragmatic/ICF and impairment-based approach.	29 (100%)	0 (0%)	CA
Clinical decision making should be based on a prescriptive/protocol-based approach.	5 (17.24%)	24 (82.76%)	CD
Clinical decision making should be based on following related clinical practice guidelines (region or pathology).	28 (96.55%)	1 (3.45%)	CA
Progressive loading of the LHBT should be matched to tissue capacity.	29 (100%)	0 (0%)	CA
Progressive loading of the LHBT should be matched to pain severity/ irritability.	29 (100%)	0 (0%)	CA
LHBT tendinopathy is often a primary shoulder pathology.	12 (41.38%)	17 (58.62%)	NC
LHBT tendinopathy is often a secondary shoulder pathology (accompanying other primary shoulder pathologies).	28 (96.55%)	1 (3.45%)	CA

Abbreviations: LHBT=Long head of the biceps tendon; ICF=International Classification of Functioning, Disability and Health; CA=consensus agree; NC=non consensus; CD=consensus disagree; n=number of participants

techniques specifically for treating individuals with LHBT tendinopathy. The subtheme of dry needling did not reach consensus on four of five interventions, with dry needling to the biceps brachii muscle being the only intervention reaching consensus (Table 4). Recent research recommends needling for the treatment of tendinopathy,[41–43] but only a single case series specific to dry needling of the LHBT for the treatment of LHBT tendinopathy was identified.[21]

A third notable finding was the consensus "disagree" in the theme of *biophysical agents* on seven of nine items including iontophoresis, phonophoresis, electrical stimulation (interferential current, neuromuscular electrical stimulation and transcutaneous electrical nerve stimulation), ultrasound, and low-level laser (Figure 4). In the theme of *other* there was also consensus "disagree" on shock wave therapy. Findings from a recent review of systematic reviews, specific to tendinopathies, found moderate-quality evidence to support the use of low level laser for pain and disability in the short-term and shock wave therapies showed a statistically significant improvement in pain and function at all follow-up periods.[33] However, the opinion persists that most of the available therapeutic modalities are only supported by weak evidence[44] with moderate evidence of no effect for interventions, such as laser therapy, extracorporeal shockwave therapy, pulsed electromagnetic energy, and ultrasound.[30] Additionally, based on the systematic review of the literature performed prior to the study, only low quality randomized controlled trials exist specifically outlining meaningful improvements using biophysical agents to treat LHBT tendinopathy.

Overall, the pooled recommendations of the respondents are consistent with current recommendations that a multimodal approach is optimal for the management of shoulder pain.[37,45–48] Physical therapy management of LHBT tendinopathy may involve a multimodal approach addressing associated impairments of the shoulder, scapular region and cervicothoracic spine with the application of exercise, joint and soft tissue mobilization as well as retraining dysfunctional movement patterns.[3] As such, the respondents reached consensus on a number of interventions across different themes and subthemes supporting a multimodal approach to treatment. Preliminary evidence on the PT management of LHBT tendinopathy is not robust enough to draw strong conclusions[1,2,13,16,19–21] and few studies focus on a multimodal approach. Therefore, obtaining international expert consensus on a multimodal treatment approach further informs treatment recommendations, which could potentially be utilized prior to electing for surgical options. Surgery (biceps tenodesis) may be a safe option and may offer a satisfactory rate of return to sport in young athletes,[4] however, according to Frank et al.[49,50] there is an increased risk of surgical revision in athletes under 20 years old with a history of throwing activity. Therefore, based on the results of this Delphi study conservative PT based management prior to individuals electing for more aggressive surgical intervention for the management of LHBT tendinopathy may be recommended based on these expert opinions.

LIMITATIONS

There were several limitations to this Delphi study. First, the respondents included in this study were those willing to participate and may not reflect all clinicians and researchers with expertise in treating shoulder pathologies. Additionally, the respondent group consisted of individuals from various countries. Although this diversity was also seen as a strength, the definitions that were used in this study may not have been commonly used by all respondents. Further, the views of the Delphi panelists may differ from other content experts who declined the offer to participate in the study, thus the expressed opinions may not be fully representative of all experts in the field. Further, any recommendations made as a result of this Delphi, warrant further investigation in trials as evidence of effectiveness of the recommended interventions is still lacking in this specific patient population.

CONCLUSION

The results of this study highlight the current absence of well-defined, PT interventions used to treat LHBT tendinopathy. Expert respondents reached consensus that a multimodal approach including exercise, manual therapy and patient education could be used to manage LHBT tendinopathy. Given the chronic nature of the condition combined with the lack of established guidelines for PT intervention, future research is needed to guide physical therapists who manage the condition.

CONFLICTS OF INTEREST

All authors do not have conflicts of interest to report.

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SUPPLEMENTARY MATERIALS

Appendix 1

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CHAPTER 7. Treatment of Individuals with Bicipital Tendinopathy using Dry Needling and Eccentric Exercise; A Case Series

7.1 Overview

Chapter 6 of this thesis highlights recommended interventions, based on expert consensus, which may be used for LHBT tendinopathy including: resistance exercise, manual therapy, stretching, patient education, biophysical agents, and dry needling. Chapter 2 of this thesis described several interventions including therapeutic exercise (including heavy slow-load exercise) as a recommended intervention with substantial evidence for its use in treating individuals with tendinopathy (Mead et al., 2018; Millar et al., 2021). Clinical practice guidelines published on subacromial pain syndrome recommend a multimodal approach to treatment including therapeutic exercise, manual therapy, biophysical agents, or modalities, (Diercks et al., 2014) however, there is limited guidance on the treatment pain specific to LHBT tendinopathy. Therefore, further investigation of specific interventions in the form of a mechanistic study, a randomized controlled trial or a case series to emulate a practice setting was warranted. This chapter reports on a case series report which describes a treatment regime that integrates information from Chapter 2, Chapter 5, and Chapter 6. In Chapter 6, it was evident that a multi-modal approach was recommended yet some interventions may target pain localized to the LHBT and other interventions target impairments on the glenohumeral joint, spine, and associated musculature. This chapter is an example of a multimodal treatment approach targeting pain localized to the LHBT for individuals with LHBT tendinopathy using heavy slow load exercise, dry needling, and stretching.

The case series includes ten patients with a diagnosis of LHBT tendinopathy based on examination by an orthopedic treating physician (which may or may not have included diagnostic imaging or ultrasound) and examination by the treating physical therapist. Each patient included in the case series received a multimodal approach to treatment which included dry needling (in the form of tendon fenestration to the painful LHBT tendon) followed by heavy slow load exercises based on a protocol by Alfredson et al. (1998) and stretching of the long head of the biceps muscle. Patient demographic information and baseline scores for patient-reported outcome measures (PROMS) were reported as well as relevant examination findings including evidence-based special tests of the shoulder. At discharge, PROMS and repeated special tests are reported. The results of this case series report provide an example of a multimodal approach to treating individuals with LHBT tendinopathy, based on a multimodal approach supported by clinical practice guidelines (Kelley et al., 2013a) and systematic reviews (Krey et al., 2015; Pieters et al., 2020) specific to subacromial pain syndrome. Achieving an understanding of effective interventions that can be implemented into a plan of care for individuals with LHBT tendinopathy may lead to effective care including avoidance of surgery. Demonstration of efficacy requires the development of randomized trials to determine effectiveness. Nonetheless, this case series provides a first step in gathering information on a possible approach to physical therapy management of individuals with LHBT tendinopathy based on the results of Chapter 3, Chapter 4 and Chapter 6, combined with expert recommendations in the literature (Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022).

7.2 Citation

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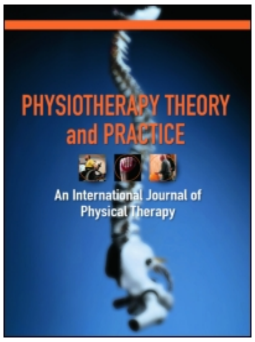

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Treatment of individuals with chronic bicipital tendinopathy using dry needling, eccentric-concentric exercise and stretching; a case series

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ABSTRACT

Objectives: To describe the outcomes of 10 patients with chronic biceps tendinopathy treated by physical therapy with the novel approach of dry needling (DN), eccentric-concentric exercise (ECE), and stretching of the long head of the biceps tendon (LHBT). **Methods**: Ten individuals reporting chronic anterior shoulder symptoms (> 3 months), pain with palpation of the LHBT, and positive results on a combination of tests including active shoulder flexion, Speed's, Hawkins Kennedy, Neer, and Yergason's tests participated in this case series. Validated self-reported outcome measures including the mean numeric pain rating scale (NPRS) and Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) were taken at baseline. Participants were treated with two to eight sessions of DN to the LHBT and an ECE program and stretching of the biceps muscle. At discharge, patients completed the global rating of change (GROC), QuickDASH and NPRS. **Results**: Patients had an improved mean NPRS of 3.9 (SD, 1.3; $p < 0.001$), QuickDASH of 19.01% (SD, 10.8; $p < 0.02$) and GROC +5.4 (SD, 1.3). **Conclusion**: Findings from this case series suggest that DN and ECE may be beneficial for the management of patients with chronic LHBT tendinopathy. Further research on the efficacy of this novel treatment approach is warranted.

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Dry needling; biceps tendinopathy; eccentric exercise

Introduction

Shoulder pain is extremely common with a point prevalence ranging from 7 to 26% in the general population, and a lifetime prevalence of up to 67% (Luime et al., 2004). Additionally, several studies have reported low rates of overall recovery < 50% at 1 year for individuals with a primary complaint of shoulder pain (Assendelft, Bouter, and Knipschild, 1996; Bang and Deyle, 2000; Krupp et al., 2009). The prognosis is generally poor and Rekola, Levoska, Takala, and Keinanen-Kiukaanniemi (1997) have reported that over 50% of individuals with neck or shoulder pain in a cohort of 440 patients experience a recurrence of their symptoms and pursue additional episodes of care within 12 months. In addition, several authors have reported a low rate of perceived recovery for individuals with a primary complaint of shoulder pain (Bang and Deyle, 2000); and a high economic burden on the medical system (Croft, Pope, and Silman, 1996; Kuijpers et al., 2006; Meislin, Sperling, and Stitik, 2005; Winters et al., 1999).

Shoulder pain related to pathology of the long head of the biceps tendon (LHBT) can be debilitating and may interfere with an individual's activity and participation (Ahrens and Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). Acute tendinopathy of the LHBT may start as an inflammatory condition or tenosynovitis of the LHBT as it courses through the bicipital groove of the humerus (Ahrens and Boileau, 2007; Krupp et al., 2009; Nho et al., 2010). Degenerative tendinopathy of the LHBT may involve the presence tendon thickening, disorganization, and irregularity of the tissue as well as the presence of hemorrhagic adhesions and scarring (Krupp et al., 2009). The overall incidence of bicipital tendinopathy remains unclear (Murthi, Vosburgh, and Neviaser, 2000; Nho et al., 2010) as it is often associated with other pathologic conditions of the shoulder including rotator cuff disease and subacromial impingement (Ahrens and Boileau, 2007; Krupp et al., 2009; Murthi, Vosburgh, and Neviaser, 2000). Controversy persists in the literature regarding the function of the LHBT and the diagnosis and appropriate management of disorders related to the LHBT (Murthi, Vosburgh, and Neviaser, 2000; Nho et al., 2010).

Chronic tendinopathy of the LHBT is a common condition which is often difficult to treat. Medical management of LHBT tendinopathy may include

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physical therapy, rest, activity modification, nonsteroidal anti-inflammatory drugs, corticosteroid injections, and tendon fenestration (Ahrens and Boileau, 2007; Nho et al., 2010; Yeh et al, 2009). More invasive surgical interventions include biceps tendon distal reattachment (tenodesis) or release (tenotomy) (Boileau et al., 2007; Nho et al., 2010). The LHBT tenodesis procedure releases the LHBT from the glenoid with subsequent anchoring to the humerus. Tenotomy procedures involve the release of the biceps tendon just distal to its proximal insertion; however, this is typically only indicated in individuals exhibiting significant partial tears and/or instability of the LHBT in the bicipital groove. However, both of these invasive procedures have been reported as recommended surgical interventions in cases of recalcitrant biceps tendinopathy (Boileau et al., 2007; Krupp et al., 2009; Walch et al., 1991). Other surgical procedures include arthroscopic debridement of the LHBT, subacromial decompression and or decompression of the LHBT with release of the transverse ligament (Krupp et al., 2009). Little consensus exists regarding ideal indications for LHBT diagnosis; moreover, there is a lack of general agreement on the ideal approach to treating chronic, recalcitrant pain of the LHBT (Ahrens and Boileau, 2007; Becker and Cofield, 1989; Krupp et al., 2009). A recent study looking at tenodesis versus tenotomy for biceps tendinopathy found equivocal results in the Disabilities of the Arm, Shoulder and Hand (DASH) visual analog scale (VAS) and American Shoulder and Elbow Surgeons score (ASES) between the two procedures (Friedman et al., 2015). However, it has been hypothesized that both surgeries may lead to late sequelae, particularly superior migration of the humeral head and a potential decrease in the acromiohumeral interval (Slenker et al., 2012).

Conservative physical therapy management of shoulder pain including LHBT pathology may involve a multimodal approach addressing associated impairments of the shoulder, scapular region, and cervicothoracic spine with the application of exercise, joint, and soft tissue mobilization as well as retraining dysfunctional movement patterns (Krupp et al., 2009). There is a paucity of literature outlining the conservative management of LHBT tendinopathy in isolation due to its typical presentation as a secondary shoulder pathology (Krupp et al., 2009). Due to the seemingly chronic nature of the symptoms associated with LHBT tendinopathy, after a thorough course of physical therapy over 3–4 months, individuals are often left with anterior shoulder pain resulting from LHBT tendinopathy and may need surgical intervention (Krupp et al., 2009). Conservative management alone may be suboptimal in relieving symptoms associated with chronic LHBT pain and many patients go on to seek more invasive treatment options such as surgical intervention.

One particular physical therapy management strategy, dry needling (DN) is defined as a skilled intervention that involves the use of a monofilament needle that penetrates the skin and is used to stimulate myofascial trigger points within the muscle in order to restore normal movement and function (Clewley, Flynn, and Koppenhaver, 2014; Kietrys et al., 2013). Dry needling has been demonstrated to be an effective, minimally invasive intervention for individuals with chronic shoulder pain and range of motion (ROM) deficits (Clewley, Flynn, and Koppenhaver, 2014; Ingber, 2000; Osborne and Gatt, 2010) as well as myofascial trigger point pain (Kietrys et al., 2013). DN has also historically been used by physicians to treat tendon pathology and pain by means of ultrasound guided tendon fenestration (Chiavaras and Jacobson, 2013; Housner, Jacobson, and Misko, 2009; Housner et al., 2010). The purpose of tendon fenestration is to induce a "healing response," which includes bleeding, inflammation and release of local tissue factors resulting in the remodeling of chronic pathologic tendon changes (Chiavaras and Jacobson, 2013; Estevez-Loureiro et al., 2013).

Physical therapists also commonly use eccentric exercise (EE) in the management of LHBT pathology, which has been found to be an effective treatment for other tendinopathies (Alfredson, Pietila, Jonsson, and Lorentzon, 1998; Camargo et al., 2012; Jayaseelan, Moats, and Ricardo, 2014; Jonsson, Wahlstrom, Ohberg, and Alfredson, 2006). More recently, a study by Stasinopoulos found that the eccentric-concentric exercise (ECE) combined with isometrics was more effective over ECE or EE alone in individuals with lateral elbow tendinopathy (Stasinopolous and Stasinopolous, 2017). Proposed mechanisms contributing to its effectiveness include the loading and lengthening of the tendon resulting in localized tendon remodeling and tensile strength (Alfredson, Pietila, Jonsson, and Lorentzon, 1998; Rutland et al., 2010). EE has been shown to be beneficial in individuals with shoulder impingement (Bernhardsson, Klintberg, and Wendt, 2011; Camargo et al., 2012; Jonsson, Wahlstrom, Ohberg, and Alfredson, 2006); chronic tendinopathy of the Achilles (Alfredson, Pietila, Jonsson, and Lorentzon, 1998); and patellar tendonopathy (Rutland et al., 2010) but to our knowledge, no studies have examined the effects of ECE on individuals with LHBT tendinopathy.

While DN and ECE have independently been shown to be beneficial in treating tendon pathology, to our knowledge, the combined effect of these interventions on LHBT tendinopathy has not been evaluated. Potentially, these two complimentary, conservative approaches may result in positive benefits such as reducing pain and improving function in individuals with recalcitrant LHBT, a condition that is often chronic and difficult to treat. The purpose of this retrospective case series is to describe the outcomes of 10 individuals with suspected LHBT tendinopathy treated with DN combined with an ECE protocol.

Methods

Patient descriptions

A total of 10 individuals with a primary complaint of > 3 months of anterior shoulder pain in the region of the LHBT presented to the University of Colorado Sports Medicine Center and the University of Colorado Student Health Center and participated in this case series. The case series was IRB approved from the Colorado Multiple Institution Review Board. Five individuals presented direct access and five individuals were referred by their orthopedist with a primary diagnosis of biceps tendinopathy. Clinical diagnosis by physical therapists included a combination of patient history, patient report of symptoms, palpation, and orthopedic special tests purported to identify bicep pathology. In five individuals presenting to physical therapy via direct access, LHBT tendinopathy was suspected based on the aforementioned. One individual presented 6-months post biceps tenodesis with a slow return of familiar symptoms while the other nine reported an insidious onset of symptoms. The 10 patients in this case series were evaluated at baseline and again at their discharge from physical therapy services. Information related to each individuals' age, relevant history, and primary symptoms are included in Table 1.

Patient examination

A thorough history was performed on each individual as a component of a routine physical therapy examination. Prior to the specific examination of the shoulder region, all 10 patients underwent an upper quarter screen examining according to common practice for the presence of neurological symptoms, cervical involvement, or other potential contributing mechanisms. Standard practice in the participating clinics involves assessment of ROM, muscle length, and muscle strength. Additionally, data related to function and pain was assessed by the shortened version of the Disabilities of the Arm, Shoulder and Hand questionnaire (QuickDASH) (Beaton, Wright, and Katz, 2005) and the NPRS (Jensen, Karoly, and Braver, 1986), respectively.

ROM of the shoulder was assessed and measured actively and passively according to Norkin and White (2009) and in some patients, a goniometric measurement of active shoulder flexion was taken at the point in the range that created a reproduction of anterior shoulder pain symptoms. Muscle length testing included assessment of pectoralis minor and pectoralis major, latissimus dorsi, and shoulder rotators (Kendall and Provance, 1993). Strength assessment was performed using the graded manual muscle tests described by Kendall and Provance (1993) and included scapular stabilizers (i.e., middle trapezius, lower trapezius, and serratus anterior) and glenohumeral muscles (i.e., shoulder flexors and extensors, shoulder lateral and medial rotators as a group). Pathoanatomic special tests for the shoulder utilized in the examination included: Speed's test (Magee, 2008); Yergason's (Magee, 2008); Neer impingement (Magee, 2008); Hawkins Kennedy (Magee, 2008); and palpation in the region of the LHBT (Kibler et al., 2002; Michener, Walsworth, Doukas, and Murphy, 2009). Speed's test (sensitivity 32%, specificity 75% for biceps pathology) was performed by having the clinician extend the elbow, supinate the arm and elevate the humerus with resistance to approximately 60°; a positive test is pain in the bicipital groove region (Calis et al., 2000; Holtby and Razmjou, 2004; Magee, 1992). Yergason's test (sensitivity 43%, specificity 79% for biceps pathology) was performed by having the clinician flex the elbow to 90° with a pronated forearm. The clinician would then have the patient resist supination with pressure at the patient's wrist. A positive test is pain in the area of the bicipital groove (Magee, 2008; Razmjou, Holtby, and Myhr, 2004). The Neer test (sensitivity 81% specificity 54% for subacromial impingement) was performed by having the clinician stabilize the scapula in a downward fashion while concurrently flexing the humerus maximally with the addition of overpressure; a positive test was reproduction of pain in the region of the superior shoulder (Calis et al., 2000; Michener, Walsworth, Doukas, and Murphy, 2009; Neer, 1983). The Hawkins-Kennedy test (sensitivity 63%, specificity 62% for subacromial impingement) was performed by having the clinician flex the humerus to 90°, followed by internally rotating the humerus maximally with the addition of overpressure; a positive test was reproduction of familiar symptoms (Calis et al., 2000; Hawkins and Kennedy, 1980; Michener, Walsworth, Doukas, and Murphy, 2009).

Depending on each patient's presentation, other special tests commonly used to diagnose shoulder

Table 1. Patient Demographic Information, Primary Complaint and Relevant Examination Findings in participating patients with long head of biceps tendinopathy (n = 10). Abbreviations: PT, physical therapy; RH, relevant history; ADLs, activities of daily living; AROM, active range of motion; DA, direct access; R, referral.

Patient	Gender	Occupation Patient Participation Relevant History(RH)	Complaints	Relevant examination findings	Method of access
1	Male	Student Volleyball player Failed two previous courses of PT; duration of symptoms 8 months	Pain with overhead serving, spike and pain with pushing	+ Speed's + Yergason's + Palpation + Neer + Hawkins-Kennedy + Pain AROM flexion at 90	DA
2	Male	Nurse Snowboarding, basketball History of biceps tenodesis; duration of symptoms 6 months; failed previous course of PT	Anterior shoulder pain with lifting weights, throwing	+ Speed's + Palpation + Neer + Hawkins-Kennedy	R
3	Male	Retired Tai Chi History of rotator cuff tear	Pain with active flexion, Tai Chi with arm in flexed position	+ Speed's + Palpation + Neer + Hawkins-Kennedy	R
4	Female	Writer Rock climber, musician Duration of symptoms 6 months	Difficulty with overhead climbing, overhead lifting	+ Speed's + Palpation + Neer + AROM flexion at 100	DA
5	Male	Surgeon Rock climber, Cross-fit Duration of symptoms 3.5 months	Anterior shoulder pain; difficulty surgeries; pain with rock climbing and weight lifting	+ Speed's + Yergason's + Palpation	R
6	Male	Finance Weight lifting Duration of symptoms 3 months	Pain with weight lifting and fly fishing	+ Speed's + Yergason's + Palpation	R
7	Female	Nurse	Pain with lifting, most ADLs, carrying and working as a nurse	+ Speed's + Palpation + Neer + Hawkins-Kennedy	R
8	Male	Student Rock climber Failed previous course of PT; duration of symptoms 11 months	Pain with rock climbing and pain with flexion, reaching	+ Speed's + Yergason's + Palpation + Neer + Hawkins-Kennedy	DA
9	Male	Student Competitive climber Failed previous course of PT; duration of symptoms 14 months	Pain with rock climbing	+ Speeds + Yergason's + Palpation + Neer + AROM flexion at 90	DA
10	Male	Self-Employed Volleyball player Failed previous course of PT; duration of symptoms 7 months	Pain with overhead serves	+ Speed's + Yergason's + Palpation + Neer + Hawkins-Kennedy	DA

pathology may have been performed. All 10 patients exhibited a combination of positive signs and symptoms known to be consistent with pain and pathology in the area of the LHBT (Table 1). All participating patients had a prior history of additional, suspected shoulder pain/pathology including extra-articular pathology (i.e., rotator cuff tendinopathy) or intra-articular pathology (i.e., labral pathology) but continued to have pain in the area of the biceps tendon after resolution of other shoulder symptoms. More specifically, the patients were either previously treated for pain specific to the area of the biceps tendon, or received physical therapy to treat other pathology of the shoulder (e.g., impingement, rotator cuff pathology, and labral pathology) and after their course of physical therapy, continued to have anterior shoulder pain in the region of the LHBT. Table 1 outlines the specific patient information including relevant history and examination findings for each patient.

Treatment protocol

Physical therapists (n = 4) with a range of clinical experience (12–22 years) performed examinations and provided treatment to all 10 patients. All four of the therapists are board certified in orthopedics and two had fellowship training in manual therapy. All four therapists were previously trained and certified in trigger point DN. A total of 10 patients presented to physical therapy for treatment over 2 years (March 2014–July 2016). Five of the patients presenting with LHBT tendinopathy in this case series had previously received physical therapy which most commonly included manual therapy, strengthening of the rotator cuff and scapular stabilizers, stretching and electrotherapeutic, and thermal modalities. For the current course of treatment outlined in this case series, there were three components that were performed in all 10 patients. Each individual received DN to the LHBT, ECE, and stretching.

Prior to initiating treatment, all patients read and signed a consent form for DN and were educated on

Figure 1. a and b. LHBT palpation and dry needling technique. The most painful and thickened areas of the tendon were palpated (a) and needled (b) with a pistoning technique for 20–30 repetitions in up to three areas.

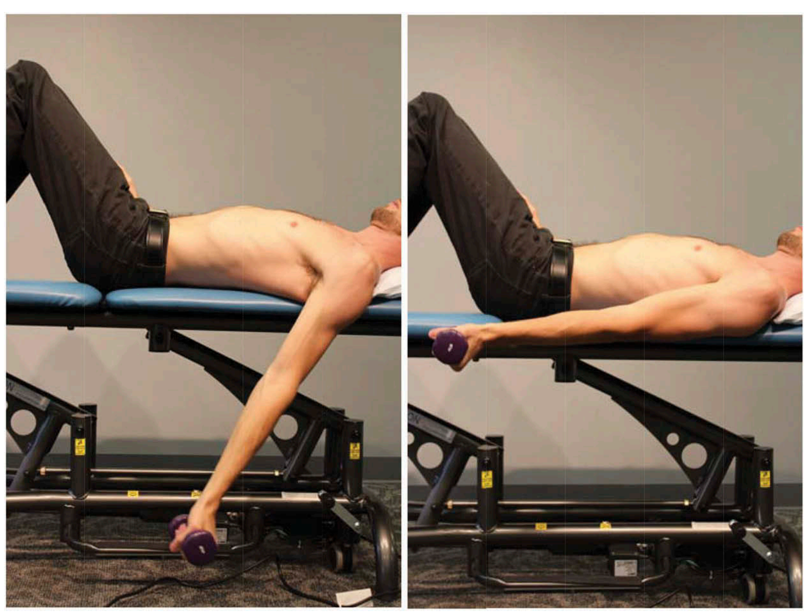

Figure 2. (a and b) Concentric and EE was performed with an emphasis on the eccentric component of the movement. Concentric shoulder flexion and eccentric shoulder extension was performed with the elbow extended. The upper extremity moved from full extension (a) to approximately 5°–10° of shoulder flexion (b) and back. The patient lowered eccentrically for a count of approximately 3–4 s followed by a 1 s concentric contraction. The patient performed 3 sets of 15 repetitions (4–6 pounds) once daily.

the benefits and risks associated with DN. The DN was performed with standard, disposable stainless-steel needles (.3 × 40 mm; Seirin; Weymouth, MA) inserted into the skin over the most painful and/or thickened areas of the tendon, confirmed with palpation (Figure 1). The technique utilized was a fast-in and fast-out (pistoning) technique for 20–30 repetitions per area in up to three areas, as described for tendon fenestration in the literature (Chiavaras and Jacobson, 2013; Housner, Jacobson, and Misko, 2009).

An ECE program that emphasized the eccentric component of the movement (Figures 2 and 3) was performed after the DN intervention in two positions. In the first position (Figure 2) the patient was supine, holding a free weight with the shoulder extended and the elbow extended. The patient was instructed to move the arm in the direction of flexion until they reached approximately 5°–10° above the level of the plinth or table and then eccentrically lower the shoulder to the full available range of extension for a count of 3–4 s. The concentric component of the exercise was performed for a count of only 1 s.

In the second position (Figure 3) the patient was supine with the shoulder extended. The patient moved the elbow in the direction of flexion until they reached their full amount of available elbow flexion. They would then eccentrically lower the arm for a count of 3–4 s. Again, the concentric component of the exercise was performed for a count of only 1 s.

The physical therapist selected a free weight heavy enough to create subjective, localized discomfort. This usually ranged between 4 and 6 pounds initially. The dosing of the exercise was based on the protocol used to treat Achilles tendinopathy therefore, it was recommended that patients perform approximately 3 sets of 15 repetitions of each exercise (Alfredson, Pietila, Jonsson, and Lorentzon, 1998). The Alfredson, Pietila, Jonsson, and Lorentzon (1998) protocol was modified slightly as patients in this case series were instructed to perform the exercises only once daily. The patients were instructed to increase the weight if they no longer reported localized discomfort with the exercise. Due to the position of the patient, the weight was lifted concentrically for approximately 1 s prior to the eccentric contraction however weight was chosen based on the patient's report of discomfort with the eccentric phase.

Stretching of the biceps muscle/tendon (Figure 4) was performed following the ECE and it was recommended that the patient perform this daily during the course of treatment. With the patient in standing and the back and neck in a neutral position, the shoulder joint was placed in a position of extension, while resting the hand on a surface behind the patient. The forearm was positioned in either supination or pronation, whichever position intensified the patient's perception of stretch locally over the anterior shoulder. The stretch was held for 30 s and repeated twice; this was repeated at home twice daily.

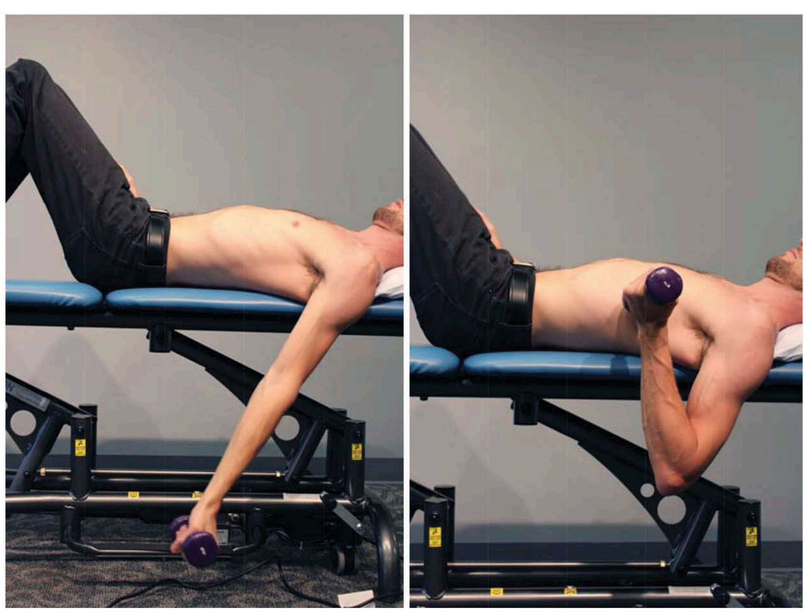

Figure 3. (a and b) Concentric and EE was performed with an emphasis on the eccentric component of the movement. Concentric elbow flexion and eccentric elbow extension was performed with the shoulder in full extension. The upper extremity moved from full elbow flexion to neutral elbow extension and back. The patient lowered eccentrically for a count of approximately 3–4 s followed by a 1 s concentric contraction. The patient performed 3 sets of 15 repetitions (4–6 pounds) once daily.

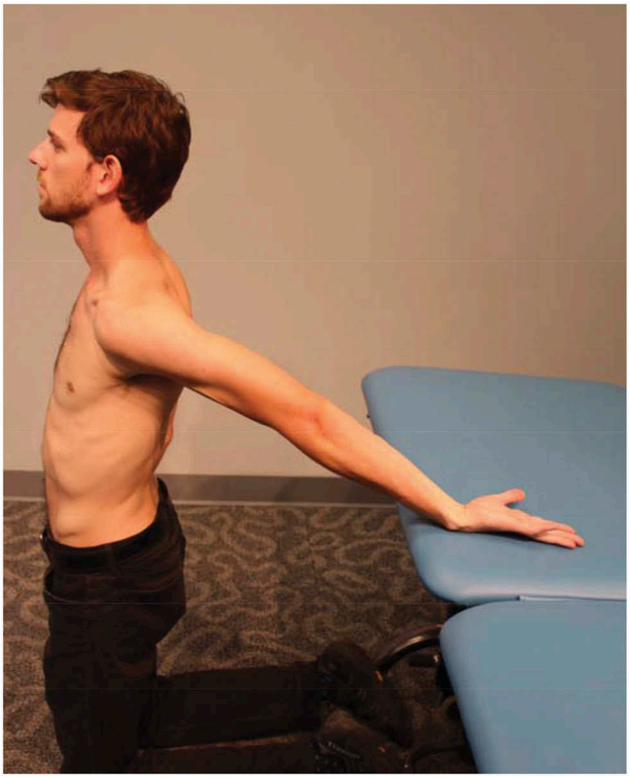

Figure 4. Static stretching of bicep with shoulder extension, elbow extension and forearm pronation. With palm facing up, the patient extended their shoulder until familiar tendon discomfort was felt, the stretch was held statically for 30 s; repeated twice; twice daily.

General advice was given to patients to maintain usual activity. Patients were instructed to do all daily living, work, and recreational activities that did not increase symptoms, and avoid activities which aggravated their familiar symptoms.

Outcome measures

Patients completed commonly used instruments at baseline and at discharge to assess their level of disability and the behavior of their shoulder pain including the QuickDASH and NPRS. The QuickDASH is an 11 item, self-administered questionnaire that addresses symptoms and physical function in individuals with disorders of the upper limb (Beaton, Wright, and Katz, 2005). The QuickDASH is scored from 0–100% (0% = no disability). The QuickDASH has demonstrated reliability, validity, and responsiveness when used as a tool to measure dysfunction in individuals with upper extremity disorders (Gummesson, Ward, and Atroshi, 2006.) The overall test–retest reliability and minimal clinically important difference (MCID) for the QuickDASH in individuals with shoulder pain has been reported to be .90 and 8.0%, respectively (Mintken, Glynn, and Cleland, 2009). An 11-point NPRS was used to measure pain intensity as the NPRS has been shown to be reliable and valid (Downie et al., 1978; Jensen, Karoly, and Braver, 1986; Jensen, Miller, and Fisher, 1998; Jensen, Turner, and Romano, 1994; Katz and Melzack, 1999). Patients rate their current, worst and least amount of pain in the last 24 h. Subsequently, the average of the three ratings was used to represent the patient's level of pain. The MCID for the NPRS has been reported to be between 1.1 and 2.2 points (Jensen, Karoly, and Braver, 1986; Jensen, Turner, and Romano, 1994; Michener, Snyder, and Leggin, 2011; Price, Bush, Long, and Harkins, 1994). To capture the patient's perceived recovery, the Global Rating of Change Scale (GROC) (Jaeschke, Singer, and Guyatt, 1989) was also collected at discharge. The 15-point global rating scale described by Jaeschke, Singer, and Guyatt (1989) was used at the end of the patient's episode of care. The GROC scale ranges from −7 (a very great deal worse) to 0 (about the same) to +7 (a very great deal better). Descriptors of perceived worsening or improving are assigned values from −1 to −7 and +1 to +7, respectively. We have used these instruments in clinical practice and in previous, published studies and the psychometric properties have been well documented (Boyles et al., 2009; Michener, Walsworth, Doukas, and Murphy, 2009; Mintken, Glynn, and Cleland, 2009).

Participants received a minimum of two and a maximum of eight treatment sessions (mean = 4.6) ranging from one to two sessions per week over a total duration of treatment ranging from 10 to 42 days. The interventions described above were utilized at each follow-up treatment session and patients were discharged when they had perceived improvement in function/disability and pain. None of the patients reported adverse events however one individual (64-year-old male), had significant pain and palpable, localized swelling in the area of the LHBT and proximal biceps muscle for 2 days after his first needling treatment. However, he requested a repeat treatment despite these symptoms due to his overall perceived improvement in pain and symptoms following the initial session. No further events were reported.

Data analysis

Descriptive statistics, including frequency counts for categorical variables and measures of central tendency and dispersion for continuous variables were calculated to summarize the data. Pretest and posttest data were analyzed using dependent *t* tests for

Table 2. Differences between baseline and discharge clinical outcomes (QuickDash and NPRS) in patients with long head of biceps tendinopathy (n = 10) receiving dry needling, eccentric-concentric exercise and stretching. Abbreviations: SD, standard deviation; t, test statistic; CI, confidence interval.

Outcome	Mean	SD	t	95% CI low	95% CI high	P value
QuickDash	19.0	10.8	4.971	9.97	28.06	0.002
NPRS	4.56	1.33	10.250	3.53	5.58	0.000

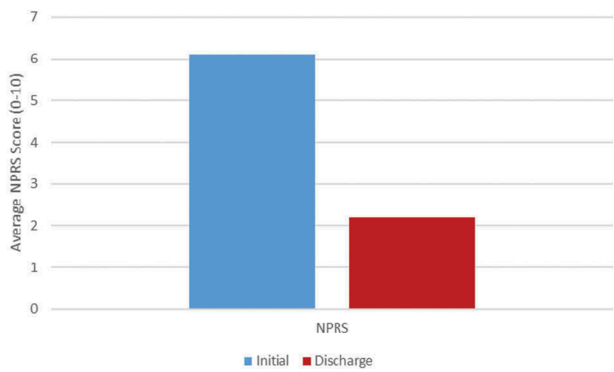

Figure 5. Change in numerical pain rating score (NPRS, average of current, best, and worst 0–10 NPRS over the previous 24 h) between baseline and patient discharge in patients with long head of biceps tendinopathy receiving dry needling (n = 10), eccentric-concentric exercise, and stretching (mean improvement 3.9 points +/-1.3, 95% CI 3.53, 5.58, $p < 0.001$).

both the NPRS and QuickDASH (Table 2). An alpha level of 0.05 was set for all analyses.

Results

The 10 patients (8 males, 2 females) in this case series ranged in age from 24 to 64 (mean age 40 years ±13) and reported anterior shoulder symptoms ranging from 3 to 14 months (mean 9.6 months +/- 3.9). The mean NPRS score at initial examination was 6.1 (+/- 1.6) and the mean QuickDASH score at initial examination was 33.61 (+/- 17.1). At discharge, the patients improved to a mean NPRS of 2.2 (+/- 1.3; $p < 0.001$) and to a QuickDASH of 7.75 (+/- 10.8; $p < 0.02$), and GROC +5.4 (+/- 1.3). (Figures 5 and 6)

Discussion

This retrospective case series describes the outcomes of 10 patients who attended physical therapy reporting a history of chronic anterior shoulder symptoms greater than 3 months, and pain in the vicinity of the LHBT which resulted in functional limitations. All patients exhibited a combination of positive examination findings suggesting LHBT pathology including pain with

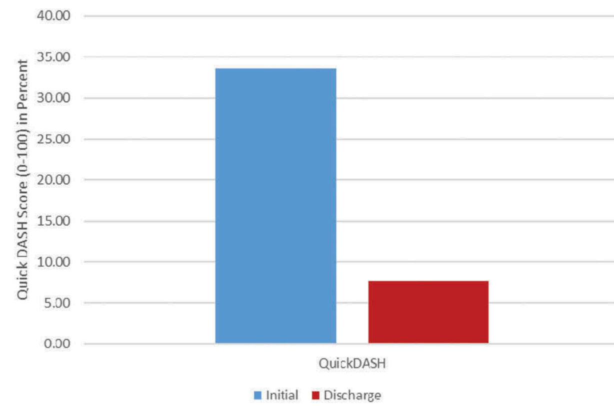

Figure 6. Change in disability (QuickDASH) between baseline and patient discharge in patients with long head of biceps tendinopathy receiving dry needling (n = 10), eccentric-concentric exercise, and stretching (mean improvement 19.01 +/-10.8, 95% CI 9.97, 28.06, $p < 0.02$).

palpation of the LHBT, Speed's, Hawkins Kennedy, Neer and Yergason's tests. Of the 10 patients, eight had a history of prior physical therapy that failed to resolve their symptoms. All patients were treated with two to eight sessions of DN, ECEs, and stretching. At the end of the course of treatment, which was typically determined based on patient symptoms, mean NPRS, and QuickDASH scores improved beyond the MCID. Even the lower bound estimates of the 95% CI exceeded the MCID in both the NPRS and QuickDASH. Patients' perception of their recovery as measured by the GROC also improved at patient discharge by an average of +5.4.

The mechanisms proposed to be at work with tendon DN and EE interventions have been described independently in the literature. According to Chiavaras and Jacobson (2013) the purpose of tendon fenestration is to induce bleeding, inflammation, and release of local tissue factors to create a healing response, resulting in the remodeling of chronic pathologic tendon changes. The concentric and eccentric component of the exercise intervention may be promoting tissue healing by a process Khan and Scott (2009) describe as "mechanotransduction" or the ongoing physiological process of cells sensing and responding to mechanical loads. The more active term "mechanotherapy" describes how load may be used therapeutically to stimulate tissue repair and remodel tendon. Studies (Alfredson, Pietila, Jonsson, and Lorentzon, 1998; Boyer, Goldfarb, and Gelberman, 2005) have shown that tendons can respond to controlled loading following injury. Additionally, a systematic review by Malliaras, Barton, Reeves, and Langberg (2013) concluded that the eccentric-concentric loading should be utilized either alongside or in replacement of eccentric loading in tendinopathy. However, the balance between managing what Vicenzino (2015) terms "offending activities" versus ideal, controlled loading activities can be difficult to determine. Our hypothesis is that somehow the combination of these two interventions may have stimulated tissue remodeling.

There are a number of limitations to this case series. There were four physical therapists treating the patients included in this case series which may limit the generalizability. Additionally, the ideal diagnostic criteria or "test cluster," which should be used to diagnose LHBT tendinopathy is not clear in the literature. Therefore, it is difficult to definitively determine without further diagnostics such as ultrasonography if the LHBT was indeed the symptomatic tissue. However, according to Simpson et al. the diagnosis of tendinopathy indicates clinically diagnosed tendon pain, with or without the presence of pathology on imaging (Simpson, Rio, and Cook, 2016). The authors of this case series agree that more comprehensive exploration of the "symptomatic area" may be important as we are unable to definitely determine if the tissue needled was the LHBT, the subscapularis or other pain provoking tissue in the anterior region of the shoulder. Regarding palpation of the LHBT, Gazillo et al. (2011) found that the overall accuracy of physicians palpating the LHBT was 5.3%, with all inaccurate palpations occurring medially to the intertubercular groove and a mean distance away of 1.4 cm. The most optimal position for palpating the LHBT in physical therapists remains unknown (Mattingly and Mackarey, 1996). More in depth exploration of the most optimal position for LHBT palpation combined with further study of the accuracy and interrater reliability of LHBT palpation is warranted in order to better determine and understand where the treatment effect is occurring locally. An additional limitation to this case series is that there was no long-term follow-up of patients after their discharge from physical therapy. As a result of these limitations and the fact that there was not a patient control group, we cannot infer a cause and effect relationship with this treatment approach.

In conclusion, the results of this retrospective case series suggest the combination of DN, ECE, and stretching may have the potential to improve pain and disability in individuals with chronic LHBT tendinopathy. We believe that these findings are potentially meaningful, as the next step for many of these patients is surgical intervention including biceps debridement, tenodesis, and tenotomy. Additionally, the results of this case series may suggest that this combination may be a compliment treatment to traditional manual therapy and strengthening of the rotator cuff and scapular stabilizing musculature typically utilized as a "first line" intervention to treat shoulder pain. Conservative management of individuals with chronic LHBT pain is often challenging and is not well described in the literature. The clinical outcomes observed in this case series suggest that further controlled trials of this novel treatment approach are warranted.

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Declaration of Interest

None Declared

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CHAPTER 8. Summary & Conclusions

8.1 Overview

The research conducted in this thesis fills an important gap in the literature on interventions used to treat individuals with LHBT tendinopathy. The studies in this thesis identified: (1) interventions in research studies primarily based on therapeutic modalities used to treat tendon pain; (2) interventions recommended by other literature for conservative management recommending physical therapy and a multimodal approach including exercise; (3) interventions actually implemented with this population in a clinical setting (large hospital system), which seem to align with recommendations from "other literature"; (4) the challenges of accurately diagnosing the condition based on physical therapists' limited accuracy with palpation; (5) recommended interventions based on the opinions of international experts in the field which align with “other literature”; and (6) promising results from a multimodal intervention approach targeting specific tendon pain. The collective information gained from these studies and the thesis provide the first steps towards identifying intervention variables that warrant further study in the form of multimodal interventions to address specific tendon pain and regional impairments associated with LHBT tendinopathy.

To fulfill the broader aim of the thesis, a blend of research methods was employed to comprehensively examine and address the sub-aims of the thesis. The first two manuscripts in this series examine the interventions identified in the literature and by physical therapists in a hospital system for the treatment of LHBT tendinopathy to provide context to current management of the condition. The third manuscript assesses physical therapists' ability to palpate the LHBT, which is an important factor in accurately diagnosing pathology and treating the tendon locally. The fourth manuscript presents interventions recommended by a consensus of international experts. The final study, in the form of a case series, describes the use of a multimodal approach to treat individuals with LHBT tendinopathy pain by implementing interventions directly to the tendon.

8.2 Summary of Study Findings

8.2.1 Identify specific, physical therapy-based interventions recommended to treat individuals with LHBT tendinopathy. (Scoping review and Delphi study, Chapter 3 and Chapter 6)

The aim of Chapter 3 was to identify and describe PT interventions reported in the literature used to treat individuals with proximal LHBT tendinopathy. Following a comprehensive search of electronic databases, records including research reports and articles (literature reviews, clinical commentaries and a Delphi study) were included in the review (Alizadeh et al., 2018; Barbosa et al., 2008; R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; Liu et al., 2012; McDevitt et al., 2022; McDevitt, Snodgrass, et al., 2020; Paynter, 2004; Taskaynatan et al., 2007; Xiao et al., 2021; Živanović et al., 2007). Interventions used to treat proximal LHBT identified in research reports primarily included the use of passive, therapeutic modalities (extracorporeal shock wave therapy, polarized light, ultrasound, low-level laser, iontophoresis) with little investigation of a multi modal approach to treating the condition. Therapeutic modalities have often been used by physical therapists to treat musculoskeletal conditions, including tendon pathology (Lindsay et al., 1995; Watson, 2000), however, opinion persists that passive modalities should be reserved for the initial stages of rehabilitation to mitigate localized tendon pain (Krupp et al., 2009). According to Millar et al., the efficacy of a treatment should be based on reversal of tendon pathology and not just resolution of patient symptoms (Millar et al., 2021) which seems to be the goal of the randomized controlled trials.

Multiple rehabilitation strategies have been recommended to treat tendinopathy which act through divergent mechanisms (Millar et al., 2021), however, randomized controlled trials on the management of LHBT tendinopathy seemingly focus on one approach and one mechanism. While it is not surprising that therapeutic modalities have been studied and used to treat LHBT-related pain, it should be noted that there is generally weak evidence supporting their overall effectiveness (Cardoso et al., 2019), and some research suggests that there is evidence of no effect (Pieters et al., 2020). Extracorporeal shock wave therapy and low level laser are two approaches that are supported by the literature (Girgis & Duarte, 2020; Irby et al., 2020), however, this unimodal approach may not be sufficient to restore impairments of mobility and strength which often accompany tendinopathies. Many of the studies included in this review investigated the use of therapeutic modalities as a treatment for LHBT tendinopathy.

In contrast, the non-research articles included in this review (literature reviews, clinical commentaries, and Delphi study), primarily recommend the use of a multimodal approach including, manual therapy, exercise (including tendon loading), dry needling, patient education and, therapeutic modalities to treat LHBT tendinopathy (R. E. Chen & Voloshin, 2018; Ejnisman et al., 2010; Harwood & Smith, 2004; Krupp et al., 2009; R. B. Lewis et al., 2016; McDevitt et al., 2022; Paynter, 2004). This multimodal approach seems to be more comprehensive than the unimodal approach and is also one that is more aligned with current treatment of other tendinopathies and shoulder pain. The authors of one review recommended a four-phase progression including pain management, restoration of range of motion, active range of motion, early strengthening, rotator cuff and periscapular strengthening, and return to sport (Krupp et al., 2009) which included many elements recommended by experts in Chapter 6. A multimodal approach was supported by several other commentaries including education on activity modification, stretching, joint mobilization, dry needling, and various forms of strengthening, including isometrics, isotonics, core, rotator cuff, and scapular strengthening (R. B. Lewis et al., 2016; Paynter, 2004). The combined results of these recommendations continue to suggest that a multimodal approach may be the optimal management strategy for treating individuals with LHBT tendinopathy. Further, this information is very reflective of information gleaned from literature on the management of tendinopathy and shoulder pain (Cardoso et al., 2019; Millar et al., 2021; Pieters et al., 2020). Again, it is clear that more research is needed to establish formal treatment guidelines for managing individuals with LHBT pathology. The results from this study may serve to reinforce work adopted from literature on tendinopathy and shoulder pain while concurrently informing future work, however, the findings of this scoping review suggest that this preliminary evidence is not robust enough to draw strong conclusions. Randomized controlled trials are needed, however, it is uncertain which interventions should be investigated to determine optimal management strategies and efficacy of treatments.

Chapter 6 had a similar aim which was to establish consensus on physical therapy interventions for individuals with LHBT tendinopathy using the Delphi method approach. A total of 136 potential participants were contacted with a final respondent group comprised of 29 international experts in the physical therapy management of individuals with shoulder pain. A benchmark of ≥ 75% agreement was the a priori cutoff utilized to determine consensus among respondents. Findings demonstrated that 61/86 interventions across 7 intervention themes met the criteria for consensus (agree) as being effective for the management of individuals with LHBT tendinopathy and 9/86 interventions across 7 themes met the criteria for consensus disagree for being ineffective (disagree); 15 interventions did not achieve consensus (McDevitt et al., 2022). Consensus agreement was high for multimodal interventions including exercise (resistance exercise, muscle performance, stretching/flexibility), manual therapy and patient education. These findings are not surprising, again, considering the strong recommendations in the literature for including a multimodal approach supporting exercise therapy as the first-line treatment to improve pain, mobility, and function in patients with tendinopathy (Cardoso et al., 2019) and subacromial shoulder pain (Pieters et al., 2020). Further, respondents agreed that "progressive loading of the LHBT should be included which is consistent with information reported in Chapter 1. Respondents had consensus disagreement on the use of several biophysical agents/therapeutic modalities and dry needling (other than the biceps brachii muscle). This is an interesting finding considering the information reported in Chapter 3 which described a focus on therapeutic modalities in the randomized controlled trials. According to our findings in Chapter 6, there is consensus among experts that several physical therapy interventions, including resistance exercise, stretching and flexibility, manual therapy, and patient education, are effective in the treatment of individuals with LHBT tendinopathy (McDevitt et al., 2022). While further research is needed to determine the optimal management of this condition, these interventions may serve as a start to a proposed recommendation for clinicians to use in future clinical trials and in clinical practice.

8.2.2 Identify the types of rehabilitation CPT billing codes and number of visits and summarize the types of interventions used for patients with LHBT tendinopathy in a large hospital-based system. (Retrospective chart review, Chapter 4)

The aim of Chapter 4 was to investigate the use of physical therapy prior to biceps tenodesis and tenotomy surgeries by identifying types of rehabilitation billing codes, the number of physical therapy visits and the themes and types of interventions utilized by clinicians. The information reported in Chapter 4 is necessary to capture and understand how individuals with LHBT tendinopathy are currently managed in an authentic clinical setting. Medical records in a large hospital-based system database and chart notes reporting on patient visits were analyzed, including procedure codes based on active or passive interventions, and themes of interventions utilized by physical therapy. Only 20.1% of patients who met inclusion criteria attended physical therapy prior to surgery. There is similar, prior evidence that only 21.3% of individuals who had surgery for femoroacetabular impingement attended physical therapy (Young et al., 2019) prior to surgery.

In our study, the median number of PT visits was 4, and 63% of patients had 4 or more visits to physical therapy. Active interventions were used slightly more than passive interventions based on billing codes utilized including a high utilization of therapeutic exercise (muscle performance/resistance, functional activity, motor control and stretching). The highest utilized passive intervention was manual therapy which included soft tissue mobilization, non-thrust manipulation (glenohumeral joint and cervical spine) and thrust manipulation (thoracic spine). The chart notes within the active code of therapeutic exercise included themes of resistance exercise/muscle performance (including tendon loading techniques and progressive resistance exercise) and muscle length/mobility (including stretching and flexibility and range of motion). The chart notes within the passive code of manual therapy included themes of joint mobility (with subthemes of non-thrust manipulation and thrust manipulation), soft tissue mobilization (with subthemes of general techniques and specific techniques) to the shoulder region and LHBT, and range of motion (with subthemes of passive range of motion and active assisted range of motion).

There was overall low utilization of the passive code for biophysical agents (electrical stimulation, transcutaneous electrical nerve stimulation, iontophoresis, ultrasound/phonophoresis, and hot/cold therapy) which is consistent with our findings from Chapter 6 that reported disagreement among experts on the utilization of biophysical agents.

Overall, the findings in Chapter 4 align with the evidence presented in Chapter 6, showcasing that healthcare professionals adopt a multi-modal approach to patient care while experts endorse the use of near exact interventions to be implemented in clinical practice. Further, it is encouraging that physical therapy interventions utilized in an authentic clinical setting were consistent with contemporary evidence for the treatment for shoulder pain (Pieters et al., 2020). However, it is unknown if these evidence-based recommendations based on information reported in Chapter 3, Chapter 4 and Chapter 6 are to be considered the ideal management for individuals with LHBT tendinopathy. Prospective investigation should occur to determine if the results of this retrospective cohort study are consistent. Additionally, it is unclear why a small number of individuals with LHBT tendinopathy received physical therapy prior to surgery and it is worth investigating on a larger scale outside of one hospital system.

8.2.3 Determine if physical therapists can accurately and reliably palpate the LHBT to guide the examination and treatment of individuals with LHBT tendinopathy including the implementation of interventions directly to the tendon. (Palpation reliability study, Chapter 5)

The aim of Chapter 5 was to determine physical therapists' ability to accurately and reliably palpate the LHBT in two different arm positions with the use of ultrasound as the gold standard. Tenderness over the bicipital groove is still considered one of the most common and important clinical tests for diagnosing biceps tendinopathy (Ahrens & Boileau, 2007; Ditsios et al., 2012; Gill et al., 2007). Therefore, accurate palpation of the LHBT is critical for accurate diagnosis and subsequent management for LHBT pathology. Physical therapists palpated the LHBT in the intertubercular groove of the humerus on the bilateral shoulders of 32 asymptomatic participants in two different arm positions, as suggested by previous research (Gazzillo et al., 2011; Mattingly & Mackarey, 1996). The present study found that physical therapists exhibited poor inter-rater reliability in palpating the LHBT in two tested positions, with an accuracy rate of just under 50%

(McDevitt, Cleland, et al., 2020). This accuracy rate was higher than that previously reported for physicians palpating the LHBT (5.3%), (Gazzillo et al., 2011), but the present study's chosen positions for palpation (supine with 90° elbow flexion, 0° shoulder abduction, 20° medial rotation; supine with 90° elbow flexion, 30° shoulder abduction and neutral rotation) had similar accuracy rates and no difference in magnitude of accuracy.

These results suggest that neither of the supine positions tested can be highly recommended for clinical practice, and it remains possible that palpation in positions other than supine may be more accurate, however, this is unknown. Physical therapists heavily rely on both knowledge of anatomical structures and digital palpation to examine and treat patients; therefore, these results call to question our ability to properly identify individuals with LHBT tendinopathy. Specific to this study, there are clearly factors that may have influenced palpation accuracy including lack of pain in the tendon, clinician experience, and ultrasound methodology. Pain in the tendon upon palpation is considered a hallmark finding, crucial to accurate diagnosis of tendinopathies (Cardoso et al., 2019; Millar et al., 2021; Scott et al., 2020). Therefore, our hypothesis is that the inclusion of participants with non-painful tendons made the results of this study difficult to interpret and generalize to a population of individuals with a dominant characteristic of pain with palpation of the LHBT. According to Simpson et al. (2020) the diagnosis of tendinopathy assumes clinically diagnosed tendon pain, with or without the presence of pathology on imaging. Despite this recognition, the most ideal position to palpate the biceps tendon remains unknown which is problematic. Considering the prevalence of LHBT injuries, it is crucial to enhance our knowledge of healthcare providers' ability to palpate for pain and potential pathology in the LHBT to assess the feasibility of prioritizing palpation more fully as a clinical test to diagnose the condition. Chapter 5 elucidated our lack of understanding which represents a significant challenge in accurately diagnosing the condition. It is possible that these findings are what compromise the overall certainty with regards to diagnosis and treatment of LHBT tendinopathy.

8.2.4 Describe the outcomes of patients with LHBT tendinopathy who received physical therapy-based interventions (dry needling, eccentric-concentric exercise, and stretching) directly to the tendon. (Case series, Chapter 7)

The aim of Chapter 7 was to describe the outcomes of ten patients with chronic LHBT tendinopathy treated by physical therapy with dry needling, eccentric-concentric exercise, and stretching directly to the LHBT. Ten individuals reporting chronic anterior shoulder symptoms (> 3 months), pain with palpation of the LHBT, and positive results on a combination of tests including active shoulder flexion, Speed's, Hawkins Kennedy, Neer, and Yergason's tests participated. Self-reported outcome measures included the mean numeric pain rating scale and Quick Disabilities of the Arm, Shoulder, and Hand. Participants were treated with 2-8 sessions of dry needling to the LHBT, and an eccentric and concentric exercise program followed by stretching of the biceps muscle. At discharge, patients improved a mean of 3.9 (SD, 1.3; $p<.001$) on the numeric pain rating scale, 19.01% (SD, 10.8; $p<.02$) on the Quick Disabilities of the Arm, Shoulder and Hand, and +5.4 (SD, 1.3) on the global rating of change (McDevitt, Snodgrass, et al., 2020).

A systematic review by Malliaras et al. (2013) concluded that the eccentric-concentric loading should be utilized either alongside or in replacement of eccentric loading in tendinopathy. However, the balance between managing what Vicenzino terms "offending activities" versus ideal, controlled loading activities can be difficult to determine (Vicenzino, 2015). Our hypothesis is that the combination of 2 direct interventions to the tendon may have stimulated tissue remodeling or tolerance to tendon load by other physiologic mechanisms. Individuals with LHBT tendinopathy often present with chronic symptoms, so these findings provide clinicians with preliminary information on the potential utility of a combination of direct interventions (used to treat tendon pain) and indirect interventions (used to treat other associated impairments). This discovery suggests that a multimodal approach may need to incorporate both direct and indirect approaches to physical therapy management. The findings of this case series are potentially meaningful, as the next step for many of these patients is surgical intervention including biceps debridement, tenodesis and tenotomy. Additionally, the results of this case series may suggest that this combination may be a compliment treatment to traditional manual therapy and strengthening of the rotator cuff and scapular stabilizing musculature typically utilized as a “first line” intervention to treat shoulder pain. Conservative management of individuals with chronic LHBT pain is often challenging and is not well described in the literature. The clinical outcomes observed in this case series suggest that further controlled trials of this novel treatment approach are warranted.

8.3 Strengths and Limitations of the Thesis

The diagnosis and physical therapy management of individuals with LHBT tendinopathy is onerous due to challenges with 1) diagnosis including the reliance on clinical tests and 2) a lack of meaningful information on management of the condition. These identified obstacles, in combination, have created an opportunity to better understand the condition which may drive meaningful approaches to care. A significant strength of this thesis was the systematic and thorough collection of information and data available on the topic of LHBT tendinopathy. Data was assessed on multiple levels using several methods including a scope of the literature, an analysis of care in multiple clinics across a large hospital system, to expert consensus on identified interventions and the piloting of an experimental approach using multimodal interventions.

Another strength of the thesis was the inclusion of an experimental study to aid in fostering better understanding of diagnosis through tendon palpation which is a priority clinical test necessary to confirm diagnosis. Results of this study elucidated some of the current challenges with proper diagnosis which could also impact future research if not considered thoroughly. There are several strengths specific to each chapter which contribute to the strength of the thesis.

A major of strength of Chapter 3 was the systematic collection of information, diverse in design which included qualitative information specific to various interventions. Further, the subsequent interpretation of the findings and comparisons to the management of shoulder pain and tendinopathies fostered understanding of similar management strategies which parallel one another. To our knowledge, data of this nature has not been collected and summarized in a comprehensive format to describe the interventions used to treat individuals with LHBT tendinopathy.

A strength of Chapter 4 is that, to our knowledge, it is the first retrospective cohort study to describe the physical therapy interventions used to treat individuals with suspected LHBT tendinopathy. Understanding pragmatic care provided in an authentic clinical setting is informative to future work. This chapter also highlights an important gap in care which may include: 1) a lack of referral to physical therapy and/or 2) a lack of recognition of the potential benefits of physical therapy prior to the consideration of surgery. This study may also increase awareness of the fact that surgery is popular, but its necessity as a treatment option for recalcitrant LHBT pain warrants further exploration.

A significant strength of Chapter 5 is that it provided insight into the challenges of diagnosing LHBT tendinopathy, as even experienced clinicians who participated in this study had difficulty accurately locating the LHBT with digital palpation. This is an important insight that may affect future study including the recruitment of patients with LHBT tendinopathy. Further, we believe this study is a unique contribution to the field and future work as it highlights notable challenges with diagnosis as it relates to the clinical test of palpation for pain provocation.

Chapter 6 reported on the recommended interventions identified by experts in clinical practice and research. Chapter 6 summarized specific recommendations across 7 intervention themes. Due to the present dearth of literature on interventions used to treat individuals with LHBT tendinopathy, Chapters 3, 4 and 6 may provide important initial recommendations to physical therapists working with this population and may serve to inform higher level evidence in the form of randomized controlled trials.

Finally, despite several identified strengths of this thesis, a result of this work is also the identification of limitations of the thesis. A major limitation of the thesis was the lack of existing information combined with the relatively small sample sizes across studies included in this thesis. However, both of these were likely due to the paucity of existing knowledge and challenges with identifying the target population. It is important to acknowledge the specific limitations of each chapter contained in this thesis.

A limitation to Chapter 3 is that some relevant studies and information may not have been identified and additional information on this topic may be available from sources not included in this review. Also, the research reports included in this review were few and of questionable quality, which prevented the use of conclusive summative statements, thus limiting the generalizability of our findings. However, the scoping review (Chapter 3) did highlight important gaps that informed subsequent investigations of the thesis and may inform future research.

Chapter 4 has inherent limitation due to the retrospective nature of the data used which only represents one cohort in one geographical location making the findings less generalizable. Another limitation of Chapter 4 is we were unable to identify patients with LHBT tendinopathy who did not have biceps tenodesis or tenotomy surgery potentially leading to omitted cases in analysis. Further, due to challenges with diagnosis of the condition, the primary way to confidently identify patients with the condition was to describe individuals who eventually had surgery for the condition.

A significant limitation of Chapter 5, the palpation study, was that individuals with known LHBT pain were not included. We hypothesized that the accuracy of LHBT palpation may have increased in individuals with tendon pain, as pain with palpation is a key clinical finding used by clinicians to diagnose the condition.

A key limitation noted in the Delphi study (Chapter 6) is the potential for selection bias, as only those who agreed to participate were included in the study. This may not accurately represent the views of all experts in the field, particularly those who declined to participate. As a result, the opinions expressed by the Delphi panelists may not be a comprehensive representation of all professionals and researchers with expertise in treating shoulder pathologies.

Finally, a known limitation to the case series, (Chapter 7), is the ideal diagnostic criteria or "test cluster" used to diagnose LHBT tendinopathy is not known. Therefore, it is difficult to definitively determine (without further diagnostics) if the LHBT was indeed the symptomatic tissue in the patients treated for local tendon pain surmised to be resulting from LHBT tendinopathy. A more comprehensive exploration of the "symptomatic area" may have been important as we were unable to definitively determine if the tissue palpated and subsequently dry needled was the LHBT, the subscapularis, or other pain-provoking tissue of the anterior shoulder. In summary, identification of the aforementioned limitations is in itself an important contribution to the medical community including future researchers as recognition of these limitations may inform the methodology and improve the quality of future work.

8.4 Implications Clinical Practice and Future Research

8.4.1 Implications for Clinical Practice

As a first step, this thesis identified important and key interventions for treating individuals with LHBT tendinopathy based on multiple sources. By the rigorous collection and analysis of data on the current practices, combined with an increased understanding of pragmatic PT interventions for management of the condition, this thesis contributes evidence-based recommendations for clinical practice. There is currently a lack of high-level evidence or established guidelines for managing this patient population, leading to the widespread use of surgery as a management strategy. Without recommendations, physical therapists must rely on guidelines for related conditions such as shoulder pain and tendinopathy and may not be able to determine the most effective treatment strategies for managing LHBT tendinopathy. This thesis is a first step towards contributing to information needed for clinicians to make informed decisions by way of the recommendations summarized below. This thesis sheds light on the significant challenges involved in diagnosing and treating LHBT tendinopathy. The findings of the studies systematically analyzed within this thesis provide valuable recommendations for addressing these challenges.

8.4.1.1 Implications for Clinical Practice-Therapeutic Exercise

Therapeutic exercise is a recommendation for the treatment of LHBT that was pervasive across Chapters 1 and 2 and the studies contained in this thesis: Chapter 3 (scoping review), Chapter 4 (retrospective review), Chapter 6 (Delphi study), and Chapter 7 (case series). From this evidence it is recommended that a treatment plan be developed to address specific patient impairments in muscle length, strength, and performance in individuals with LHBT tendinopathy. Impairments in muscle length can be addressed through stretching of the biceps brachii, latissimus dorsi, upper trapezius, medial rotators of the shoulder, pectoralis major and minor and the posterior capsule. Impairments of muscle strength and performance in the rotator cuff muscles, biceps brachii and periscapular muscles should be addressed using progressive resistance exercises, open and closed chain exercises and task specific activities including reaching, overhead, occupational and sport specific. Tendon loading is an important aspect of a patient's plan of care and should include concentric/eccentric techniques and isometrics. The patient's response to treatment including pain should be considered as the patient progresses through a course of rehabilitation.

8.4.1.2 Implications for Clinical Practice-Manual Therapy

Based on the studies contained in this thesis, it is recommended that manual therapy be included as a component of a comprehensive treatment plan; recommendations include both thrust and non-thrust techniques to address mobility impairments in the shoulder, cervical spine, and thoracic spine. Thrust manipulation can be used for the thoracic spine and non-thrust manipulation for the glenohumeral joint, cervical, and thoracic spine, and acromioclavicular joint. Soft tissue mobilization techniques may be beneficial for addressing pain, stiffness, and dysfunction and should be applied to the cervical region, periscapular muscles, rotator cuff muscles and, biceps brachii muscle. Additional techniques supported by Chapter 4 (retrospective review) and Chapter 6 (Delphi study) only include instrument assisted soft tissue techniques, trigger point therapy to the biceps brachii muscle and deep transverse friction to the LHBT and biceps brachii muscle.

8.4.1.3 Implications for Clinical Practice-Patient Education

Patient education is is a recommendation for the treatment of LHBT that was present across Chapters 1 and 2 and the studies contained in this thesis: Chapter 3 (scoping review), Chapter 4 (retrospective review), Chapter 6 (Delphi study), and Chapter 7 (case series). Patient education plays a crucial role in the comprehensive rehabilitation of an individual with biceps tendinopathy. Patient education recommendations include educating the patient on activity modification (Chapters 3, 4, 6, 7) incorporating occupational and sport specific tasks. Initially, activity modification may include temporary withdrawal from aggravating activities. Additional recommendations (Chapters 3, 4, 6) include educating the patient on postural control, load modification and pain neuroscience education in cases of increased chronicity of the condition.

8.4.1.4 Implications for Clinical Practice-Biophysical Agents/Therapeutic Modalities

Recommendations for the use of biophysical agents are unclear as evidence collected in the studies in this thesis was often conflicting. Biophysical agents including low level laser, polarized light, ultrasound, and interferential current were studied and recommended in randomized controlled trials (Chapter 3), however, expert opinion based on the Delphi study resulted in disagreement on their use in the plan of care for a patient with LHBT tendinopathy. It is possible that biophysical agents have utility for managing local tendon pain in the earlier stages of rehabilitation. Therefore, further research is needed to elucidate this recognized conflict in information.

8.4.1.5 Implications for Clinical Practice-Other (Dry Needling)

Based on this thesis, the recommendation is that dry needling to the biceps brachii muscle might be utilized as an adjunct to a patient's plan of care to treat impairment and/or pain in the muscle (Chapters 3, 4, 6, 7). Dry needling to the LHBT may be utilized to induce healing and treat localized pain (Chapters 3, 4, 7), however, experts in the Delphi study (Chapter 6) did not have consensus on its use. The retrospective review (Chapter 4) demonstrated additional use of dry needling in other muscles including the upper trapezius, rotator cuff, pectoralis major, latissimus dorsi, and deltoid muscles likely based on specific patient impairments in the aforementioned muscles, however, these findings were not consistent in other chapters of this thesis.

8.4.2 Implications for Future Research

The combined results of this thesis provide detailed considerations for future research. The recommendations outlined above are based on Level IV and V evidence. As such, these recommendations are considered preliminary, and randomized controlled trials should be conducted before strong recommendations can be made. The studies in this thesis consisted of reviews, survey-based data and a small sample of patients in the form of a case series which limits translation to practice. For example, recommendations made as a result of the Delphi study (Chapter 6), warrant further investigation in trials as evidence of the effectiveness of the recommended interventions is still lacking in this specific patient population. Information reported in Chapter 7 (the case series) suggest that a combination of interventions, directed toward tendon pain, may be a complement treatment to traditional manual therapy and exercise typically utilized as a "first line" intervention to treat shoulder pain. The case series shed light on the idea that tendon pain may need to be addressed in concert with interventions targeted towards other regional impairments which may contribute to pain and pathology.

Intervention strategies elucidated by this thesis need to be tested in controlled trials utilizing large samples of patients suspected to have LHBT tendinopathy. Future studies need to include patient reported outcomes, specifically pain and disability which seem to be drivers for patients electing to have surgery. Further, future studies need to be intervention based to explore the efficacy of interventions reported throughout this thesis. One potential next step would be to outline a detailed or treatment protocol for a randomized controlled trial based on the information provided in this thesis, drawing from Chapter 1, Chapter 2, Chapter 3, Chapter 4, and Chapter 6. A high quality randomized controlled trial could incorporate a wide range of evidence-based information from various sources including this thesis and subsequent randomized controlled trials. A randomized controlled trial (similar to what was outlined in the Appendix A with a larger cohort of patients who have been diagnosed with LHBT tendinopathy is important to test the recommended interventions. A second step to future research would be to produce a practice guideline to inform clinical practice. A comprehensive practice guideline could be created with feedback elicited by stakeholders and experts prior to adoption. Future prospective studies could then compare a multimodal treatment package based on these guidelines to injection or usual care, to determine which treatments produce the best patient outcomes. In summary, given the chronic nature of the condition combined with the lack of established guidelines for PT intervention, future research is necessary to guide physical therapists who manage the condition.

8.5 Conclusion

The chapters included in this thesis serve as a starting point to understanding LHBT tendinopathy including diagnosis and intervention. Interventions recommended include therapeutic modalities to remediate pain and irritability while a multimodal approach including manual therapy, education and exercise is recommended to treat additional impairments associated with the condition. This thesis is the first to report on information related to LHBT tendinopathy management from a multitude of sources and should serve as an important step to providing clinical recommendations to foster future trials and practice guidelines.

CHAPTER 9. References

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CHAPTER 10. Appendices

Appendix A. COVID-19 Pandemic Impact on Thesis Supporting Documents

Dry needling and heavy slow load exercise versus traditional physical therapy in the treatment of individuals with biceps tendinopathy; a pilot study

Project Description

I. Purpose and Specific Feasibility Objectives and Goals

Purpose

The overall purpose of the pilot study is to test the feasibility of methods and procedures for later use to conduct a large study to determine if patients who receive physical therapy including dry needling, heavy slow load exercise and a comprehensive rotator cuff and scapular stabilization program achieve greater reductions in pain and disability in the short (4 weeks) and long term (6 months) compared to those who receive soft tissue mobilization and a comprehensive rotator cuff and scapular stabilization program. A secondary purpose is to search for possible effects and associations between variables that may be worth following up in a subsequent, larger study.

Specific Feasibility Objectives

1. Determine if the outlined study procedures and methods are feasible

2. Assess execution of randomization and blinding procedures and determine if randomization is acceptable to study participants

3. Assess overall recruitment rates (number of participants recruited in a 4 week period)

4. Determine percentage of eligible participants who enroll and participate in the study

5. Determine acceptability and feasibility of the experimental treatment through treatment effect and its variance; and therapist views

6. Assess participation retention rates in the form of drop-out/lost to follow-up

7. Determine the number of participants who cross over to receive another treatment intervention including physical therapy, injections and surgery

8. Assess treatment safety

9. Determine appropriate number of researchers and research assistants to run a larger trial

10. Assess results of outcome measures in both groups to inform powering of a larger trial

Specific Feasibility Outcomes

1. Treating therapists are able to adhere to all intervention procedures as reported by the documentation integrity checklists for both groups.

2. Through qualitative survey results, determine if randomization was acceptable to study participants.

3. Number of participants recruited (4 subjects per month across 2 sites)

4. At least 70% of all eligible participants will enroll

5. At least 50% of participants in experimental group met MCID for NPRS, ASES, SPADI, QuickDASH; through qualitative survey results, determine if treating therapists found value in the experimental procedure

6. At least 95% retention of participants at 3 months and 80% retention of participants at 6 months

7. Less than 10% of recruited individuals to cross-over to another intervention

8. Manage adverse event tracking form; <5% of participants report adverse event

9. Determine resource need for research personnel based on qualitative survey results; tracking of hours spent on all pilot study procedures including recruitment, consent, patient interaction, and patient follow-up

10. For continuous outcomes, preliminary data such as the mean and standard deviations for the control and experimental group will be calculated in an effort to adequately power a larger trial.

Large Multicenter Trial Hypotheses

1) *Individuals with biceps tendinopathy who receive an intervention of soft tissue mobilization, dry needling (DN), heavy slow load exercise and a comprehensive rotator cuff and scapular stabilization program will demonstrate significant differences in disability and pain scores compared to the control group as measured by the:*
    a. *American Shoulder and Elbow Surgeons Standardized Shoulder Form (ASES.) This improvement will be a minimum mean difference of 8 points (standard deviation, 12 points) between groups which would indicate a clinically meaningful improvement.*
    b. *Disabilities of the Arm Shoulder and Hand (DASH)*
    c. *Patient Specific Functional Scale (PSFS)*

d. *Numeric Pain Rating Score (NPRS)*
e. *Shoulder Hand and Disability Index (SPADI)*

Specific Aim

To test the feasibility of a study comparing two physical therapy intervention groups and determine the benefits of using dry needling combined with heavy slow load exercise in a population of individuals with biceps tendinopathy.

II. Background and Significance

Shoulder pain is extremely common with a reported point prevalence ranging from 7-26% in the general population, and a lifetime prevalence of up to 67%.[1] In addition, several studies have reported low rates of perceived recovery for individuals with a primary complaint of shoulder pain. [2,3] In general, the prognosis is poor, with overall low recovery rates and a high cost burden on the medical system.[4-7] Shoulder pain related to long head of the biceps tendon (LHBT) pathology due to inflammation (tendinopathy, tendinitis) can be debilitating and may interfere with an individual's activity and participation due to consistent complaints of pain.[8-10] The overall incidence of bicipital tendinitis or tendinopathy remains unclear[8,11] as it is often associated with other pathologic conditions of the shoulder including rotator cuff disease and subacromial impingement.[9-11]

Chronic tendinopathy of the LHBT is a common condition which is often difficult to treat. Studies have reported that 76-85% of patients with rotator cuff tears had associated LHBT tendinopathy.[12,13] Medical management of LHBT tendinopathy may include physical therapy, rest, activity modification, non-steroidal anti-inflammatory drugs, corticosteroid injections and tendon fenestration.[8,9,14] More invasive surgical interventions include biceps tendon distal reattachment (tenodesis) or release (tenotomy).[8,15] The LHBT tenodesis procedure releases the LHBT from the glenoid with subsequent anchoring to the humerus more distally. Tenotomy procedures involve the release of the biceps tendon just distal to its proximal insertion, however this is typically only indicated in individuals exhibiting significant partial tears and/or instability of the LHBT in the intertubercular groove. However, both of these invasive procedures have been reported as recommended surgical interventions in cases of recalcitrant biceps tendinopathy.[10,15,16] Other surgical procedures include arthroscopic debridement of the LHBT, subacromial decompression and or decompression of the LHBT with release of the transverse ligament.[10] Little consensus exists regarding LHBT diagnosis as the clinical tests are not specific enough to diagnose the disorder, moreover there is a lack of general agreement on the ideal approach to treating chronic, recalcitrant pain of the LHBT.[9,10,17] A recent study comparing tenodesis versus tenotomy for biceps tendinopathy found equivocal results for function as measured by the Disabilities of the Arm, Shoulder and Hand (DASH) visual analog scale (VAS) and American Shoulder and Elbow Surgeons score (ASES) between the two procedures.[18] However, it has been hypothesized that both surgeries may lead to undesirable post-surgical sequelae, specifically superior migration of the humeral head and a potential decrease in the acromiohumeral interval.[19]

Conservative physical therapy management of shoulder pain including LHBT pathology may involve a multimodal approach addressing associated impairments of the shoulder, scapular region and cervical spine with the application of exercise, joint and soft tissue mobilization as well as retraining dysfunctional movement patterns.[10] A rotator cuff and scapular stabilizers strengthening program described by Tate et al has shown to have positive outcomes including decreased pain and disability in individuals with generalized shoulder pain[20] and impingement.[21] However, there is a paucity of literature outlining the conservative management of LHBT tendinopathy in isolation due to its typical presentation as a secondary shoulder pathology.[10] Due to the chronic nature of the symptoms, some patients fail traditional physical therapy management. Conservative management alone may be suboptimal in relieving symptoms associated with chronic LHBT pain and many patients go on to require more aggressive medical management including surgical intervention.[10]

One particular physical therapy management strategy, dry needling (DN) is defined as a skilled intervention that involves the use of a monofilament needle that penetrates the skin and is used to stimulate myofascial trigger points within the muscle in order to restore normal movement and function.[22,23] Dry needling has been demonstrated to be an effective, minimally-invasive intervention for individuals with chronic shoulder pain and shoulder range of motion (ROM) deficits[23-25] as well as myofascial trigger point pain around the shoulder and neck region.[22] DN has also historically been used by physicians to treat various tendon pathologies and pain (patellar tendon, supraspinatus tendon, infraspinatus tendon, gluteus medius tendon) by means of ultrasound guided tendon fenestration. [26-28] The purpose of tendon fenestration is to induce a "healing response" which includes bleeding, inflammation and release of local tissue factors resulting in the remodeling of chronic pathologic tendon changes.[26,29] DN has been used by physical therapists for LHBT with anecdotally good effects due to the proposed mechanism of action but robust evidence is lacking.[26,30]

Physical therapists also commonly use eccentric exercise in the management of tendon pathology, which has been found to be an effective treatment for various tendinopathies. [31-34] More recently, a study by Stasinopoulus found that the eccentric-concentric exercise combined with isometrics was more effective over concentric-eccentric or eccentric exercise alone in individuals with lateral elbow tendinopathy.[35] Proposed mechanisms contributing to its effectiveness include the loading and lengthening of the tendon resulting in localized tendon remodeling and tensile strength.[31,36] Eccentric exercise has been shown to be beneficial in individuals with shoulder impingement,[32,34,37] chronic tendinopathy of the Achilles;[31] and patellar tendinopathy[36] but to our knowledge, no studies have examined the effects of eccentric-concentric exercise (a more contemporary term being heavy slow load exercise) on individuals with LHBT tendinopathy.

While dry needling and ECE or heavy slow load exercise (HSLE) have independently been shown to be beneficial in treating tendon pathology similar to LHBT, the combined effect of these interventions on bicipital tendinopathy has not been fully evaluated. Dry needling has been shown to promote localized tissue healing and eccentric activity may contribute to tendon lengthening and remodeling which may improve the overall tensile strength in the tissue. Combining these two complimentary, conservative approaches could represent a significant advance in treating recalcitrant LHBT pain in that there is a possibility of avoiding surgical intervention. The purpose of this pilot study is to examine the feasibility of studying this approach to treating chronic biceps tendinopathy with the use of DN combined with an HSLE protocol for individuals with chronic biceps tendinopathy. Results of a pilot study will further inform a large scale multisite trial.

In a retrospective case series[30] we reported the results of treating 10 patients with chronic LHBT tendinopathy in the course of their routine physical therapy. All of these individuals had chronic anterior shoulder symptoms > 3 months, pain with palpation of the LHBT, and a combination of positive results on Speed's, Hawkins Kennedy, Neer and Yergason's tests. Of the 10 patients, 8/10 reported a history of failing traditional physical therapy and 2/10 patients were presenting to physical therapy for the first time. One patient who previously failed traditional physical therapy, reported chronic biceps pain which began 6 months after a biceps tenodesis. Overall, it was deemed not necessary to repeat a traditional course of physical therapy so treatment focused on providing DN, ECE and stretching. All patients were treated with 2-8 sessions (over 2-6 weeks) of DN into the most painful and/or thickened areas of the tendon, confirmed with palpation. Treatment included eccentric and concentric exercise to the biceps and stretching of the biceps muscle/tendon following each DN session. In summary at the end of treatment, average Quick DASH improved from mean 33.61% (SD, 17.1) to mean QuickDASH of 7.75% (SD, 10.8; $p<.02$); NPRS improved from mean 6.1(SD, 1.6) to 2.2 (SD, 1.3; $p<.001$).

In summary, the findings of the recent evidence suggest that the combination of DN, heavy slow load, and stretching may be beneficial in patients with chronic LHBT tendinopathy resulting in improvements in both pain and disability. However, to date the evidence is limited to treating various tendinopathies with ECE[31,37,38] or with tendon fenestration[26,28] but little evidence suggests these interventions have been utilized as a combined approach to treating tendinopathy. Additionally, the results of the case series may suggest that this combination may be a compliment treatment to traditional manual therapy and strengthening of the rotator cuff and scapular muscles typically utilized as a "first line" intervention to treat shoulder pain. Therefore, further exploration of this physical therapy treatment approach is warranted. Clinical implications from this treatment approach could include avoidance of more invasive techniques commonly used to treat this condition including injection, and surgical intervention including biceps tenotomy and tenodesis. Our group has extensive experience with these therapeutic interventions in our daily physical therapy practice and will be able to apply treatments consistently in the clinical research setting.

III. Preliminary Studies/Progress Report:

The outcomes of ten patients with chronic LHBT tendinopathy were reported in a retrospective case series.[30] All of these individuals had chronic anterior shoulder symptoms > 3 months, pain with palpation of the LHBT, and a combination of positive results on Speed's, Hawkins Kennedy, Neer and Yergason's tests. Treatment focused on providing DN, ECE or heavy slow load exercise and stretching. All patients were treated with 2-8 sessions (over 2-6 weeks) of DN into the most painful and/or thickened areas of the tendon, confirmed with palpation. Treatment included eccentric and concentric exercise to the biceps and stretching of the biceps muscle/tendon following each DN session. In summary at the end of treatment, average Quick DASH improved from mean 33.61% (SD, 17.1) to mean QuickDASH of 7.75% (SD, 10.8; $p<.02$); NPRS improved from mean 6.1(SD, 1.6) to 2.2 (SD, 1.3; $p<.001$).

IV. Research Methods

Based on results of a retrospective case series[30], a pilot study exploring feasibility to proceed to a larger scale multisite randomized controlled trial is warranted in order to determine the following: 1) if the outlined study procedures and methods are feasible 2) if randomization is acceptable to study participants 3) if recruitment rates are acceptable 3) if participant retention rates are acceptable 4) if the mechanisms used to collect patient reported outcomes is sound and effective 6) if procedures related to data management and clinician compliance to protocol at sites is acceptable. Additionally, the results of a pilot study may inform a sample size calculation for a subsequent main study and may increase clinical experience with the experimental intervention while assisting in determining optimal dose of the experimental treatment.

A. Outcome Measure(s):

All participants will complete several commonly used outcome measures (detailed below) to assess their level of disability and the behavior of their shoulder pain. We have used these instruments in previous, published studies and the psychometric properties have been well documented.[39-41] We will also use the Patient Acceptable Symptom State (PASS)[42] to capture the effect of treatment on the perceived level of disability as well as the Global Rating of Change Scale (GROC)[43] to measure the patient's perceived recovery.

Primary Outcome:

American Shoulder and Elbow Surgeons Scale (ASES) Pain Subscale: The ASES is a 100-point shoulder-specific self-report questionnaire consisting of 2 subscales including pain and disability. Lower scores are indicative of higher levels of disability. The ASES was found to be valid and reliable in measuring outcomes in individuals with shoulder dysfunction.[44-46] In a study by Michener et al., the minimal clinically important difference (MCID) for improvement was 12-17 points (sensitivity 91% and specificity 75%).[44] The MCID for the disability subscale was found to be 12 points and the MCID for the pain subscale was found to be 16.97. The primary outcome for is the ASES pain subscale as anecdotally patients in our healthcare system presenting to the sports medicine orthopedists tend to have higher levels of pain and lower levels of disability. Additionally, isolated pathology of the LHBT is common in younger athletic populations including throwing athletes, gymnasts, swimmers, contact sports and martial arts[9] where pain over disability tends to be the broader complaint.

Secondary Outcomes:

American Shoulder and Elbow Surgeons Scale (ASES): Disability subscale

Numeric Pain Rating Scale (NPRS) and Pain Diagram: An 11-point NPRS will be used to measure pain intensity. Numeric pain scales have been shown to be reliable and valid.[47-51] Patients rate their current level of pain and their worst and least amount of pain in the last 24 hours. The average of the three ratings or any single rating may be used to represent the patient's level of pain.

Disabilities of the Arm, Shoulder and Hand Questionnaire (DASH): The DASH is a 30 item, self-administered questionnaire that addresses symptoms and physical function in individuals with disorders of the upper limb.[52] The DASH is scored from 0-100% (0% = no disability). The DASH has demonstrated reliability, validity and responsiveness when used as a tool to measure dysfunction in individuals with upper extremity disorders[53], with test-retest reliability of 0.92-.96 and a MDC of 10.7-12.8 in individuals with shoulder pain.[46]

Medication Usage: A medication ontology called RXNorm will be used to track medications used for pain/inflammation. The frequency and dosage of the listed medications will be tracked throughout the course of the study at each timepoint. RXNorm standardizes participant responses then categorizes the drugs.

The Patient-Specific Functional Scale (PSFS): The PSFS is an instrument more sensitive to change than other region-specific instruments and has been utilized across a wide variety of health conditions.[54,55] Individuals are instructed to rate their ability to perform functional activities on a 0-to-10 scale. They are instructed to rate anywhere from 1 to 5 functional activities in total. Task scores are averaged and lower average scores indicate higher levels of disability. The MCID for the PSFS is 1.3 for a small change, 2.3 for a medium change, and 2.7 for a large change.[54-56]

Shoulder Pain and Hand Disability Index (SPADI): The SPADI is a 13 item questionnaire. The pain domain consists of five questions and the disability domain consists of eight. The validity and responsiveness to change of SPADI have been described in physical therapy, as well as primary and secondary care settings.[57] The minimal clinically important difference (MCID) has been reported to range from 8 – 13 points and the minimal detectable change (MDC) is 18 points.[58]

Patient Global Rating of Change (GROC): The fifteen-point global rating scale described by Jaeschke et al. will be used.[43] The scale ranges from –7 (a very great deal worse) to zero (about the same) to +7 (a very great deal better). Descriptors of worsening or improving are assigned values from –1 to –6 and +1 to +6 respectively. Success will be defined by patients who rate their perceived recovery on the GROC as “a very great deal better”, “a great deal better”, “quite a bit better”, or “moderately better” (i.e., a score of +4 or greater).

Patient Acceptable Symptom State (PASS): The PASS defines the level of symptoms beyond which patients consider themselves well.[42] The PASS question is “Taking into account all the activities you have during your daily life, your level of pain, and also your functional impairment, do you consider that your current state is satisfactory?” Individuals who respond “yes” are categorized as a success.

Percentage of Individuals Failing Control or Dry Needling and Heavy Slow Load Exercise: The number (percentage) of within group individuals who fail standard of care or DN and HSLE and opted to have injection or surgery will be tracked as a secondary outcome.

B. Description of Population to be Enrolled

Participants

A total of 60 participants who meet the inclusion/exclusion criteria and consent to participate will be enrolled from University of Colorado- Anschutz Medical Campus and Hendricks Regional Health, Danville, IN. Eligible subjects will be individuals who are being evaluated clinically for anterior shoulder pain. Referral to physical therapy is within the course of routine medical practice and is not a study procedure. Both the control group and the DN + HSLE group will receive interventions commonly used in routine physical therapist practice. We will consider the DN + HSLE treatment as the research procedure since assessing the combination of these treatments is the aim of this pilot study.

Potential participants will present to the CU Anschutz Medical Campus and Hendricks Regional Health, Danville, IN. All individuals who present to physical therapy with anterior shoulder pain will undergo a historical and physical examination conducted by the examiner (physical therapist). The clinical examination procedures that will be performed are all commonly used to assess and classify patients with shoulder pain and are within the usual care for physical therapists. All participants who are willing and agree to participate and meet inclusion criteria will provide written informed consent. if they are willing to participate. Following formal consenting, participants will complete a series of self-report questionnaires. The questionnaires will be repeated following completion of the treatment program and at 6 months. Enrolled participants will not be paid for participation in this study.

Inclusion Criteria:

1. Age 18-64 years old
2. Primary complaint of anterior shoulder pain in the area of the LHBT
3. Clinical exam findings (must have positive findings for at least 1/2 of the following). Several tests have been described for isolating pathology of the LHBT, however literature has shown that none of these tests are specific enough in isolation to confirm the diagnosis[9] and Speed's test and Yergason's test do not perform consistently and they do not generate a large change in post-test probability.[59] Additionally, better diagnostic utility is accomplished when 2 highly sensitive tests and one highly specific test[60] however, Speed's and Yergason's tests are both specific. Therefore, it was decided that 1/2 specific tests would still be potentially inclusive of the pathology since neither of the tests is specific enough to confirm diagnosis either combined or in isolation.[9,61] A test cluster of Speed's test combined with biceps palpation was reported to have a sensitivity of 68% and a specificity of 49%.[12]
    a. Speed's
        i. Speed's test (sensitivity 32%, specificity 75% for biceps pathology) was performed by having the clinician extend the elbow, supinate the arm and elevate the humerus with resistance to approximately 60 degrees; a positive test is pain in the bicipital groove region.[62-64]
    b. Yergason's
        i. Yergason's test (sensitivity 43%, specificity 79% for biceps pathology) was performed by having the clinician flex the elbow to 90 degrees with a pronated forearm. The clinician would then have the patient resist supination with pressure at the patient's wrist. A positive test is pain in the area of the bicipital groove.[65,66]

4. Pain with palpation in area of the LHBT. Positive pain with palpation in the region of the LHBT and intertubercular groove has been found to be diagnostic for bicipital tendinopathy (sensitivity 27-53%, specificity 54-66%). [9,41,67]
5. Patient identification of pain in the area of the proximal biceps tendon.[8,9]
6. NPRS of at least 3/10 at worst in the past week
    a. A minimal score of 3/10 was utilized in a case series on individuals with bicipital tendinopathy who were treated with DN and eccentric-concentric exercise.[30] In addition, anecdotally these patients tend to have low but persistent pain.

Exclusion Criteria:

1. History of biceps tendon injection in the past 3 months
2. History of rotator cuff surgery
3. History of biceps tenodesis or tenotomy
4. History of bleeding disorder or anti-coagulation therapy
5. Diagnosis of adhesive capsulitis (as defined by 50% loss of range of motion in 2 out of 3 of the following motions: Shoulder flexion, abduction and external rotation)
6. Known underlying non-modifiable medical condition (e.g. tumor, fracture, metabolic disease)
7. Two or more positive neurological signs consistent with nerve root compression
8. Known allergy to metal
9. Participant reported aversion to needles

The above exclusion criteria are designed to exclude individuals for whom needling is contraindicated and are designed to rule-out competing causes of shoulder pain such as adhesive capsulitis and neurological symptoms. Medication and healthcare utilization will be recorded from all participants at baseline and each follow-up period. Participants will not be excluded based on their use of pain medication and for ethical purposes, participants will be encouraged to continue taking all medication as directed by their physicians. Medication usage will be recorded.

C. Study Design and Research Methods

The study design will be a pilot study serving to inform a larger randomized controlled trial according to the CONSORT guidelines. Consecutive individuals presenting to University of Colorado Anschutz Medical Campus and Hendricks Regional Health, Danville, IN with anterior shoulder pain suspected to be bicipital tendinopathy (based on positive provocation with ¾ selected clinical examination tests) will be screened for further eligibility criteria. Consecutive individuals with a primary complaint of pain in the area of the biceps tendon will be enrolled.

See Figure 1 Flow Sheet below.

Physical therapists

Four physical therapists who have all agreed to participate in this pilot study will be trained in the study protocols regarding recruitment/screening/examination and participant consent by the candidate (AM), who is a licensed physical therapist with a Doctor of Physical Therapy (DPT) degree, board-certification in Orthopaedic physical therapy, advanced training in manual therapy and over 18 years of clinical experience treating patients with musculoskeletal pain, including shoulder pain. The training session will include instruction in the administrative aspects of the study (subject recruitment, and screening procedures) and specific training in the performance of the examination procedures related to eligibility. The purpose of this training is to ensure the screening and examination procedures are performed using the same techniques across physical therapists. Physical therapists involved in this study all have previous clinical experience and frequently use the examination and treatment procedures in this study as part of their routine physical therapy practice. In addition to the screening exam, all physical therapists will perform a standard physical therapy examination on all participants which is standard physical therapy practice. The physical therapy examination will also include assessment of: movement analysis, range of motion, muscle length, muscle strength.

Physical therapists who will be delivering the interventions for this pilot study and will be trained to implement the DN and HSLE, soft tissue mobilization and the rotator cuff and scapular strengthening program intervention by AM. All therapists have training in dry needling and have completed the appropriate training as outlined by the Colorado and Indiana Physical Therapist Practice Act in order to practice dry needling. The intervention training session will include instruction in the administrative aspects of the study (participant consenting, outcome measures, intervention procedures) and specific training in the performance of the intervention procedures, including soft tissue mobilization, the dry needling techniques and the exercise program. The purpose of this training is to ensure the intervention procedures are performed in a similar fashion with similar dosage across clinicians, although each physical therapist has been trained to provide dry needling and is certified to do so. Each participating clinician will be provided with a Manual of Standard Operations and Procedures (MSOP) that outlines all the study procedures in detail just as would be expected in a larger multisite trial.

Study Flow Chart

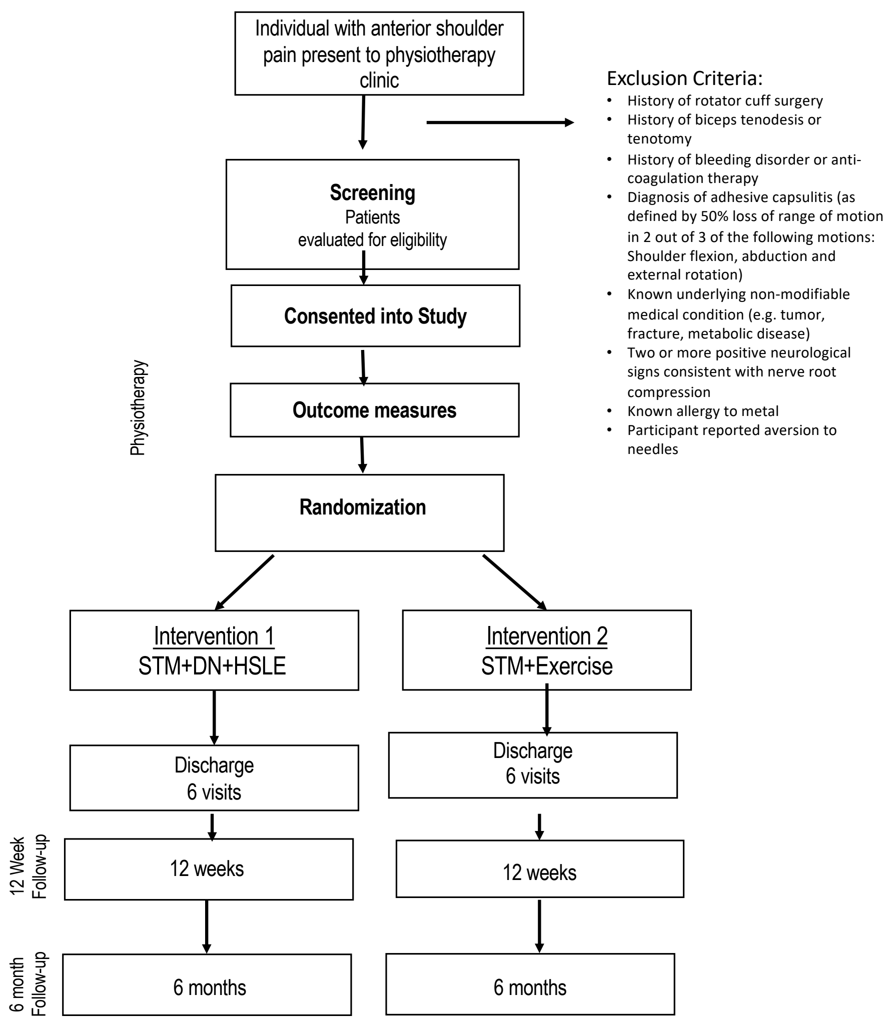

Figure 1: Study Flow Chart

Physical Therapy-Initial Visit

Upon arrival to the physical therapy clinic, potential participants will be read the informed consent prior to any examination procedures being initiated. If potential participants are found to be eligible, they will have an opportunity to ask questions before giving their written informed consent. Following consent, the physical therapist will perform the screening procedures (performance of 2 shoulder tests and palpation of the biceps tendon) outlined in the above eligibility inclusion criteria. If individuals are deemed eligible (based on positive results of these 3 tests), the participants will proceed in the study and complete additional baseline outcome measures specific to this study. Individuals will undergo a standardized physical examination conducted by the physical therapist which is usual medical care for this patient population at an initial exam or follow-up visit. A typical physical therapy visit and examination with include: medical history, medication usage, neurologic screening examination, movement analysis, range of motion, muscle strength, palpation and special tests of the shoulder.

Participants will then be randomized to one of the physical therapy groups via concealed allocation to receive either intervention 1(DN+HSLE) or intervention 2 (control).

<u>Outcome Measures Completed at Initial Visit (described in further detail under "Outcome Measures")</u>

1. American Shoulder and Elbow Surgeons Scale (ASES)[44]
2. Numeric Pain Rating Scale (NPRS)[68]
3. Disabilities of the Arm, Shoulder and Hand Questionnaire (DASH)[52]
4. Shoulder Pain and Disability Index (SPADI)[57]
5. Medication usage
6. Patient specific functional scale (PSFS)[54]

<u>Additional Outcome Measures Completed at 3, 12 weeks and 6 months (described in further detail under "Outcome Measures")</u>

7. Global Rating of Change (GROC)[43]
8. Patient Acceptable Symptom State (PASS)[42,69]
9. Healthcare utilization to include questions about whether the participant received alternative physical therapy treatment, injections, surgery or other interventions

Individuals will complete the first 3 weeks of the study (either DN +HSLE or control) and will be asked to complete outcome measures (ASES, NPRS, DASH, SPADI, Medication usage, PSFS, GROC, PASS) at 3, 12 weeks, and 6 months, following the initiation of therapy for follow-up measurements. A flow diagram of the research design can be found in **Table 1.** Both treatment arms are interventions that will be utilized in this study are familiar to the treating providers and are part of standard care in physical therapy. What is not known is if one standard of care or intervention package for treating biceps tendinopathy is more favorable over the other for the treatment of chronic biceps tendinopathy which to date has not been examined in a randomized clinical trial.

Table 1: Summary of Data Collection

Measure	Initial PT visit	Discharge 3-4 weeks (visits 6)	12-week Follow-up	6-month Follow-up
Informed Consent	X			
Examination	X			
Demographics	X			
Medication Usage	X	X	X	X
ASES	X	X	X	X
DASH	X	X	X	X
SPADI	X	X	X	
PSFS	X	X	X	X
NPRS	X	X	X	X
GROC		X	X	X
PASS		X	X	X

Intervention Visits 1-6

Intervention 1 DN+Heavy Slow Load Exercise (HSLE) Group

Patients in the intervention 1 (DN+HSLE) group will attend physical therapy one to two sessions per week for up to 4 weeks for a total of 6 sessions. Each treatment session will last for a total of 45 minutes. A standardized physical therapy program will be used and will include soft tissue mobilization to the shoulder and biceps tendon followed by DN, HSLE and a standardized exercise program. The DN will be performed with disposable stainless-steel needles (.3 X 40mm; Seirin; Weymouth, MA) inserted into the skin over the most painful and/or thickened areas of the tendon, confirmed with palpation. Prior to insertion of the needle the overlying skin will be cleaned with alcohol. The needle will be inserted into the tendon. The technique will be a fast-in and fast-out technique described by Chiavaras et al.[26] for 20-30 repetitions per session in up to 3 areas. A HSLE program of the biceps muscle/tendon will follow each DN session and will be performed daily for the course of treatment and will be performed as described by McDevitt et al.[30] See **Appendix A.** Heavy slow load and eccentric exercise protocols have been found to be an effective treatment for tendinopathies of the upper and lower extremities [31-34] and recent evidence supports heavy slow resistance training (including the addition of a concentric phase) as having better outcomes over eccentric exercise alone.[70] Patients will be instructed to do all activities that do not increase symptoms and avoid activities which aggravate symptoms as advice to maintain usual activity has been found to assist in recovery from shoulder pain. Both groups will be treated with a stretching and strengthening program. The rotator cuff and scapular stabilization strengthening and flexibility program used in this study can be found in **Appendix B**. Progression of the strengthening program will be accomplished using the exercises listed in **Appendix B**. Patients in both groups will be instructed to perform the warm-up and strengthening/flexibility exercises as a home program once daily.

Intervention 2 (Control Group) -

Participants in the control group will attend physical therapy one to two sessions per week for up to 4 weeks for a total of 6 sessions. Each treatment session will last for a total of 45 minutes. A standardized physical therapy program will be used and will include soft tissue mobilization to the shoulder and biceps tendon and a standardized exercise program. Neither dry needling nor heavy slow load exercise will be integrated into the "control" plan of care. Participants will be instructed to do all activities that do not increase symptoms and avoid activities which aggravate symptoms as advice to maintain usual activity has been found to assist in recovery from shoulder pain. Both groups will be treated with a stretching and strengthening program. The rotator cuff and scapular stabilization strengthening and flexibility program used in this study can be found in **Appendix B.** Progression of the strengthening program will be accomplished using the exercises listed in **Appendix B.** Participants in both groups will be instructed to perform the warm-up and strengthening/flexibility exercises as a home program once daily.

D. Description, Risks and Justification of Procedures and Data Collection Tools

The risks associated with a participant's participation in this study are minimal. The examination and procedures used in this study are routinely used by physical therapists as the standard of care treatment for patients with biceps tendinopathy. However, there are a few small risks to be considered. First, there is the risk of loss of confidentiality. Second, patients may experience an increase in pain intensity after dry needling or after any of the exercises due to a muscle injury. Based on our clinical experience, the chance of this happening is rare, which means it occurs in less than 1% of people (less than 1 out of 100).

<u>Adequacy of Protection Against Risks</u>

The risk of confidentiality will be mitigated by having all individuals participating in research to have completed human subjects and CITI training in HIPAA, human subjects research and data management and confidentiality. Additionally, all data will be stored on the REdCap database. We have attempted to minimize this risk by having a board certified and licensed physical therapist examine all patients and instruct them in the proper exercise technique. In addition, a therapist will re-examine a participant at any time, if appropriate. It is also possible that participants will experience mild muscle soreness after the soft tissue mobilization, dry needling or heavy slow load exercises or standard shoulder and scapular strengthening exercises are performed. Based on our clinical experience, the chance of this happening is common, which means it occurs in 1% to 25% of people (1-25 out of 100). However, this soreness typically resolves within 1-48 hours after activity. We have minimized the risks associated with exercise by ensuring that the licensed physical therapists participating in this study already routinely use dry needling and exercise with their treatment of participants with shoulder pain. We have further minimized this risk by ensuring that each physical therapist participating in this study has been specifically trained in the use of the intervention techniques to be used in this study. Furthermore, all potential subjects will be screened to ensure they do not exhibit any exclusion criteria that may place the individual at increased risk for a serious complication. We do not currently know the risk of combining DN and HSLE as these interventions have not been testing in combination.

Potential Benefits of the Proposed Research to Human Subjects

Benefits to human subjects include potential benefit from a particular intervention to improve pain and perceived levels of disability in individuals with bicipital tendinopathy. The information gained from this project may inform a larger trial and further the current body of evidence by offering an alternative, potentially safer approach to the conservative care of individuals with bicipital tendinopathy.

E. Potential Scientific Problems: The main scientific problems associated with this study include the potential of attrition or participants declining as they may prefer injection or surgery to physical therapy treatment.

Limitations

There are several potential limitations in the study design. The treating therapists cannot be blinded to group assignment, which may influence the verbal and non-verbal interaction with subjects. To try to manage this limitation all therapists will be trained to maximize the consistency with which the messaging related to the dry needling intervention and the control intervention will be delivered.

All treatments will be performed in 2 clinics, one within an academic institution (University of Colorado Anschutz Medical Campus) and the other at a single hospital based outpatient rehabilitation center (Hendricks Regional Health, Danville, IN), potentially limiting the generalizability to different treatment settings.

Another potential limitation is that we are not including physical measures such as range of motion or pain pressure threshold in our analyses. We have chosen to limit our outcomes to validated questionnaires to decrease the loss to follow-up, especially at long-term follow-ups.

F. Data Analysis Plan:

Sample Size Estimation

Sample size estimate for a pilot study can range and is typically based on presence of resources, funding and projected recruitment based on the incidence of the condition.[71] The sample size for this pilot study is 30 participants. The results of the pilot study will help inform sample size calculation of a larger trial by observation of confidence intervals.

Baseline Characteristics

Descriptive statistics, including measures of central tendency and dispersion will be calculated for baseline demographic data. Frequency distributions will be estimated for categorical data.

Primary Outcomes (ASES)

The hypothesis of interest is the interaction between group and time therefore, post-hoc tests will be used to describe differences between groups at each time point. We will compare a change in the ASES pain scale score from baseline to discharge between the DN+HSLE group and the control using a paired t-test.

Secondary Outcomes (NPRS, DASH, SPADI, PASS, GROC)

A similar approach will be used to compare changes in the secondary outcomes. We will use descriptive statistics to explore successful treatment within both groups (percentage of individuals completing 6 months without injection or surgery). Additionally, we will compare frequencies of success on the PASS and GROC between groups from pretreatment to post treatment (1-week, 3-weeks, 12-weeks and 6 month follow-up periods) using Chi-square tests of independence.

G. Summary of Knowledge to be Gained

Physical therapists and surgeons commonly encounter individuals with chronic biceps tendon pathology as a secondary problem often associated with rotator cuff pathology and impingement. The most advantageous and optimal treatment for these individuals remains elusive; however, our preliminary results indicate there may be a more conservative and less invasive treatment that is more effective than the more traditional standard of care physical therapy. The pilot study protocol outlined above will provide additional information to inform a larger scaled trial regarding: procedures and methods, randomization, recruitment, retention, data collection, data management, and sample size calculation. Based on the outcome of the primary feasibility objectives, the outcome of the pilot study will be one of the following: 1) stop if main study is not feasible-not feasible 2) continue with modifications to the protocol-feasible with modifications 3) continue without modifications-feasible. If the pilot protocol does not require any modification, data from the pilot study may be appropriate for pooling with a larger data set resulting from a larger trial.

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Appendix B: Co-author Statements

The following pages include co-author statements from Suzanne J. Snodgrass and Joshua A. Cleland followed by Simone Addison, Rebecca Altic, Maria Borg, Jonathan Bravman, Leah Calderon, Paisley Hiefield, Lindsay Krause, Mary Becky Leibold, Paul Mintken, Colin Strickland, and Jodi Young.

Co-author Statement from Suzanne J. Snodgrass

By signing below, I confirm that Amy McDevitt contributed to the concept and research design, acquisition of data analysis and interpretation of data, as well as writing, reviewing, and editing of the publications entitled:

- McDevitt, A. W., Cleland, J. A., Strickland, C., Mintken, P., Leibold, M. B., Borg, M., Altic, R., & Snodgrass, S. (2020). Accuracy of long head of the biceps tendon palpation by physical therapists; an ultrasonographic study. *Journal of Physical Therapy Science*, *32*(11), 760-767.
- McDevitt, A. W., Cleland, J. A., Addison, S., Calderon, L., & Snodgrass, S. (2022). Physical therapy interventions for the management of biceps tendinopathy: an international Delphi study. *International Journal of Sports Physical Therapy*, *17*(4), 677.
- McDevitt, A. W., Snodgrass, S. J., Cleland, J. A., Leibold, M. B. R., Krause, L. A., & Mintken, P. E. (2020). Treatment of individuals with chronic bicipital tendinopathy using dry needling, eccentric-concentric exercise and stretching; a case series. *Physiotherapy theory and practice*, *36*(3), 397-407.

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