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Original article

Effects of dry needling to the symptomatic versus control shoulder in patients with unilateral subacromial pain syndrome☆

Shane Koppenhaver [a, b, *], Robin Embry [a], John Ciccarello [a], Justin Waltrip [a], Rachel Pike [a], Michael Walker [b], Cesar Fernández-de-las-Peñas [c], Theodore Croy [a], Timothy Flynn [b]

[a] U.S. Army-Baylor University Doctoral Program in Physical Therapy, San Antonio, TX, USA
[b] South College Doctor of Physical Therapy Program, Knoxville, TN, USA
[c] Department of Physical Therapy, Occupational Therapy, Physical Medicine and Rehabilitation, Universidad Rey Juan Carlos (URJC), Alcorcón, Madrid, Spain

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ABSTRACT

Background: Initial reports suggest that treating myofascial trigger points in the infraspinatus with dry needling may be effective in treating patients with shoulder pain. However, to date, high quality clinical trials and thorough knowledge of the physiologic mechanisms involved is lacking.
Objectives: To examine the effect of dry needling to the infraspinatus muscle on muscle function, nociceptive sensitivity, and shoulder range of motion (ROM) in the symptomatic and asymptomatic shoulders of individuals with unilateral subacromial pain syndrome.
Design: Within-subjects controlled trial.
Methods: Fifty-seven volunteers with unilateral subacromial pain syndrome underwent one session of dry needling to bilateral infraspinatus muscles. Outcome assessments, including ultrasonic measures of infraspinatus muscle thickness, pressure algometry, shoulder internal rotation and horizontal adduction ROM, and questionnaires regarding pain and related disability were taken at baseline, immediately after dry needling, and 3–4 days later.
Results: Participants experienced statistically significant and clinically relevant changes in all self-report measures. Pressure pain threshold and ROM significantly increased 3–4 days, but not immediately after dry needling only in the symptomatic shoulder [Pressure pain threshold: 5.1 (2.2, 8.0) N/cm^2, internal rotation ROM: 9.6 (5.0, 14.1) degrees, horizontal adduction ROM: 5.9 (2.5, 9.4) degrees]. No significant changes occurred in resting or contracted infraspinatus muscle thickness in either shoulder.
Conclusions: This study found changes in shoulder ROM and pain sensitivity, but not in muscle function, after dry needling to the infraspinatus muscle in participants with unilateral subacromial pain syndrome. These changes generally occurred 3–4 days after dry needling and only in the symptomatic shoulders.
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Shoulder pain is a frequent complaint (Feleus et al., 2008) that commonly involves a spectrum of subacromial space pathologies, including partial thickness rotator cuff tears, rotator cuff tendinosis, calcific tendinitis, and subacromial bursitis, collectively referred as subacromial pain syndrome (Diercks et al., 2014; Escamilla et al., 2014). Although the pathophysiology of subacromial pain syndrome is multifactorial, it likely includes at least a subgroup of patients who present with impairments in rotator cuff muscle function (Escamilla et al., 2014). Decreased force generation of the rotator cuff muscles, in particular the infraspinatus muscle, has been shown to increase superior translation of the humeral head leading to narrowing of the subacromial space and impingement (Ebaugh et al., 2006; Royer et al., 2009). Muscle impairments associated with subacromial pain syndrome are most often treated with rotator cuff strengthening exercises, which have been found to be effective at reducing pain and dysfunction in some, but not all studies (Michener et al., 2004; Kuhn, 2009).

Myofascial trigger points are sensitive spots within palpable taut bands of muscles which commonly refer pain with mechanical stimulation (Simons, 1998). Previous studies have found that trigger points in the infraspinatus muscle can reproduce the pain

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* Corresponding author. U.S. Army-Baylor University Doctoral Program in Physical Therapy, San Antonio, TX, USA.
E-mail address: shanekoppenhaver@mac.com (S. Koppenhaver).

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complaints in individuals with shoulder pain (Ge et al., 2008; Hidalgo-Lozano et al., 2010) and have been associated with impaired shoulder muscle function (Lucas et al., 2010; Ibarra et al., 2011; Ge et al., 2014). Dry needling involves the insertion of thin filiform needles directly into muscles identified as having trigger points in an attempt to reduce pain and normalize muscle function (Kalichman and Vulfsons, 2010; Dommerholt, 2011). Initial reports suggest that treating myofascial trigger points in the infraspinatus with dry needling may be effective in treating patients with shoulder pain (Osborne and Gatt, 2010; Calvo-Lobo et al., 2015) However, supporting evidence from high quality clinical trials and an understanding of the physical mechanisms involved is lacking (Tough et al., 2009; Kietrys et al., 2013; Boyles et al., 2015; Liu et al., 2015).

Multiple studies have investigated the effect of dry needling on pain sensitivity (pressure algometry) in patients with shoulder pain and found it to decrease immediately after (Hsieh et al., 2007; Srbely et al., 2010; Tsai et al., 2010; Calvo-Lobo et al., 2015) and one week after (Hsieh et al., 2007) treatment. One of these studies also reported concurrent immediate changes in shoulder range of motion (ROM) (internal rotation) after dry needling (Hsieh et al., 2007), but none included any assessment of muscle function. The sole study to our knowledge to investigate changes in muscle function following dry needling found altered timing of scapular muscles (primarily the infraspinatus) in the presence of trigger points that was "normalized" immediately following treatment (Lucas et al., 2004). Although this study used surface electromyography (EMG) and asymptomatic participants with latent myofascial trigger points (i.e. only painful upon palpation), the results preliminarily suggest that the mechanism of effect of dry needling in patients with shoulder problems could include a "resetting" of normal scapulo-humeral muscle function.

No study to date has investigated potential changes in infraspinatus muscle function after dry needling in patients with subacromial pain syndrome. Therefore, the purpose of this study was to examine the effect of dry needling to the infraspinatus muscle on muscle function, nociceptive sensitivity, and shoulder ROM in the symptomatic and asymptomatic shoulders of individuals with unilateral subacromial pain syndrome. We hypothesized that changes would occur in both shoulders after dry needling, however, that they would be larger in the symptomatic shoulders. Additionally, we aimed to assess the clinical relevance of these changes by examining their correlation with self-reported clinical improvement.

1. Methods

1.1. Study design

The study was a within-subjects design in which participants were used as their own control. Each participant underwent identical procedures, which included baseline measurements of outcome measures, dry needling treatment to the infraspinatus muscles, and reassessment of outcome measures both immediately after and three to four days after treatment.

1.2. Participants

Participants were all Department of Defense beneficiaries who responded to recruiting advertisements from Joint Base San Antonio, Texas. Participant selection criteria are listed in Table 1 and were aimed at including individuals who would seek healthcare for unilateral subacromial pain syndrome without any contraindications to dry needling. The study protocol was approved by the Institutional Review Board of Brooke Army Medical Center. All participants provided consent prior to study enrollment and the rights of the participants were protected.

A priori power analysis was performed using G*Power 3 (Faul et al., 2007). The amount of change in infraspinatus muscle thickness that would be considered clinically important is currently unknown. Therefore, we powered this study to have at least 80% power to detect an effect size of 0.40 for pre-to-post change and between shoulder differences in muscle thickness and other outcomes, assuming alpha of 0.05 and 10% attrition at follow up. Enrolling 57 subjects was planned which would additionally give adequate precision to correlational estimates.

1.3. Dry needling intervention

After collection of baseline outcome measures, participants received dry needling by an experienced physical therapist trained in dry needling. The treating therapist performed palpation, but was otherwise blinded to the clinical exam, baseline outcome measurements, and which shoulder was symptomatic unless ascertained via palpation. The dry needling technique used disposable 0.25 × 40 mm stainless steel Seirin J-type needles (Seirin Corp., Shizuoka, Japan). "Clean technique" was used throughout the treatment procedure which included hand washing, clean latex-free exam gloves, and cleaning the participants skin with an alcohol swab prior to treatment (Baima and Isaac, 2007). Treatment location was standardized for each participant. Needles were inserted into 3 general locations (superior, medial, inferior) in each infraspinatus muscle based on prior research (Ge et al., 2008) and depictions of common locations of myofascial trigger points (Simons, 1998; Fig. 1). Prior to needle insertion, manual palpation of the infraspinatus muscle was performed to localize treatment to the most painful area at each of the three locations. Each needle insertion lasted approximately 5–10 s using a "sparrow pecking" (in and out motion) technique in an attempt to elicit as many local twitch responses as possible (Itoh et al., 2006).

1.4. Outcome measures

1.4.1. Infraspinatus muscle function

Function of the infraspinatus muscle was quantified using ultrasound imaging and taking muscle thickness measurements during a contraction and comparing them to muscle thickness at rest. In addition to being less invasive than electromyography, these procedures allowed us to quantity muscle function with an alternative tool to the treatment being studied (inserting a needle) (Koppenhaver et al., 2009a).

Images of the infraspinatus muscle were acquired at rest and during submaximal contraction using a SonoSite Titan and M-Turbo with a 38 mm linear array transducer. Participants were positioned prone on an examination table with the imaged shoulder in 90° abduction and neutral glenohumeral joint rotation. The elbow was at 90° with the wrist secured to a pressure cuff attached to a fixed pole underneath the examination table. The pressure cuff was used as a biofeedback device so that the participants could monitor their force during contraction. For all images, the ultrasound transducer was placed immediately inferior to the spine of the scapula and oriented longitudinally so that the suprascapular notch was positioned at the far right image border and the medial border of the scapula was lined up on the left image border (Fig. 2). Ultrasound images were then taken in two muscle conditions, relaxed and a submaximal isometric contraction into external rotation at 20 mmHg of pressure. Each muscle condition was imaged three times to reduce measurement error (Koppenhaver et al., 2009b). Infraspinatus muscle thickness was measured in

Table 1
Eligibility criteria for study inclusion.

Inclusion criteria	Exclusion criteria
(a) Unilateral pain located in the anterior and/or lateral shoulder region, in the opinion of the screening examiner, is originating from the shoulder joint complex	(a) History of prior shoulder trauma or surgery
(b) Able to raise bilateral arms to at least to shoulder height	(b) Signs or symptoms of cervical radiculopathy, radiculitis, or referral from cervical spine
(c) Meet at least 2 out of 3 of the following clinical diagnostic criteria for subacromial pain syndrome: (Park et al., 2005)	(c) Evidence of full-thickness rotator cuff tear, including known imaging and/or positive drop arm test (Park et al., 2005)
1. Positive Hawkins-Kennedy sign	(d) Signs or symptoms consistent with shoulder adhesive capsulitis
2. Presence of a painful arc (60°–120°)	(e) Known pregnancy
3. Pain or weakness with the infraspinatus muscle test	(f) Received injection, acupuncture, dry needling, or strengthening exercise interventions to the shoulder within the past 6 months
(d) Between the age of 18–60 years	(g) Currently taking anticoagulant medications or those individuals with a medical history of bleeding disorder
(e) Reports pain with normal activity of ≥4/10	
(f) Read and speak English well enough to provide informed consent and follow study instructions	

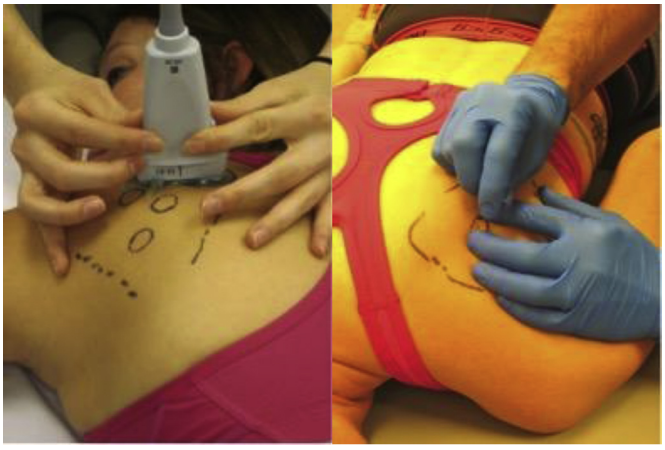

Fig. 1. Location of ultrasound imaging transducer, pain algometry, and dry needing treatment. Pain algometry measures and dry needling treatment was performed at the most painful areas of the superior, medial, and inferior infraspinatus muscle of each side for each participant.

the center of the image at a later time using Image J software (V1.38t, National Institutes of Health, Bethesda, Maryland) by an examiner who was blinded as to whether the image was from the symptomatic or asymptomatic side and before or after dry needling.

The imaging procedures used in the current study have been described previously and have been found to be reliable especially when taken by the same examiner and based on the mean of three measures (ICC = 0.96 to 0.98) (Koppenhaver et al., 2015a). Additionally, such measures were able to discriminate between resting and contracted muscle states (Koppenhaver et al., 2015a).

1.4.2. Shoulder joint range of motion

Shoulder joint internal rotation and horizontal adduction ROM was measured using a bubble inclinometer (MIE Medical Research, Leeds, UK). All shoulder ROM was assessed passively in a supine position (Fig. 3). Internal rotation ROM was assessed in 90 ° of shoulder abduction, 90 ° of elbow flexion, and a small bolster placed under the humerus to approximate the scapular plane. The distal edge of the bubble inclinometer was placed on the radial styloid process and the participants' forearm was lowered while maintaining 90 ° of elbow flexion. Horizontal adduction ROM was also assessed in 90 ° of shoulder abduction and 90 ° of elbow flexion. The bubble inclinometer was placed on the distal humerus centered between the lateral and medial epicondyles. The humerus was passively moved across the participants' body in the transverse plane while the examiner's opposite hand monitored for the onset of scapular protraction. During each motion, ROM was recorded when limited by either onset of first resistance or a participant's report of pain, whichever came first. Studies of inclinometer shoulder ROM measures usually report high reliability, (ICC = 0.63 to 0.97), (Furness et al., 2015; Sharma et al., 2015) however each measurement was taken two times and averaged to reduce variability. If the two measurements were more than 5° apart, a third measurement was taken and additionally averaged.

1.4.3. Pressure algometry

Pressure pain threshold is the minimal amount of pressure that produces pain (Ylinen, 2007) and is used to determine

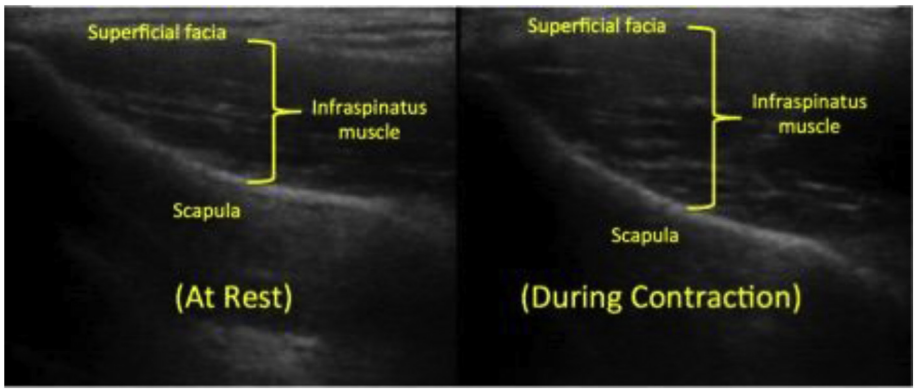

Fig. 2. Infraspinatus muscle thickness measurement on ultrasound image.

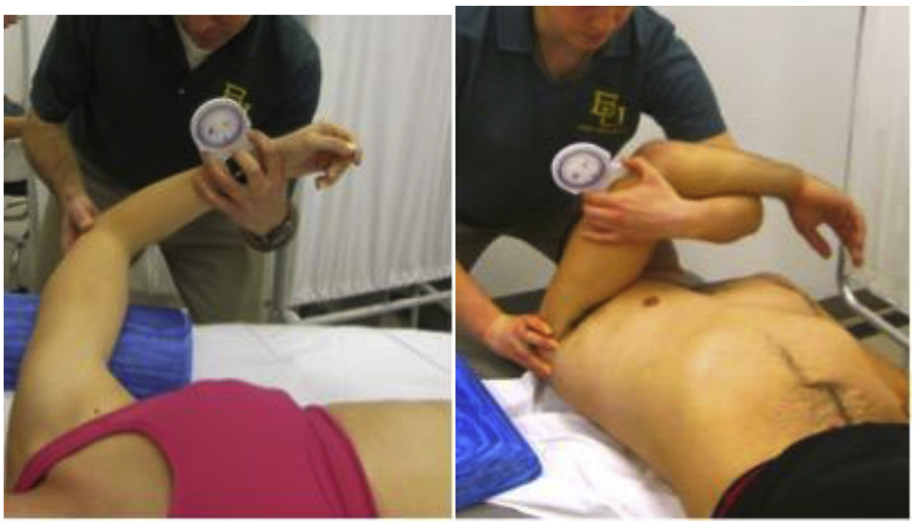

Fig. 3. Shoulder joint internal rotation and horizontal adduction range of motion.

abnormalities in nociceptive processing or hyperalgesia (Ylinen, 2007; Sterling, 2011). A digital pressure algometer (Wagner Force 25 FDX, Wagner Instruments, Greenwich, CT) was used to measure pressure pain threshold, which has been found to be highly reliable and responsive to change, especially when taken by the same rater (ICC = 0.94 to 0.97, Minimal Detectible Change [MDC] = 4.3–9.8 N/cm^2) (Walton et al., 2011). Measures were taken at the same three locations in each infraspinatus muscle as dry needling (Fig. 1). The algometer was held by an examiner directly perpendicular to the muscle belly of the infraspinatus and was advanced at a rate of approximately 5 N/sec. Participants were instructed to verbally signal when they first perceived the force exerted as painful or uncomfortable. Pressure pain threshold at each location was taken three times and averaged to reduce variability. The measurement locations were marked with a surgical marker to ensure reassessment measures were taken at the same location.

1.4.4. Pain and shoulder-related disability

The Penn Shoulder Score was used as the primary measure of clinical outcome. This 100-point shoulder-specific self-report questionnaire consists of 3 subscales of pain, satisfaction, and function. A maximum score of 100 indicates no disability, no pain, and high satisfaction with the function of the shoulder. When aggregated, the questionnaire has demonstrated high test-retest reliability (ICC = 0.94), internally consistency (Cronbach alpha = 0.93), and responsiveness (Standardized Response Mean [SRM] = 1.27) in patients, including those with subacromial pain syndrome (Cook et al., 2001; Leggin et al., 2006). The minimal clinically important difference (MCID) for improvement has been reported at 11.4 points (Leggin et al., 2006).

The Global Rating of Change and the Numerical Pain Rating Scale were additionally used to quantify clinical changes. The Global Rating of Change assesses subjective perception of overall change on a 15-point Likert type scale ranging from 1 (very great deal worse) to 15 (a very great deal better) (Jaeschke et al., 1989).

Pain during a comparable sign (Cook et al., 2015) was additionally assessed at baseline, immediately after needling, and during the follow up visit. Participants were asked to report a simple physical maneuver that could reproduce their primary shoulder symptoms. Common examples were reaching overhead or performing a push-up. Participants then were then asked to perform this maneuver and reported their pain intensity using an 11-point numeric pain rating scale (NPRS) from 0 to 10. Previous work has reported the MCID of the NPRS in patients with shoulder pain to be 1.1 points (Mintken et al., 2009).

1.5. Data analysis

All data were analyzed with IBM SPSS Version 21 software (Chicago, IL). Descriptive statistics were performed on demographic and clinical history characteristics of the sample.

Changes after dry needling in the symptomatic and asymptomatic shoulders were analyzed with 2 × 2 repeated-measures analyses of variance (ANOVA) followed by pairwise comparisons across time. The repeated measures variables were time (baseline vs. immediately after dry needling, and baseline vs. 3–4 days after dry needling) and shoulder (symptomatic vs. asymptomatic). Dependent variables included both self-report outcome variables (pain during comparable sign, Penn Shoulder Score, Global Rating of Change) and physical measures (resting and contracted muscle thickness, pressure pain threshold, internal rotation and horizontal adduction ROM).

The relationship between changes in physical measures (resting and contracted muscle thickness, pressure pain threshold, internal rotation and horizontal adduction ROM) and clinical improvement (Penn Shoulder Scale) was assessed using Pearson correlation analysis. Separate analyses were performed for each dependent variable using 2-tailed significance tests, alpha of 0.05, and pairwise deletion in the case of missing values.

2. Results

Sixty-six individuals with unilateral shoulder pain were assessed for study eligibility. Fifty-seven of the 66 individuals met all inclusion criteria and were enrolled into the study. The most common reasons for study exclusion were having less than 4 out of 10 pain with normal activity and failure to meet 2 out of 3 provocative shoulder impingement tests. One of the 57 enrolled subjects was lost to follow up leaving complete data on 56 participants for analysis. Baseline demographic and clinical history information is listed in Table 2. Overall participants' experienced statistically significant and clinically relevant changes in all self-report measures both immediately after dry needling and at the 3–4 day follow up ($P < 0.001$, Table 2). Thirty-four (60.1%) of the participants

Table 2
Demographic and clinical self-report measures at baseline and after dry needling to the infraspinatus muscle (n = 56).

	Baseline	Immediately after dry needling	3–4 days after dry needling	Immediate change	3–4 day change
Age (years)	44.1 ± 10.1				
Sex (% women)	35.7%				
BMI (kg/m^2)	28.4 ± 4.7				
Pain in dominant shoulder (%)	64.3%				
Duration of symptoms (months)	38.4 ± 71.4				
Median (interquartile range)	27.6 (6.6)				
Pain during comparable sign (0–10)	6.5 ± 2.0	3.8 ± 2.5	3.3 ± 2.2	2.7 (1.8, 3.5)[a]	3.2 (2.5, 3.9)[a]
Penn Shoulder Scale (0–100)	63.7 ± 10.4		79.7 ± 11.4		16.1 (12.5, 19.6)[a]
Global Rating of Change (1–13)			10.0 ± 2.3[b]		10.0 (9.4, 10.6)[a]

[a] Statistically significant changes at p < 0.01.
[b] Equates to "moderately better".

exhibited an improvement greater than the MCID (11.4 points) on the Penn Shoulder Score at 3–4 day follow-up. No adverse events or side effects were reported by any of the participants although one worsened by slightly more than the MCID on the Penn Shoulder Score (12.1 points).

Post-dry needling changes in physical measures (resting and contracted muscle thickness, pressure pain threshold, internal rotation and horizontal adduction ROM) in the symptomatic versus asymptomatic shoulders are detailed in Table 3. No statistically significant interactions or changes occurred in resting or contracted infraspinatus muscle thickness in either shoulder at either time point. Pressure pain threshold and both internal rotation and horizontal adduction ROM significantly increased at 3–4 days (P < 0.01 for each), but not immediately after dry needling in the symptomatic shoulder. Internal rotation ROM also significantly increased in the asymptomatic shoulder 3–4 days after dry needling (P < 0.01), but to a lesser degree than in the symptomatic shoulder. No other significant changes occurred in the asymptomatic shoulder at either time point after dry needling.

Correlation coefficient estimates (Pearson r) between changes in physical measures (resting and contracted muscle thickness, pressure pain threshold, internal rotation and horizontal adduction ROM) and clinical improvement (Penn Shoulder Scale) are detailed in Table 4. Of all the physical changes only horizontal adduction ROM was weakly to moderately associated to clinical improvement both immediately (P = 0.04) and 3–4 days after (P = 0.001) dry needling.

Table 4
Association between muscle function, nociceptive sensitivity, and range of motion changes in the symptomatic shoulder and clinical improvement after dry needling (n = 56).

	Immediate change	3–4 day change
Symptomatic shoulder		
Infraspinatus muscle function		
Resting thickness (mm)	−0.10 (−0.39, 0.20)	0.24 (−0.02, 0.49)
Contracted thickness (mm)	−0.06 (−0.32, 0.23)	0.18 (−0.09, 0.46)
Pressure pain threshold (N/cm^2)	−0.17 (−0.46, 0.17)	0.12 (−0.22, 0.42)
Range of motion		
Internal rotation (degrees)	−0.15 (−0.50, 0.18)	0.07 (−0.23, 0.32)
Horizontal adduction (degrees)	0.27 (0.01, 0.50)*	0.43 (0.25, 0.58)**

Values are mean Pearson r correlations coefficient (95%CI).
Statistically significant correlations at *p < 0.05 and **p < 0.01 levels.

3. Discussion

The purpose of this study was to examine the effect of dry needling on infraspinatus muscle function, nociceptive pain sensitivity, and shoulder ROM in the symptomatic and asymptomatic shoulders of individuals with unilateral subacromial pain syndrome. We hypothesized that changes would occur in both shoulders after dry needling and that these changes would be larger in the symptomatic shoulders. Additionally, we aimed to assess the clinical relevance of these changes by examining their correlation with self-reported clinical improvement.

Table 3
Muscle function, nociceptive sensitivity, and range of motion changes after dry needling to the infraspinatus muscle (n = 56).

	Baseline	Immediately after dry needling	3–4 days after dry needling	Immediate change	3–4 day change
Symptomatic shoulder					
Infraspinatus muscle function					
Resting thickness (mm)	16.5 ± 3.7	16.8 ± 3.8	16.2 ± 3.7	0.4 (−0.1, 0.8)	−0.2 (−0.7, 0.3)
Contracted thickness (mm)	19.2 ± 4.0	19.6 ± 4.1	19.1 ± 4.1	0.4 (−0.04, 0.9)	−0.1 (−0.5, 0.4)
Percent thickness change (as a percentage of rest)	17.6%	18.2%	18.2%	0.6%	0.6%
Pressure pain threshold (N/cm^2)	30.9 ± 13.3	30.2 ± 13.7	35.9 ± 12.8	0.6 (−3.7, 2.4)	5.1 (2.2, 8.0)[a]
Range of motion					
Internal rotation (degrees)	49.4 ± 17.2	52.5 ± 17.3	59.0 ± 17.1	3.1 (−0.7, 7.0)	9.6 (5.0, 14.1)[a]
Horizontal adduction (degrees)	118.5 ± 14.0	120.9 ± 12.1	124.4 ± 12.6	2.4 (−0.6, 5.4)	5.9 (2.5, 9.4)[a]
Control shoulder					
Infraspinatus muscle function					
Resting thickness (mm)	16.2 ± 3.8	16.2 ± 3.9	16.1 ± 3.8	0.1 (−0.5, 0.6)	−0.1 (−0.6, 0.3)
Contracted thickness (mm)	19.3 ± 4.2	19.5 ± 4.2	19.3 ± 4.0	0.2 (−0.3, 0.7)	0.0 (−0.5, 0.5)
Percent thickness change (as a percentage of rest)	20.1%	21.2%	21.4%	1.0%	1.2%
Pressure pain threshold (N/cm^2)	35.1 ± 14.2	34.4 ± 14.1	37.7 ± 13.1	0.7 (−3.5, 2.1)	2.6 (−0.2, 5.4)
Range of motion					
Internal rotation (degrees)	58.6 ± 13.3	59.4 ± 13.6	63.5 ± 12.7	0.8 (−1.6, 3.3)	4.9 (1.4, 8.3)[a]
Horizontal adduction (degrees)	127.6 ± 9.6	126.9 ± 8.8	129.1 ± 9.0	−0.7 (−2.9, 1.4)	1.5 (−0.9, 4.0)

Values are mean ± SD.
[a] Statistically significant changes at p < 0.01.

3.1. Infraspinatus muscle function

Contrary to our expectations, we found no statistically significant changes in either resting or contracted infraspinatus muscle function in either shoulder at any time point. Moreover, the percent change of infraspinatus muscle thickness between resting and contracted states (a surrogate measures of muscle contraction) remained fairly stable during each measurement session both before and after dry needling (Table 3) and change in muscle function was not associated with clinical improvement (Table 4).

It is difficult to compare our results to previous studies as no prior research has investigated changes in muscle contraction in patients with subacromial pain syndrome. We have previously studied changes in lumbar multifidus muscle contraction after dry needling in patients with low back pain, and found that improved contraction occurred only in patients that experienced clinical improvement one week after, rather than immediately after, dry needling treatment (Koppenhaver et al., 2015b). A similar study in asymptomatic individuals found increased lumbar multifidus contraction after dry needling, but not after sham dry needling (Dar and Hicks, 2015). The only study to investigate changes in shoulder muscle function after dry needling used surface EMG to evaluate the timing, rather than the quantity of muscle contraction. The authors' reported altered timing of scapular muscles (primarily the infraspinatus) in the presence of trigger points that was "normalized" immediately following treatment (Lucas et al., 2004).

Therefore, while it is certainly possible that dry needling does not change infraspinatus muscle function, it is also conceivable that our measurement technique simply did not detect changes that did occur. Specifically, one possible explanation for the lack of change in muscle function in the current study could be that dry needling changes the timing of infraspinatus muscle function rather than the quantity or intensity of muscle contraction. Another possible explanation for our findings could be due to our location of ultrasound measurement in relation to the location of dry needling treatment. Using ultrasound to measure muscle contraction relies upon the ability of the examiners to reproducible boney and/or fascial landmarks from which muscle thickness (or cross sectional area) measures can be obtained. The procedures used in the current study were developed to maximize the reproducibility of these landmarks and involved measuring the superior-medial portion of the infraspinatus immediately inferior to the spine of the scapula (Koppenhaver et al., 2015a). While these measures have been found to be reliable and able to discriminate between resting and contracted muscle states (Koppenhaver et al., 2015a), they resulted in measurements of a portion of the infraspinatus muscle at a different location than where the dry needling occurred (Fig. 3). This differs from the methods of the previous studies in the lumbar multidifus muscle (Dar and Hicks, 2015; Koppenhaver et al., 2015b) that measured muscle function more directly at the area of dry needling treatment. Therefore, it is possible that muscular changes after dry needling did occur, but they were isolated to the treated area of the infraspinatus muscle and were undetected superiorly.

3.2. Shoulder joint ROM and pressure algometry

Shoulder joint ROM and pressure pain threshold consistently increased after dry needling in the symptomatic shoulder. Immediate changes were small and not statistically significant, whereas 3–4 day changes were larger and all statistically significant. Changes in the asymptomatic shoulder followed a similar trend, but were much smaller and generally non-significant. These finding supported our hypothesis and are generally consistent with previous literature suggesting a mechanical hypoalgesic effect of trigger point dry needling (Hsieh et al., 2007; Srbely et al., 2010; Tsai et al., 2010; Calvo-Lobo et al., 2015). However, these results should be interpreted with the notion that all of these changes, especially in pressure pain threshold, are within some estimates of measurement error (Walton et al., 2011).

Regarding ROM, multiple studies have reported large changes in ROM immediately after dry needling (Hsieh et al., 2007; Tsai et al., 2010; Mejuto-Vázquez et al., 2014). In the single study performed in shoulder pain, Hsieh et al. (Hsieh et al., 2007) compared the effect of dry needling vs. no dry needling to the infraspinatus muscles of patients with bilateral shoulder pain. They reported large immediate changes in active and passive internal rotation ROM (>20°) in the shoulders that received dry needling, but not in the shoulders that received no dry needling. Although they did not evaluate the association between change in ROM and clinical improvement, they reported concurrent large improvements in pain intensity in the shoulders that received dry needling.

Additional studies have investigated the effect of dry needling on pain sensitivity (pain pressure threshold) in patients with shoulder pain and found it to decrease both immediately after (Hsieh et al., 2007; Srbely et al., 2010; Tsai et al., 2010; Calvo-Lobo et al., 2015) and one week after (Hsieh et al., 2007) treatment. Of interest, some of these studies report both local muscle changes and distal changes in muscles that are innervated by the same spinal nerve root (Srbely et al., 2010) and/or in proximal (Tsai et al., 2010) or distal (Hsieh et al., 2007; Calvo-Lobo et al., 2015) regions purported to fall within the muscle trigger point referral areas.

3.3. Pain and shoulder-related disability

Participants reported clinical improvement on all outcome measures both immediately after dry needling (pain during comparable sign) and 3–4 days afterwards (pain during comparable sign, Penn Shoulder Scale, Global Rating of Change). Moreover, these changes on average were both statistically significant and clinically relevant as even the lower bound of the 95%CI surpassed the reported MCIDs of each outcome measures. These findings appear to be consistent with the few studies that have evaluated clinical improvement after dry needling in patients with shoulder pain (Hsieh et al., 2007; Osborne and Gatt, 2010).

3.4. Associations between physical and clinical outcomes

Of all the physical changes assessed in the current study, only horizontal adduction ROM was statistically related to clinical improvements. Improved shoulder-related disability (Penn Shoulder Scale) was weakly correlated to immediate change in ROM ($r = 0.27$) and moderately correlated to 3–4 day change in ROM ($r = 0.43$). This is the first study to report such a finding and may suggest the clinical relevance of impairments in patients with subacromial pain syndrome. A deficit in pain-free horizontal adduction ROM might be an important impairment in this subgroup of patients suggesting potential clinical improvement after dry needling treatment to the infraspinatus muscle. This hypothesis should be tested in future research.

3.5. Limitations

As previously stated, the fact that ultrasound measurement of muscle function was obtained at a distinct portion of the infraspinatus muscle from the area of dry needling treatment may have been an important limitation of this study. The fact that the treating clinician was blinded to the clinical examination could be another limitation. While this allowed the treating clinician to be blind to which side was symptomatic and limit potential treatment bias, it might also have resulted in less clinically relevant dry needling

strategy. The lack of longer term follow up is another limitation of this study as we have no information on how long either the clinical or physical changes after dry needling maybe have lasted. And although the current study used the asymptomatic shoulder as a control comparison, we did not include any control condition or participants that did not receive dry needling. Therefore we cannot be certain that it was the dry needling treatment that caused the changes in ROM and pain sensitivity rather than placebo or natural history of the condition.

4. Conclusions

This study found post-dry needling changes in shoulder joint ROM and pain sensitivity, but not in muscle function, after dry needling to the infraspinatus muscle in patients with unilateral subacromial pain syndrome. These changes generally occurred only in the symptomatic shoulders and after 3–4 days as opposed to immediately after dry needling. Change in horizontal adduction ROM was associated with improved shoulder-related disability, which might be suggestive of the clinical relevance of such impairments.

Conflict of interest

None declared.

Ethical approval

This study was approved by the Institutional Review Board of Brooke Army Medical Center.

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