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Case Series

Ultrasound-Guided Percutaneous Tendon Dry Needling for Recalcitrant Distal Biceps Tendinopathy: A Case Series

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Background

Distal biceps brachii insertional tendinopathy occurs in approximately 2.6 per 100,000 individuals per year, more commonly affecting middle-aged males. Dry needling with percutaneous tendon fenestration is a common treatment for insertional tendinopathies. However, little evidence supports this treatment for the distal biceps tendon, likely secondary to difficult access without ultrasound guidance. This case series describes the treatment of two subjects with chronic distal biceps tendinopathy using ultrasound-guided percutaneous tendon dry needling with fenestration and a graded loading program in outpatient physical therapy

Study Design

Case series

Methods

Two recreationally active adults with chronic distal biceps tendon pathology underwent clinical and sonographic examination, with images reviewed by clinicians registered in musculoskeletal sonography (RMSK). Subject A (55 years of age) presented with a partial distal biceps tendon tear, and Subject B (46 years of age) presented with distal biceps tendinosis. Both had pain and exercise-related functional limitations, and each participated in a physical therapy plan of care consisting of one visit per week for five weeks, including ultrasound-guided tendon dry needling for the first three weeks and graded isotonic loading of the distal biceps tendon throughout. Each subject transitioned to a guided home exercise program and was reassessed 3 and 6 months from the evaluation date. Subject-reported outcome measures included the Numeric Pain Rating Scale (NPRS), the Upper Extremity Functional Index (UEFI-20), and the Global Rating of Change (GROC) at baseline, 5 weeks, 3 months, and 6 months.

Results

At five weeks, both subjects exceeded the minimal clinically important difference for each outcome measure. These results persisted at six months, with notable tendon healing characteristics visualized with diagnostic ultrasound.

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Conclusions

Percutaneous ultrasound-guided tendon dry needling with fenestration as an adjunct to a graded tendon loading program may have contributed to reduced pain and disability among two individuals with distal biceps tendinopathy.

Level of Evidence

4

INTRODUCTION

Tendinopathy of the distal biceps brachii affects up to 2.6 per 100,000 individuals each year and is more common in middle-aged males, creating pain and disability that may hinder household, occupational, and recreational activity participation.[1-3] Qualitative studies investigating the lived experiences of those with chronic tendon pathology highlight profound psychological and socioeconomic implications, including reduced participation in personally meaningful activities and reduced income from potential deficits in their ability to work.[4] Distal biceps tendinopathy is characterized by irritation, inflammation, or degeneration of the biceps tendon where it attaches to the radius bone near the elbow, often causing pain, swelling, and weakness.[4,5] Percutaneous fenestration for tendinopathy comprises multiple needle punctures into damaged, chronically injured tendons to stimulate healing by creating micro-injuries, promoting bleeding, and the release of growth factors, effectively inducing an acute healing response. This intervention has been commonly used for lateral elbow tendinopathy and Achilles tendinopathy.[6-11] However, a paucity of evidence exists regarding its use in distal biceps tendinopathy.

At the insertion into the ulnar aspect of the radial tuberosity, the distal tendon of the biceps brachii is bifurcated with a ribbon-like configuration.[12-15] The tendon associated with the short head runs medially but inserts anteroinferiorly to the long head, increasing the mechanical advantage of the short head for elbow flexion at ninety degrees and forearm supination in a neutral or pronated forearm position.[14,16] At insertion, the distal biceps tendon spans approximately 63% of the length and 13% of the width of the radial tuberosity, covering approximately 35.9% of the total area.[14] Various extrinsic factors are postulated to increase the risk of tendinopathy, such as mechanical impingement secondary to hypertrophy of the radial tuberosity.[17] Hilgersom and colleagues[17] found that both volume and height of the radial tuberosity are statistically greater in those with distal biceps tendon pathology versus a control group. The radioulnar space reduces notably during pronation to end-range, likely exacerbated by a more prominent radial tuberosity.[18] Similarly, the bicipitoradial bursa surrounds the distal tendon of the biceps brachii and functionally reduces friction between the tendon and radius during pronation and supination. Although rare, chronic irritation to the bicipitoradial bursa is thought to contribute to distal biceps brachii tendon pathogenesis.[19,20] The myotendinous junction of the distal biceps brachii gives rise to the lacertus fibrosis, which merges laterally with the fascial complex surrounding the pronator-flexor group at the medial elbow. The lacertus fibrosis can be a functional stabilizer of the distal biceps tendon, often limiting retraction in the presence of a full rupture.[15,21,22] However, some postulate that increased stiffness of the lacertus fibrosis can alter the mechanical efficiency of the distal biceps tendon and increase the risk of pathology.[21,22] The distal biceps tendon presents unique morphological characteristics, and the above anatomical and biomechanical factors, coupled with hypovascularity seen in dense regular connective tissue, contribute to tendon pathogenesis.[15,17-23]

Tendons are comprised of dense regular connective tissue with a unidirectional fibrillar pattern that allows for uniplanar force propagation from the muscle into the bony insertion.[24,25] Relative hypovascularity of this tissue type contributes to the pathogenesis and chronification of tendon pathology and is worsened in the presence of nicotine use and various comorbidities (e.g., obesity, diabetes).[24-27] Tendons commonly receive vascular supply from the myotendinous junction, osteotendinous junction, and nearby connective tissues (i.e., via paratenon).[25] The distal biceps brachii tendon has three zones of vascularity, and the zone comprising the tendon enthesis receives vascular supply from the posterior interosseus recurrent artery, with the neighboring tendon midportion supplied by a paratenon.[12,21,28] Per Brasseur,[29] enthesopathy of the distal biceps tendon is notably more common than more proximal tendinopathy. Distal biceps tendinopathy may include structural and biochemical changes associated with impaired tendon remodeling, and needle fenestration at the osteotendinous junction may improve tendon healing.[12,25,28,30-33]

Chronic tendon pathology often presents with disorganization of collagen fibers, degradation of the extracellular matrix, and neovascularization, with other common findings being fibrosis and ectopic ossification.[34-38] Mechanical overload of the tenocytes facilitates biochemical signaling (e.g., via interleukin-1β expression) for remodeling of the extracellular matrix, upregulation of proteoglycans, and changes in collagen composition.[35,38,39] Interleukin-1β expression upregulates pro-inflammatory cytokines (e.g., C-C motif ligand 2) and anti-inflammatory cytokines for tendon repair, and continued mechanical loading beyond the functional capacity of the tendon perpetuates this response.[38] This process disrupts the remodeling process and results in an increasingly disorganized collagen matrix and alterations in the tendon microenvironment, characterized as tendon disrepair by many authors.[35,36,38] For instance, proteoglycans are hydrophilic, and upregulation of these proteins increases water absorption in the extracellular matrix, altering its morphology (e.g., increased size) and likely con-

tributing to fibrosis.[35] Similarly, continued strain may exacerbate tissue hypoxia and induce phenotypic change in tenocytes, accompanied by increased deposition of glycosaminoglycans.[38-41] This process likely contributes to the notable loss of elasticity seen in pathologic tendons, increasing stiffness and risk of rupture.[39,40] The transformation of the tendon in the context of overuse can induce pain and disability through disorganization of collagen alignment, matrix degradation, maladaptive alterations in the tendon microenvironment, neovascularization, hypovascularity, and more, likely impeding functional strength in elbow flexion and forearm supination in the context of the distal biceps brachii tendon.[5,34-40] These maladaptive changes in tendinopathy and fasciopathy correspond with poorer prognoses (i.e., long-term symptoms that impede functional capacity).[42-44] Loading-based programs may improve short-term pain and function. However, long-term outcomes are variable, and persistent symptoms are common in chronic tendinopathy, warranting further investigation into adjunct physical therapy interventions.[42-45]

Dry needling the tendon-bone interface (enthesis) with fenestration may disrupt the maladaptive microenvironment seen in tendon disrepair and facilitate a healing response through localized bleeding and fibroblast proliferation, and the utilization of musculoskeletal ultrasound aids in the accuracy of needle location.[11,32] Tendon dry needling is a safe and inexpensive treatment methodology and has been shown to be effective for Achilles tendinopathy, lateral epicondylalgia, rotator cuff tendinopathy, and patellar tendinopathy.[7,8,11,46-49] However, to date, no research appears to have investigated ultrasound-guided dry needling with fenestration for distal biceps tendinopathy. An anterior approach to the distal biceps tendon is not warranted secondary to nearby neurovascular structures, including the brachial artery and median nerve.[5,12,13] Dry needling of the distal biceps tendon at the level of the radial tuberosity (i.e., the most commonly affected area) can be performed safely from a posterior "cobra" position, often used for injection (e.g., elbow flexion and forearm end-range pronation).[12,13] This case series describes the treatment of two subjects with chronic distal biceps tendinopathy using ultrasound-guided percutaneous tendon dry needling with fenestration and a graded loading program in outpatient physical therapy.

CASE DESCRIPTIONS

SUBJECTS

Two subjects with no clinically significant comorbidities, no significant functional limitations prior to symptom onset, and regular participation in independent resistance training were referred to an outpatient physical therapy clinic for management of symptoms related to distal biceps brachii tendinopathy. Informed consent was obtained from each subject to perform ultrasound-guided dry needling and to use their data in this study. Their baseline data were recorded on the first visit (Table 1). Subjects A and B were 55 and 46 years of age, respectively, with chronic symptoms. Both reported pain of insidious onset. Each had already tried reducing tendon load by avoiding resistance training on the affected arm without symptom improvement, prompting consultation with an orthopedic physician who referred them to the outpatient physical therapy clinic.

Table 1. Baseline variables: demographics and outcome measures

Baseline Variable	Subject A	Subject B
Age (years)	55	46
Sex	Male	Male
Laterality	Right	Left
Symptom Duration (months)	6	3
NPRS	6	6
UEFI-20	67	70

BMI – Body Mass Index; NPRS – Numeric Pain Rating Scale, 0-10, lower scores correlate with decreased subjective pain severity over the previous 24 h; UEFI-20 – Upper Extremity Functional Index, 0-80, lower scores correlate with reduced function.

TREATING CLINICIAN

The treating clinician was a physical therapist with three years of clinical experience with certifications in dry needling and musculoskeletal ultrasonography through the American Academy of Manipulative Therapy, with additional education in ultrasound-guided dry needling.[50,51]

OUTCOME MEASURES

Outcome measures comprised the Numeric Pain Rating Scale (NPRS), Global Rating of Change (GROC), and Upper Extremity Functional Index (UEFI-20), each measured at baseline, three weeks, five weeks, 12 weeks, and 6 months. The NPRS is the primary outcome measure and refers to the subject's pain severity over the previous 24 h with an 11-point scale from 0 to 10, with higher scores indicating more pain.[52] The minimum clinically important difference (MCID) for the NPRS is at least a 2.0-point change for chronic musculoskeletal pain pathologies.[53,54] Likert-type scales, such as the NPRS, may be at risk of response bias, such as extreme-response bias and non-extreme response bias.[55-57] Concurrent usage of the GROC (a secondary outcome measure) may ameliorate recall bias and improve the validity of retested NPRS scores upon follow-up.[58] The GROC is a 15-point scale from -7 (a very great deal worse) to +7 (a very great deal better) and is commonly used to assess a subject's perceived benefit of an intervention.[59] Outcome measures that assess global ratings of improvement have been recommended by the Initiative on Methods, Measurement, and Pain in Clinical Trials (IMMPACT) for chronic pain pathologies secondary to the value of understanding the subject's judgment of their treatment experience and clinical outcomes.[60] A change of five in either direction on the GROC is likely the threshold for meaningful improvement.[59]

Lastly, the UEFI-20 is a reliable outcome measure (ICC = 0.94) that allows for the assessment of functional disability at the upper extremity through a 20-item scale.[61,62] Subjects are prompted to associate a level of difficulty with each activity, from 0 (extreme difficulty or unable to perform) to 4 (no difficulty), and the resulting score ranges from 0 to 80.[62] A lower total score corresponds with increased perceived functional disability secondary to the subject's upper extremity problem. The MCID is reported to be a 7-point increase for the dominant arm and a 10-point increase for the non-dominant arm; each subject in this report had their dominant arm affected.[61]

EXAMINATION PROCEDURE

Each subject underwent a thorough physical examination to ensure the clinical presentation was consistent with that of the referral, including observation, sensation testing, range-of-motion testing, strength testing, and palpation. Both subjects presented with pain isolated to the proximal antebrachium at the anterolateral cubital fossa. In each subject, sensation was intact without evident atrophy or trophic changes. Additionally, each had normal range-of-motion at the level of the neck, shoulder, elbow, and wrist with reproduction of symptoms with resisted elbow flexion and forearm supination. Active range of motion for elbow flexion and forearm supination was not provocative; however, lengthening of the tissues using end-range elbow extension coupled with pronation was consistently provocative. Similarly, each subject demonstrated a positive tilt sign (sensitivity 35-55%, specificity 65-77%, and accuracy 55-62.50%) and a positive biceps provocation test (sensitivity 95 – 100%, specificity 95%, and accuracy 95-97.50%).[63] A positive tilt sign comprises tenderness over the radial tuberosity when the forearm is pronated and an absence of tenderness when the forearm is supinated.[64] A positive biceps provocation test occurs when resisted elbow flexion at 70 degrees is more provocative in a pronated state versus a supinated state, likely facilitated by a reduction in radioulnar space that causes a mechanical impingement with the pathologic tendon during resisted flexion.[63,65] These tests, coupled with the above exam findings, suggest that nociception is likely attributed to insertional pathology of the distal biceps brachii tendon. Of note, palpation of the medial pronator-flexor group and lateral wrist extensors was unremarkable. Similarly, each subject had a negative Mill's, Maudsley's, and Cozen's test, reducing the likelihood of the pathology being attributed to lateral epicondylalgia.[66-68]

ULTRASOUND IMAGING

Tenderness specific to the tendon attachment, in addition to the other examination findings, prompted ultrasound imaging of the distal biceps brachii tendon insertion. Subjects were placed in a sitting position with their affected extremity on a nearby stand at approximately 90 degrees of elbow flexion and end-range forearm pronation. The ultrasound transducer (L7HD3, Clarius Mobile Health, Vancouver, Canada) was placed in the long axis to the tendon and transverse to the radius on the posterolateral aspect of the proximal antebrachium at the level of the radial tuberosity; this posterior approach allows for effective visualization of the distal tendon and tendon enthesis, as described by Al-Ani and Lauder,[69] Moore,[70] and Griffith.[71] Depth was adjusted so that the tendon presented within the focal zone, allowing for improved resolution of tissues perpendicular to the ultrasound beam.[72] Because the biceps tendon wraps around the radius in this approach, dynamic movement (e.g., supination and pronation) and rocking of the probe are necessary to ensure that different segments of the tendon are perpendicular to the ultrasound beam for optimal visualization to reduce anisotropy (ultrasound waves reflecting away from the transducer).[69-72] A medial view was used to further confirm tendon pathology in Subject A. Normal distal biceps brachii tendon sonoanatomy comprises a hyperechoic, unidirectional fibrillar pattern with a tapering contour into the insertion at the radial tuberosity; this fibrillar pattern can be seen in Figure 1.[70,71]

INTERVENTIONS

Subjects first underwent screening for contraindications to dry needling, including needle aversion, cognitive impairment, dyskinesia, bleeding disorders, vascular disease, local or systemic infection, and recent surgery. In the absence of contraindications, ultrasound-guided dry needling with tendon fenestration of the distal biceps tendon, combined with graded tendon loading, was implemented to ameliorate pain and disability associated with chronic distal biceps tendinopathy. Subjects were seen once weekly for five weeks, with ultrasound-guided tendon dry needling performed at the first three visits. After education on the purposes of incorporating dry needling, the role of mechanical loading on tendon healing, and graded loading strategies for a home-exercise program, the subject was positioned in a sitting position with their elbow on a nearby stand in approximately 90 degrees of flexion and full pronation (Figure 2). Under ultrasound guidance, a single 50 mm length by 0.30 mm diameter needle was used to fenestrate the distal biceps tendon for 10 seconds (approximately 15-20 times) with subtle positional changes within the tendon (Figure 3).

After dry needling, interventions that emphasized isotonic loading of the biceps were performed by each subject, including coupled eccentric elbow flexion and supination (i.e., 3 to 5 second eccentric phase), unilateral rows, resisted supination, and resisted elbow flexion with neutral and supinated forearm positions (Supplemental File 1). Subjects were initially educated on graded loading principles consistent with some of the other load strategies for tendinopathy.[73,74] First, because initial activity tolerance was limited by pain to a greater extent than muscular fatigue, subjects were instructed to perform the highest tolerable resistance that did not provoke discomfort greater than 3/10 on a NPRS scale (minimal pain) during or after isotonic loading with a duration of greater than 24 hours for 3-4 sets of 15 repetitions.[73] This guideline stayed in place until pain was abolished in both subjects. They were then advised to lift with 2 reps-in-reserve at 3-4 sets of 6 repetitions, allowing for dynamic intensity regulation that can facilitate self-progression.[75] Both subjects performed these ex-

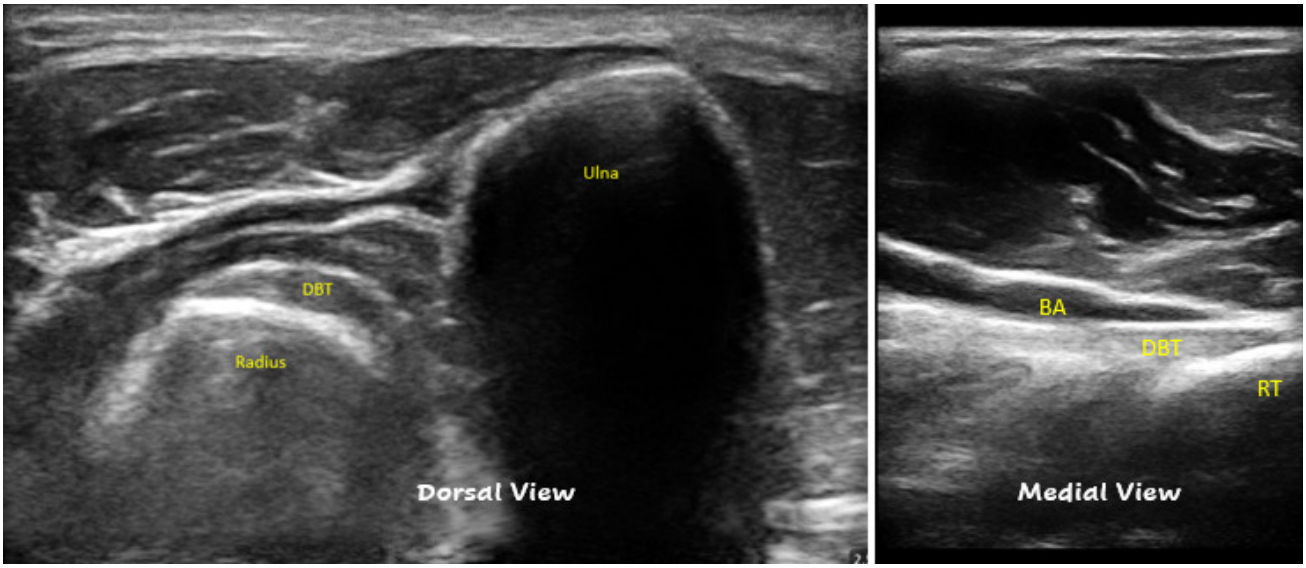


Figure 1. Normal distal biceps brachii tendon of healthy volunteers via a dorsal view (left) and medial view (right).

Abbreviations: BA – brachial artery; DBT – distal biceps tendon; RT – radial tuberosity.



Figure 2. Dry needling with ultrasound setup.

ercises 3 times per week. Baseline and 6-month resistances can be seen in Table 2. Most of the activity performed by the subjects was instruction-based and performed outside of the clinical environment. Each participant verbally reported compliance with this home exercise program at five weeks, three months, and six months.

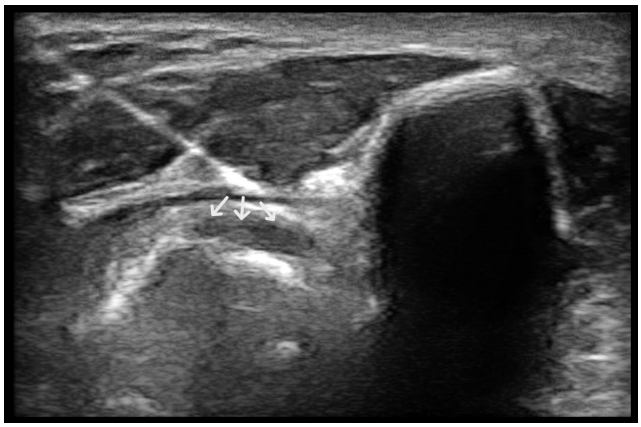


Figure 3. Dry needling of the distal biceps brachii tendon example.

White arrows highlight the fenestration pattern.

RESULTS

The same clinician treated each subject with a similar treatment approach that incorporated ultrasound-guided tendon dry needling with fenestration (included in the first 3 weeks) and a graded loading program (6 months). Both subjects noted a reduction in pain and had NPRS scores that surpassed the MCID from baseline versus three, five, and 12 weeks, with symptom relief persisting at 6 months (Table 3, Figure 4). The reduced NPRS scores correspond with perceived improvements greater than the +/- 5 MCID on the 15-point GROC scale from baseline to five weeks and onward in both subjects (Table 3).

Similarly, each subject noted a reduction in upper extremity disability with UEFI-20 scores that met or exceeded the MCID of 7 points; furthermore, subject A and subject B reported no difficulty with all UEFI-20 domains at 12 weeks,

Table 2. Exercise resistance at baseline and 6 months

Exercises (with Dumbbells)	Baseline Resistance (15 repetitions)	Resistance at 6 Months (6 repetitions)
Coupled eccentric elbow flexion and supination	6 lbs.	25 lbs.
Unilateral rows	20 lbs.	60 lbs.
Resisted supination	3 lbs.	8 lbs.
Resisted elbow flexion with neutral grip	10 lbs.	35 lbs.
Resisted elbow flexion with supinated grip	10 lbs.	35 lbs.

Table 3. Outcome assessments

	Baseline	3 Weeks	5 Weeks	12 Weeks	6 Months
Subject A					
NPRS	6	3	2	0	0
GROC	-	+4	+5	+7	+7
UEFI-20	67	-	76	80	80
Subject B					
NPRS	6	2	0	0	0
GROC	-	+3	+6	+7	+7
UEFI-20	70	-	77	80	80

NPRS – Numeric Pain Rating Scale, 0-10, lower scores correlate with decreased subjective pain severity over the previous 24 h; GROC – Global Rating of Change, -7 to +7; UEFI-20 – Upper Extremity Functional Index, 0-80, lower scores correlate with reduced function.

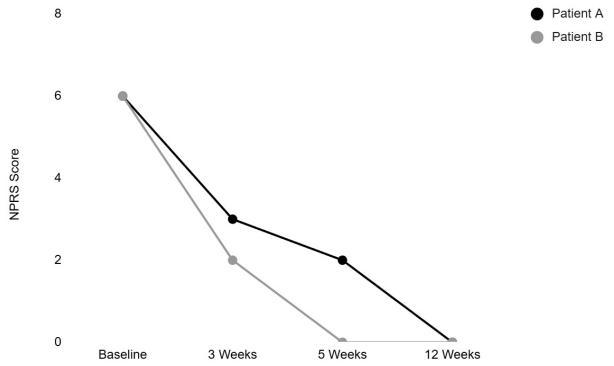


Figure 4. Changes in Numeric Pain Rating Scale.

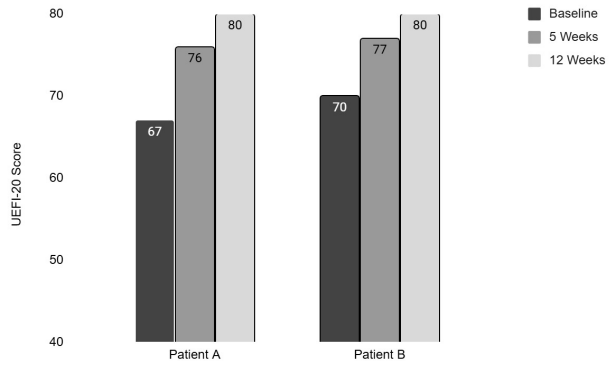


Figure 5. Changes in Upper Extremity Functional Index-20

which remained consistent at six months (Table 3, Figure 5). Therefore, each subject reported clinically meaningful improvements in pain and disability.

Notable healing characteristics were visualized in both subjects at 6-month follow-up imaging and reviewed by clinicians registered in musculoskeletal sonography (RMSK). At baseline, Subject A presented with cortical irregularity at the radial tuberosity with a focal anechoic region of the distal biceps tendon that was tender to sonopalpation and end-range passive pronation, suggestive of a partial-thickness tear. Six-month follow-up images demonstrate early regeneration at the tear site with improved fiber visualization (Figures 6 and 7). Subject B presented with milder cortical changes with thickening of the distal biceps tendon (0.25cm) and areas of hypoechogenicity but with preservation of tendon continuity. 6-month rescan demonstrates improvements in tendon echogenicity, a reduction in tendon width (0.25cm to 0.19cm), and normalization of mechanosensitivity with absent tenderness to sonopalpation and absent discomfort at end-range passive pronation (Figure 8).

TREATMENT ADVERSE EVENTS

Adverse events were defined as distressing or intolerable events (e.g., pain) that lasted for more than one week.[76] Neither subject reported any adverse events other than post-needling soreness and mild ecchymosis, which re-

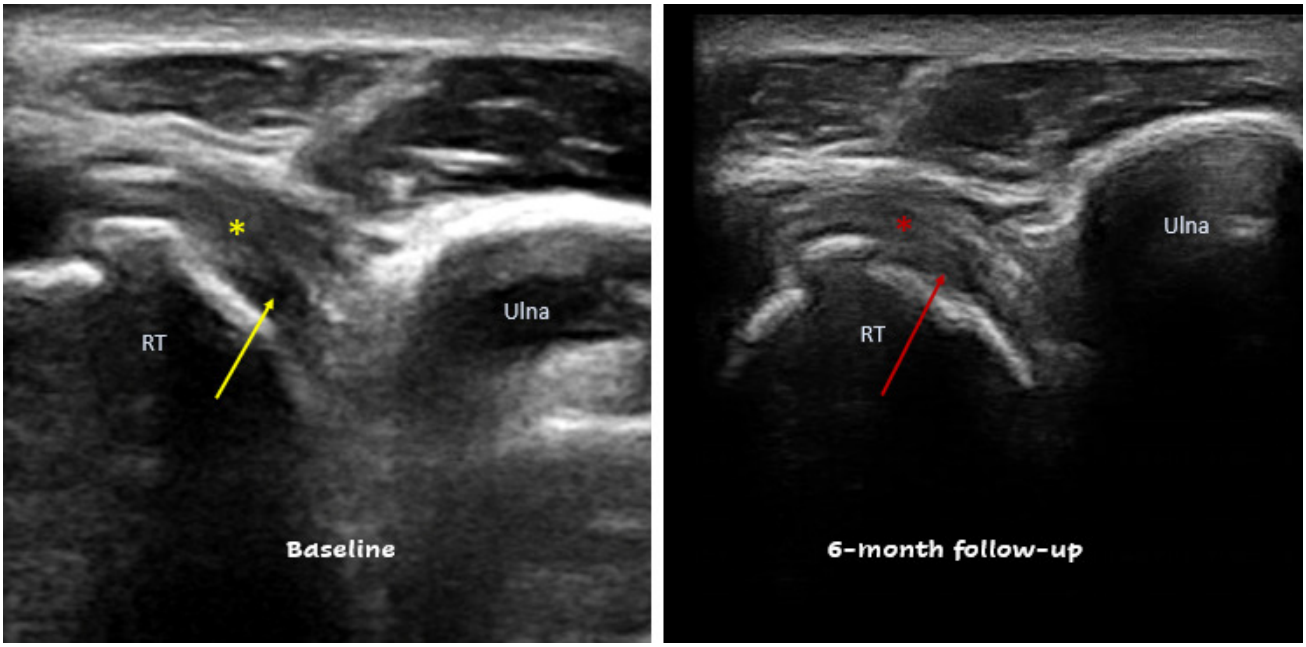


Figure 6. Dorsal view of distal biceps at baseline and 6-month follow-up in Subject A. At baseline, distal biceps tendinopathy is appreciated (yellow asterisk), with partial tear (yellow arrow) and notable cortical irregularity. 6-month follow-up demonstrates tissue healing distally (red asterisk) and regeneration at the tear site (red arrow). RT=radial tuberosity

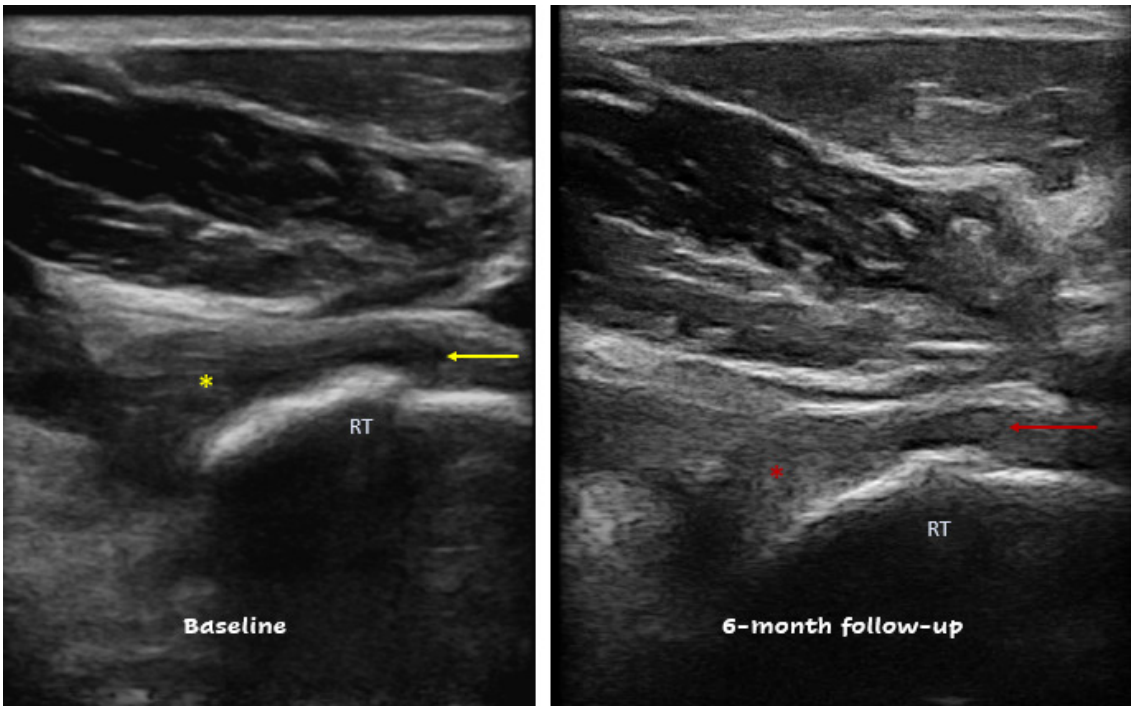


Figure 7. Medial view of distal biceps tendon at baseline and 6-months in Subject A. At baseline, distal biceps tendinopathy is appreciated (yellow asterisk), with partial tear (yellow arrow) and cortical irregularity. 6-months follow-up demonstrates tissue healing proximally (red asterisk) and regeneration at the tear site (red arrow). RT=radial tuberosity

solved by the next visit. Additionally, no subjects required load regression secondary to activity intolerance.

DISCUSSION

Two subjects participated in a care plan that incorporated ultrasound-guided dry needling of the distal biceps brachii

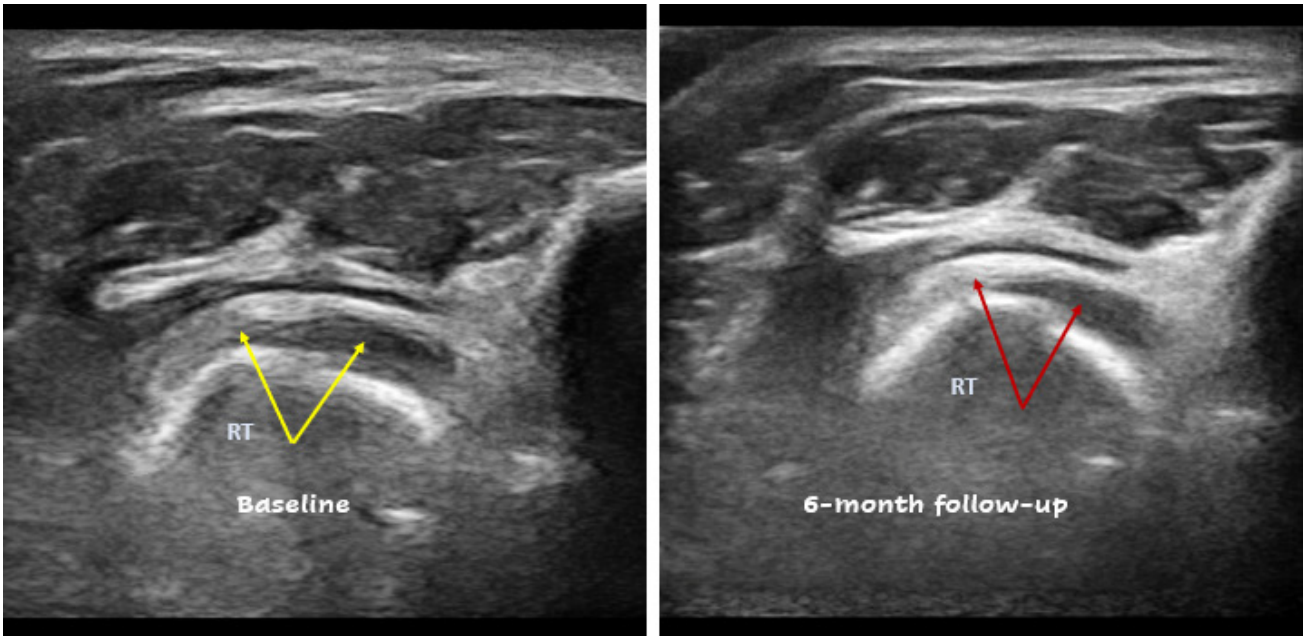


Figure 8. Dorsal view of distal biceps at baseline and 6-month follow-up in Subject B. At baseline, distal biceps tendinopathy is appreciated (yellow arrows). 6-months follow-up demonstrates tissue healing with distinct changes in echogenicity and thickness of the tendon and enthesis (red arrows). RT=radial tuberosity

tendon with tendon fenestration, alongside a graded loading program, resulting in clinically relevant reductions in pain and disability. Tendon fenestration is thought to produce a microtrauma that is beneficial for healing secondary to numerous biochemical and neurophysiological factors. This microtrauma may disrupt the maladaptive healing response seen in tendon disrepair, upregulate inflammatory cells to produce a controlled inflammatory response, and upregulate satellite cells to assist with renormalization of collagen phenotype (i.e., Type III to Type I) and matrix alignment.[10,11,32,77] Pathologic tendons often have increased neuronal ingrowth and angiogenesis, which is likely a contributing factor to pain severity and chronification.[9,25,34] Studies investigating lateral epicondylalgia have demonstrated that ultrasonic percutaneous tenotomy and electrolysis of the common extensor tendon results in a marked reduction in Doppler activity, suggesting reduced tendon hypervascularity.[6,9] However, subjects in the study by Ang and colleagues[6] also appeared to have benefited from relatively quick reductions in pain, suggesting the possibility of early symptom modulation using the technique. With tendon pathology often necessitating longer healing timeframes, early symptom modulation may be invaluable for subject buy-in and improving their participation in personally meaningful activities.[4,34] A predominant theme highlighted in a systematic review of qualitative studies investigating subject experiences with tendinopathy suggests that a significant subject concern is their ability to fully return to participating in daily activities, suggesting a reduction in quality of life and potential psychosocial strain (e.g., less participation in social activities with friends, mental strain from the financial ramifications of reduced occupational participation).[4] Thus, interventions that provide early symptom relief may facilitate continued engagement in rehabilitation for pathologies that often have longer-term recovery processes.

At six months from the initial evaluation, each subject presented with favorable ultrasonographic features, accompanied by pain and disability resolution. These structural changes included improvements in tendon echogenicity, fibrillar organization, and thickness, and findings were accompanied by marked reductions in sonopalpation tenderness and by improvements in NPRS, UEFI-20, and GROC beyond the MCID in both subjects. These changes may support structural change that should continue to demonstrate beneficial tendon remodeling when combined with a progressive loading protocol.[78-80] Tendon healing and adaptation often occur along prolonged timelines, potentially beyond symptomatic resolution. Tendon fenestration is postulated to disrupt a maladaptive repair process with chronic inflammatory infiltration and create an environment conducive to improved remodeling versus rest alone.[10,11,32,77,80] The inferior tensile tolerance that accompanies glycosaminoglycan and immature collagen deposition may be ameliorated through activity that specifically addresses the tensile capacity of the affected tendon, emphasized clinically through end-range eccentric loading.[41,80-82] Among the two subjects, the combination of education on tendon management strategies and response to load, tendon fenestration to facilitate an optimal healing response, and implementation of a graded loading program appeared to improve pain and disability.

The microtrauma induced by tendon fenestration was accompanied by a graded loading program to optimize load tolerance of the affected biceps brachii for improved upper extremity functional capacity among the two subjects. The localized microtrauma induced by fenestration may initiate a controlled inflammatory response that is thought to fa-

cilitate tendon healing.[10,11,32,77] The subsequent application of progressive mechanical loading may then provide an appropriate stimulus for tendon adaptation secondary to tenocyte sensitivity to load.[81,83] Mechanical load stimulates insulin-like growth factor-1 and transforming growth factor-β secretion to promote tendon remodeling, and long-term compliance with an exercise program that emphasizes tendon tensile load tolerance appears to ameliorate abnormalities seen in tendon structure (e.g., disruption in fibrillar alignment) through a variety of mechanisms, including increased collagen synthesis.[83-88] Continued participation in a loading protocol is important as it allows for epigenetic changes of the tendon, allowing it to adapt specifically to the loads the individual must endure (e.g., occupational lifting demands).[86] However, some studies suggest that changes in tendon structure and pain may not always be well correlated.[89,90] The intervention incorporated pain as the progression strategy for isotonic load management, avoiding pain levels above a 3/10 on NPRS.[73]

To the authors' knowledge, this is the first study to report ultrasound-guided dry needling with fenestration of the distal biceps tendon at the radial tuberosity from a posterior approach as an adjunct to a physical therapy care plan. The dorsal approach used in this study is beneficial as it avoids the neurovascular structures anteriorly.[12,13] A limitation of this retrospective case series is that Doppler ultrasound images were not included, which would have added additional information regarding hyperemia. Additionally, both subjects had minimal comorbidities and were physically active; one may expect varying subject responses in the presence of extensive comorbidities or chronic nicotine use.[24-27] Lastly, this is a case series without the ability to discern cause and effect or the ability to determine the contribution of improvements secondary to the passage of time. Future research would benefit from incorporating a multi-site, randomized controlled trial comparing fenestration of the distal biceps tendon and a graded loading program to a graded loading program alone or no intervention controls to quantify the value of tendon dry needling with fenestration for short-term analgesia and long-term clinical outcomes in those with chronic distal biceps tendinopathy.

CONCLUSION

Two subjects with chronic distal biceps brachii tendinopathy achieved clinically meaningful improvements in pain and disability with ultrasound-guided tendon dry needling with fenestration and graded resistance exercise. Further, improved tendon sonographic characteristics were observed at six months versus baseline in both subjects. Randomized controlled trials investigating ultrasound-guided needle fenestration for distal biceps tendinopathy are necessary to establish causal inference and discern generalizability.

CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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REFERENCES

1. Tagliero AJ, Till SE, Pan X, et al. Long-term outcomes of complete tears of the distal biceps tendon: An analysis of surgical management at a median follow-up of 14.7 years. *Orthop J Sports Med*. 2024;12(10). doi:10.1177/23259671241283787

2. Prada C, Li Z, Sritharan P, et al. Distal biceps tendon injuries treatment: A survey of orthopaedic surgeons' current practice and preferences. *Shoulder Elbow*. 2023;16(6). doi:10.1177/17585732231215504

3. Alentorn-Geli E, Assenmacher AT, Sánchez-Sotelo J. Distal biceps tendon injuries: A clinically relevant current concepts review. *EFORT Open Rev*. 2016;1(9). doi:10.1302/2058-5241.1.000053

4. Mesiha MS, Obst SJ, Randall S, Rebar AL, Dittman CK, Heales LJ. Exploring the beliefs, perceptions, and experiences of individuals with tendinopathy: A systematic review and meta-ethnography of qualitative studies. *Phys Ther*. 2025;105(7). doi:10.1093/ptj/pzaf060

5. Dutton M. *Dutton's Orthopaedic: Examination, Evaluation, and Intervention*. 5th ed. McGraw Hill; 2020.

6. Ang BFH, Mohan PC, Png MA, et al. Ultrasonic percutaneous tenotomy for recalcitrant lateral elbow tendinopathy: Clinical and sonographic results at 90 months. *Am J Sports Med*. 2021;49(7):1854-1860. doi:10.1177/03635465211010158

7. Dunning J, Mourad F, Bliton P, et al. Percutaneous tendon dry needling and thrust manipulation as an adjunct to multimodal physical therapy in patients with lateral elbow tendinopathy: A multicenter randomized clinical trial. *Clin Rehabil*. 2024;38(8):1063-1079. doi:10.1177/02692155241249968

8. McShane JM, Nazarian LN, Harwood MI. Sonographically guided percutaneous needle tenotomy for treatment of common extensor tendinosis in the elbow. *J Ultrasound Med*. 2006;25(10). doi:10.7863/jum.2006.25.10.1281

9. Valera-Garrido F, Minaya-Muñoz F, Medina-Mirapeix F. Ultrasound-guided percutaneous needle electrolysis in chronic lateral epicondylitis: Short-term and long-term results. *Acupunct Med*. 2014;32(6). doi:10.1136/acupmed-2014-010619

10. Mattie R, Wong J, McCormick Z, Yu S, Saltychev M, Laimi K. Percutaneous needle tenotomy for the treatment of lateral epicondylitis: A systematic review of the literature. *Phys Med Rehabil*. 2017;9(6). doi:10.1016/j.pmrj.2016.10.012

11. Stoychev V, Finestone AS, Kalichman L. Dry needling as a treatment modality for tendinopathy: A narrative review. *Curr Rev in Musculoskelet Med*. 2020;13(1):133-140. doi:10.1007/s12178-020-09608-0

12. Dupley L, Watts A. Distal biceps pathology: An evidence-based approach. *Orthop Trauma*. 2024;38(4). doi:10.1016/j.mporth.2024.05.002

13. Mezian K, Jačisko J, Novotný T, et al. Ultrasound-guided procedures in common tendinopathies at the elbow: From image to needle. *Appl Sci*. 2021;11(8). doi:10.3390/app11083431

14. Cho CH, Song KS, Choi IJ, et al. Insertional anatomy and clinical relevance of the distal biceps tendon. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(11). doi:10.1007/s00167-011-1586-x

15. Tagliafico A, Michaud J, Capaccio E, Derchi L, Martinoli C. Ultrasound demonstration of distal biceps tendon bifurcation: Normal and abnormal findings. *Eur Radiol*. 2010;20(1). doi:10.1007/s00330-009-1524-1

16. Jarrett C, Weir D, Stuffmann E, Jain S, Miller M, Schmidt C. Anatomic and biomechanical analysis of the short and long head components of the distal biceps tendon. *J Shoulder Elbow Surg*. 2012;21(7). doi:10.1016/j.jse.2011.04.030

17. Hilgersom N, Nagel M, Janssen S, Kodde I, The B, Eygendaal D. Greater radial tuberosity size is associated with distal biceps tendon rupture: A quantitative 3-D CT case-control study. *Knee Surg Sports Traumatol Arthrosc*. 2021;29(12). doi:10.1007/s00167-021-06722-5

18. Rausch V, Krieter JP, Leschinger T, et al. The radioulnar distance at the level of the radial tuberosity. *Clin Anat*. 2020;33(5). doi:10.1002/ca.23483

19. Tsz-Lung C, Tun-Hing L. Bicipitoradial bursitis: A review of clinical presentation and treatment. *J Orthop Trauma Rehabil*. 2014;18(1). doi:10.1016/j.jotr.2013.12.009

20. Draghi F, Gregoli B, Sileo C. Sonography of the bicipitoradial bursa: A short pictorial essay. *J Ultrasound*. 2012;15(1). doi:10.1016/j.jus.2012.02.003

21. Miyamoto R, Elser F, Millett P. Distal biceps tendon injuries. *J Bone Joint Surg*. 2010;92(11). doi:10.2106/JBJS.I.01213

22. Caekebeke P, Duerinckx J, Riet R v. Acute complete and partial distal biceps tendon ruptures: What have we learned? A review. *EFORT Open Rev*. 2021;6(10). doi:10.1302/2058-5241.6.200145

23. Abate M, Gravare-Silbernagel K, Siljeholm C, et al. Pathogenesis of tendinopathies: Inflammation or degeneration? *Arthritis Res Ther*. 2009;11(3). doi:10.1186/ar2723

24. Saladin KS. *Anatomy & Physiology: The Unity of Form and Function*. 10th ed. McGraw Hill; 2023.

25. Fenwick SA, Hazleman BL, Riley GP. The vasculature and its role in the damaged and healing tendon. *Arthritis Res*. 2002;4(4). doi:10.1186/ar416

26. Kelly MP, Perkinson SG, Ablove RH, Tueting JL, Mick P, Kelly SGP. Distal biceps tendon ruptures. *Am J Sports Med*. 2015;43(8). doi:10.1177/0363546515587738

27. Safran MR, Graham SM. Distal biceps tendon ruptures: Incidence, demographics, and the effect of smoking. *Clin Orthop Relat Res*. 2002;404:275-283. doi:10.1097/01.blo.0000026560.55792.02

28. Seiler J, Parker L, Chamberland P, Sherbourne G, Carpenter W. The distal biceps tendon. Two potential mechanisms involved in its rupture: Arterial supply and mechanical impingement. *J Shoulder Elbow Surg*. 1995;4(3). doi:10.1016/s1058-2746(05)80044-8

29. Brasseur J. The biceps tendons: From the top and from the bottom. *J Ultrasound*. 2011;15(1). doi:10.1016/j.jus.2011.11.002

30. Settergren R. Treatment of supraspinatus tendinopathy with ultrasound guided dry needling. *J Chiropr Med*. 2013;12(1). doi:10.1016/j.jcm.2012.11.002

31. Mattie R, Wong J, McCormick Z, Yu S, Saltychev M, Laimi K. Percutaneous needle tenotomy for the treatment of lateral epicondylitis: A systematic review of the literature. *PM R*. 2017;9(6). doi:10.1016/j.pmrj.2016.10.012

32. Chiavaras M, Jacobson J. Ultrasound-guided tendon fenestration. *Semin Musculoskelet Radiol*. 2013;17(1). doi:10.1055/s-0033-1333942

33. Housner JA, Jacobson JA, Misko R. Sonographically guided percutaneous needle tenotomy for the treatment of chronic tendinosis. *J Ultrasound Med*. 2009;28(9). doi:10.7863/jum.2009.28.9.1187

34. Gehwolf R, Tempfer H, Cesur N, Wagner A, Traweger A, Lehner C. Tendinopathy: The interplay between mechanical stress, inflammation, and vascularity. *Adv Sci*. 2025;12(36). doi:10.1002/advs.202506440

35. Xu Z, Hou W, Zhang T, Chen R, Skutella T. Exploring molecular and cellular signaling pathways: Unraveling the pathogenesis of tendinopathy. *J Orthop Transl*. 2025;51. doi:10.1016/j.jot.2025.02.003

36. Canosa-Carro L, Bravo-Aguilar M, Abuín-Porras V, et al. Current understanding of the diagnosis and management of the tendinopathy: An update from the lab to the clinical practice. *Dis Mon*. 2022;68(10). doi:10.1016/j.disamonth.2021.101314

37. Fu S, Rolf C, Cheuk Y, Lui P, Chan K. Deciphering the pathogenesis of tendinopathy: A three-stages process. *Sports Med Arthrosc Rehabil Ther Technol*. 2010;2. doi:10.1186/1758-2555-2-30

38. Fouda MB, Thankam FG, Dilisio MF, Agrawal DK. Alterations in tendon microenvironment in response to mechanical load: Potential molecular targets for treatment strategies. *Am J Trans Res*. 2017;9(10):43141-44360.

39. Steinmann S, Pfeifer CG, Brochhausen C, Docheva D. Spectrum of tendon pathologies: Triggers, trails and end-state. *Int J Mol Sci*. 2020;21(3). doi:10.3390/ijms21030844

40. Soslowsky LJ, Thomopoulos S, Tun S, et al. Overuse activity injures the supraspinatus tendon in an animal model: A histologic and biomechanical study. *J Shoulder Elbow Surg*. 2000;9(2). doi:10.1067/mse.2000.101962

41. Samiric T, Parkinson J, Ilic MZ, Cook J, Feller JA, Handley CJ. Changes in the composition of the extracellular matrix in patellar tendinopathy. *Matrix Biol*. 2009;28(4). doi:10.1016/j.matbio.2009.04.001

42. Deng J, Oosterhof JJ, Eygendaal D, Breda SJ, Oei EHG, Vos RJ d. Long-term prognosis of athletes with patellar tendinopathy receiving physical therapy: Patient-reported outcomes at 5-year follow-up. *Am J Sports Med*. 2025;53(7). doi:10.1177/03635465251336466

43. Plas AV d., Jonge S d., Vos RJ, d. A 5-year follow-up study of Alfredson's heel-drop exercise programme in chronic midportion Achilles tendinopathy. *Br J Sports Med*. 2011;46(3). doi:10.1136/bjsports-2011-090035

44. Hansen L, Krogh TP, Ellingsen T, Bolvig L, Fredberg U. Long-term prognosis of plantar fasciitis: A 5- to 15-year follow-up study of 174 patients with ultrasound examination. *Orthop J Sports Med*. 2018;6(3). doi:10.1177/2325967118757983

45. Kuliś S, Kłobuchowski W, Skorulski M, et al. Beyond mechanical load: Metabolic factors and advanced rehabilitation in sports tendinopathy: A comprehensive systematic review. *J Clin Med*. 2025;14(21). doi:10.3390/jcm14217480

46. Rha D, Park G, Kim Y, Kim M, Lee S. Comparison of the therapeutic effects of ultrasound-guided platelet-rich plasma injection and dry needling in rotator cuff disease: A randomized controlled trial. *Clin Rehabil*. 2013;27(2). doi:10.1177/0269215512448388

47. Dragoo J, Wasterlain A, Braun H, Nead K. Platelet-rich plasma as a treatment for patellar tendinopathy: A double-blind, randomized controlled trial. *Am J Sports Med*. 2014;42(3). doi:10.1177/0363546513518416

48. Krey D, Borchers J, McCamey K. Tendon needling for treatment of tendinopathy: A systematic review. *Phys Sports Med*. 2015;43(1). doi:10.1080/00913847.2015.1004296

49. Dunning J, Butts R, Henry N, et al. Electrical dry needling as an adjunct to exercise, manual therapy and ultrasound for plantar fasciitis: A multi-center randomized clinical trial. *PLoS One*. 2018;13(10). doi:10.1371/journal.pone.0205405

50. American Academy of Manipulative Therapy. DN-1: Dry Needling for Craniofacial, Cervicothoracic & Upper Extremity Conditions: an Evidence-Based Approach (Part 1 of the Certification in Dry Needling®). Accessed May 13, 2026. https://spinalmanipulation.org/dates-and-locations/dn-1-dry-needling/?gad_source=1&gad_campaignid=9617308231&gbraid=0AAAACdv64uRPF8ISNCK2PwOy5wNFZvIz&gclid=CjwKCAiAmePKBhAfEiwAU3Ko3HhYEpSmu5RcPO7MzWO_kj49ZD9MIFoMbe1qtGsPwW4EWXW6ZGrSJBoCM4sQAvD_BwE

51. American Academy of Manipulative Therapy. Certified Musculoskeletal Ultrasonographer. Accessed May 13, 2026. https://spinalmanipulation.org/certified-msk-ultrasonographer/

52. Jensen MP, McFarland CA. Increasing the reliability and validity of pain intensity measurement in chronic pain patients. *Pain*. 1993;55:195-203. doi:10.1016/0304-3959(93)90148-I

53. Hawker GA, Mian S, Kendzerska T, French M. Measures of adult pain: Visual Analog Scale for Pain (VAS Pain), Numeric Rating Scale for Pain (NRS Pain), McGill Pain Questionnaire (MPQ), Short-Form McGill Pain Questionnaire (SF-MPQ), Chronic Pain Grade Scale (CPGS), Short Form-36 Bodily Pain Scale (SF-36 BPS), and Measure of Intermittent and Constant Osteoarthritis Pain (ICOAP). *Arthritis Care Res*. 2011;63:S240-S252. doi:10.1002/acr.20543

54. Farrar J, Young J, LaMoreaux L, Werth J, Poole M. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. *Pain*. 2001;94(2). doi:10.1016/S0304-3959(01)00349-9

55. Kim TK. Practical statistics in pain research. *Korean J Pain*. 2017;30(4). doi:10.3344/kjp.2017.30.4.243

56. Dolnicar S. 5/7-point "Likert scales" aren't always the best option: Their validity is undermined by lack of reliability, response style bias, long completion times and limitations to permissible statistical procedures. *Ann Tour Res*. 2021;91. doi:10.1016/j.annals.2021.103297

57. Liu M, Harbaugh AG, Harring JR, Hancock GR. The effect of extreme response and non-extreme response styles on testing measurement invariance. *Front Psychol*. 2017;8. doi:10.3389/fpsyg.2017.00726

58. Bobos P, Ziebart C, Furtado R, Lu Z, MacDermid JC. Psychometric properties of the global rating of change scales in patients with low back pain, upper and lower extremity disorders. A systematic review with meta-analysis. *J Orthop*. 2020;21. doi:10.1016/j.jor.2020.01.047

59. Kamper SJ, Maher CG, Mackay G. Global rating of change scales: A review of strengths and weaknesses and considerations for design. *J Man Manip Ther*. 2009;17(3). doi:10.1179/jmt.2009.17.3.163

60. Dworkin RH, Turk DC, Farrar JT, et al. Core outcome measures for chronic pain clinical trials: IMMPACT recommendations. *Pain*. 2005;113(1). doi:10.1016/j.pain.2004.09.012

61. Chesworth BM, Hamilton CB, Walton DM, et al. Reliability and validity of two versions of the upper extremity functional index. *Physiother Can*. 2014;66(3). doi:10.3138/ptc.2013-45

62. Stratford P, Binkley J, Stratford D. Development and initial validation of the upper extremity functional index. *Physiother Can*. 2001;53(4):259-267.

63. Caekebeke P, Meglic U, Bekerom MPJ v. d., Riet R v. Evaluation of clinical tests for partial distal biceps tendon ruptures and tendinitis. *J Shoulder Elbow Surg*. 2022;31(3). doi:10.1016/j.jse.2021.10.012

64. Shim SS, Strauch RJ. A novel clinical test for partial tears of the distal biceps brachii tendon: The Tilt sign. *Clin Anat*. 2018;31(2). doi:10.1002/ca.23038

65. Caekebeke P, Schenkels E, Bell SN, Riet R v. Distal Biceps Provocation Test. *J Hand Surg*. 2021;46(8). doi:10.1016/j.jhsa.2020.12.012

66. Fairbank S, Corlett R. The role of the extensor digitorum communis muscle in lateral epicondylitis. *J Hand Surg*. 2002;27(5). doi:10.1054/jhsb.2002.0761

67. Karanasios S, Korakakis V, Moutzouri M, et al. Diagnostic accuracy of examination tests for lateral elbow tendinopathy (LET) - A systematic review. *J Hand Ther*. 2022;35(4). doi:10.1016/j.jht.2021.02.002

68. Valdes K, LaStayo P. The value of provocative tests for the wrist and elbow: A literature review. *J Hand Ther*. 2013;26(1). doi:10.1016/j.jht.2012.08.005

69. Al-Ani Z, Lauder J. Ultrasound assessment in distal biceps tendon injuries: Techniques, pearls and pitfalls. *Clin Imaging*. 2021;75. doi:10.1016/j.clinimag.2021.01.017

70. Moore RE. Sonography of the extremities: Techniques and protocols. In: *General Musculoskeletal Imaging*. 2015.

71. Griffith JF. *Diagnostic Ultrasound: Musculoskeletal*. 3rd ed. Elsevier; 2025.

72. Wu WT, Chang KV, Hsu YC, Hsu PC, Ricci V, Özçakar L. Artifacts in musculoskeletal ultrasonography: From physics to clinics. *Diagn*. 2020;10(9):1-14. doi:10.3390/diagnostics10090645

73. Malliaras P, Cook J, Purdam C, Rio E. Patellar tendinopathy: Clinical diagnosis, load management, and advice for challenging case presentations. *J Orthop Sports Phys Ther*. 2015;45(11). doi:10.2519/jospt.2015.5987

74. Kongsgaard M, Kovanen V, Aagaard P, et al. Corticosteroid injections, eccentric decline squat training and heavy slow resistance training in patellar tendinopathy. *Scand J Med Sci Sports*. 2009;19(6). doi:10.1111/j.1600-0838.2009.00949.x

75. Bastos V, Machado S, Teixeira DS. Feasibility and usefulness of repetitions-in-reserve scales for selecting exercise intensity: A scoping review. *Percept Mot Skills*. 2024;131(3):940-970. doi:10.1177/00315125241241785

76. Carlesso LC, MacDermid JC, Santaguida LP. Standardization of adverse event terminology and reporting in orthopaedic physical therapy: Application to the cervical spine. *J Orthop Sports Phys Ther*. 2010;40:455-463. doi:10.2519/jospt.2010.3229

77. McAphee D, Bagwell M, Falsone S. Dry needling: A clinical commentary. *Int J Sports Phys Ther*. 2022;17(4). doi:10.26603/001c.35693

78. Bohm S, Mersmann F, Arampatzis A. Human tendon adaptation in response to mechanical loading: A systematic review and meta-analysis of exercise intervention studies on healthy adults. *Sports Med*. 2015;1(1). doi:10.1186/s40798-015-0009-9

79. Williams B, Gyer G. Tendons under load: Understanding pathology and progression. *J Musculoskelet Surg Res*. 2025;9(3). doi:10.25259/JMSR_86_2025

80. Darrieutort-Laffite C, Blanchard F, Soslowsky LJ, Goff BL. Biology and physiology of tendon healing. *Joint Bone Spine*. 2024;91(5). doi:10.1016/j.jbspin.2024.105696

81. Benage LG, Sweeney JD, Giers MB, Balasubramanian R. Dynamic load model systems of tendon inflammation and mechanobiology. *Front Bioeng Biotechnol*. 2022;10. doi:10.3389/fbioe.2022.896336

82. McMahon G. No strain, no gain? The role of strain and load magnitude in human tendon responses and adaptation to loading. *J Strength Cond Res*. 2022;36(10). doi:10.1519/JSC.0000000000004288

83. Docking SI, Cook J. How do tendons adapt? Going beyond tissue responses to understand positive adaptation and pathology development: A narrative review. *J Musculoskel Neuronal Interact*. 2019;19(3):300-310.

84. Langberg H, Skovgaard D, Petersen LJ, Bülow J, Kjær M. Type I collagen synthesis and degradation in peritendinous tissue after exercise determined by microdialysis in humans. *J Physiol*. 1999;521(1). doi:10.1111/j.1469-7793.1999.00299.x

85. Docherty S, Harley R, McAuley JJ, et al. The effect of exercise on cytokines: Implications for musculoskeletal health: A narrative review. *BMC Sports Sci Med Rehabil*. 2022;14(1). doi:10.1186/s13102-022-00397-2

86. Stańczak M, Kacprzak B, Gawda P. Tendon cell biology: Effect of mechanical loading. *Cell Physiol Biochem*. 2024;58(6). doi:10.33594/000000743

87. Wang M, Zhang J, Li H, Li Y, Li Z. Insulin-like growth factor-1 (IGF-1) empowering tendon regenerative therapies. *Front Bioeng Biotechnol*. 2025;13. doi:10.3389/fbioe.2025.1492811

88. Rieber J, Wolint P, Meier-Bürgisser G, et al. Synergistic effects of insulin-like growth factor-1 and platelet-derived growth factor-BB in tendon healing. *Int J Mol Sci*. 2025;26(9). doi:10.3390/ijms26094039

89. de Jonge S, Tol J, Weir A, Waarsing J, Verhaar J, de Vos R. The tendon structure returns to asymptomatic values in nonoperatively treated achilles tendinopathy but is not associated with symptoms: A prospective study. *Am J Sports Med*. 2015;43(12). doi:10.1177/0363546515605077

90. de Vos R, Heijboer M, Weinans H, Verhaar JA, van Schie JT. Tendon structure's lack of relation to clinical outcome after eccentric exercises in chronic midportion Achilles tendinopathy. *J Sport Rehabil*. 2012;21(1). doi:10.1123/jsr.21.1.34

SUPPLEMENTARY MATERIALS

Supplemental File 1

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