# Non-traumatic chronic shoulder pain is not associated with changes in rotator cuff interval tendon thickness

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# TITLE PAGE

**Title: Unilateral chronic shoulder pain does not alter shoulder rotator interval tendons thickness when compared to contralateral shoulder and healthy individuals.**

ABSTRACT

Objective: To determine whether the thickness of the rotator interval tendons is different when comparing both symptomatic and non-symptomatic sides in people with chronic shoulder pain, and to those free of pain. Furthermore, to calculate the level of association between the rotator interval tendon thicknesses and perceived shoulder pain-function.

Design: A cross-sectional, observational study.

Method: The supraspinatus, subscapularis and biceps brachii tendon thickness of sixty two patients with chronic shoulder pain were determined from standardized ultrasonography measures performed on both shoulders, whereas only the dominant arm was measured for the control subjects.

Findings: Supraspinatus, subscapularis and biceps brachii tendon thickness was comparable between sides in the symptomatic group and was also comparable between the symptomatic and asymptomatic participants. In addition, the correlation between the tendon thickness and shoulder pain-function was non-significant.

Interpretations: Tendon thickness was unaltered in people with chronic shoulder pain. These findings do not rule out the possibility that other changes in the tendon are present such as changes in the elastic properties and cell population and this should be explored in future studies.

Keywords: ultrasound; shoulder pain; chronic pain; tendon.

## HIGHLIGHTS

These results suggest that non-traumatic chronic shoulder pain does not alter the thickness of the tendons, with the thickening of the tendon possibly being rather an early traumatic or mechanical loading response.

The tendon thickness cannot explain differences in pain perception, and should not be used as an indicator of shoulder pain-function in chronic conditions

## INTRODUCTION

The shoulder is the third most common joint for musculoskeletal soft tissue disorders(Lewis, 2010)with half of the patients who present with shoulder pain still reporting symptoms after one year(van der Windt et al., 1995).The rotator cuff interval, which is formed by tendons (supraspinatus, biceps and subscapularis) and ligaments (coracohumeral and superior glenohumeral ligaments) is commonly affected and implicated in people with shoulder pain(Nové-Josserand et al., 1996).

Tendinopathy is common and involves alterations in the tendon structure, such as the loss of the parallel, longitudinal collagenous architecture, and the presence of mucinous material(Khan et al., n.d.), yet the extent of changes in tendon morphology do not usually correlate with the average level of pain intensity (Auliffe et al., 2017). Studies have revealed differences in the thickness of the supraspinatus tendon on the symptomatic compared to the asymptomatic side in people with unilateral shoulder pain, (Joensen et al., 2009) and also differences in tendon thickness between people with shoulder pain and asymptomatic control subjects(Michener et al., 2013).In contrast, other studies have shown degeneration and/or thinning of the rotator cuff bilaterally in patients with unilateral shoulder pain (Ro et al., 2015; Teunis et al., 2014; Yamaguchi et al., 2006).Yet in all of these studies, the supraspinatus was examined and there is a lack of research on the other tendons that define the rotator interval. Teunis et al. highlighted the need for additional studies to analyse and characterize rotator cuff morphological features using ultrasound imaging, and to determine whether abnormalities are associated with the level of perceived symptoms.

Hence, the aim of this study was to determine with ultrasound, the thickness of the tendons of the rotator cuff interval (supraspinatus, long head biceps brachii and subscapularis) and to compare the symptomatic and asymptomatic side in people with unilateral shoulder pain. Moreover, asymptomatic participants were recruited to act as a control group to allow comparisons between those with and without shoulder pain. Additionally, an aim was to determine the level of association between rotator interval tendon thicknesses and shoulder pain-function in those with chronic shoulder pain.

## METHODS

### Study design

A cross-sectional, observational study, conducted according to the Declaration of Helsinki.Ethical approval was obtained from the Ethics Committee of [redacted] and the participants provided written consent. Confidentiality of the participants' information and informed consent were password protected and stored.

### Participants

Based on preliminary studies (Michener et al., 2013), to detect a difference of tendon thickness greater than 1 mm between people with and without shoulder pain, with a standard deviation of 1 mm, and significance set at $\alpha = 0.05$, a power analysis for t-tests indicated a sample size of at least n = 22 per group for 95 % power.

A convenience sample of 73 patients with chronic, unilateral shoulder pain of their dominant arm were recruited from three different primary care centres. General practitioners (GPs) carried out the recruitment and research assistants screened all participants for eligibility, with a final sample size of 62 participants obtained after applying the following inclusion criteria: i) positive Neer test; ii) positive Hawkins-Kennedy test; iii) positive Jobe test; iv) positive Speed test; v) positive Gerber test; vi) painful arc present during flexion or abduction; vii) pain during resisted lateral rotation and/or abduction; viii)and a focal hypoechoic zone within the substance of the rotator interval tendons and/or small hypoechoic discontinuities of the internal or external surfaces of these tendons, without swelling image(McCreesh et al., 2015).

The following additional inclusion criteria had to be met: ix) men and women aged between 18 and 55 years; (x) no history of significant shoulder trauma, such as fracture; and (xi) clinically and or ultrasonography-suspected full thickness cuff tear(Wiener and Seitz, 1993); (xii) negative subacromial impingement test by ultrasound(Beggs et al., 2015). Participants were ineligible to participate if any of the following conditions they presented with: (i) recent shoulder dislocation, systemic illnesses such as rheumatoid arthritis, and evidence of adhesive capsulitis as indicated by passive range of motion loss > 50 % in two planes of shoulder motion; (ii) shoulder pain that was deemed to be originating from neck movement or if there was a neurological impairment, osteoporosis, hemophilia and/or malignancies; iii) corticosteroid injections over the six months prior to the study;iv) analgesic-anti-inflammatory medication intake; (vi) participation in overhead physical activities; (vii), presence of subacromial-subdeltoid bursitis,

subcoracoid bursitis as well as mild tendon pathology as tiny calcific tendinopathy, evaluated during ultrasound assessment during the recruitment of participants.

The patient group completed the Shoulder Pain and Disability Index (SPADI)(Roach et al., 1991) which is a self-administered questionnaire that consists of two dimensions, one for pain and the other for functional activities with score ranges from 0 to 100 (0=best and 100=worst).

A convenience sample of 40 participants with both shoulders free of pain over the last year, and similar age/gender characteristics to the patient sample, was also recruited from a list of volunteers of the three different primary care centres. Inclusion criteria for the asymptomatic group were: (i)a SPADI score≤ 15 points, based on the minimal clinically detectable change for this tool. (Ekeberg et al., 2010); (ii) negative results for Neer, Hawkins-Kennedy, Jobe, Speed and Gerber tests; iii) no painful arc present during flexion or abduction; iv) no pain during resisted lateral rotation and/or abduction; (v) not participating in overhead physical activities.

**Outcome measures**

ASonosite M-turbo (GE Healthcare, Wauwatosa, WI) ultrasound device with a dynamic range up to 165 dB, was used.A 6–13-MHz linear transducer with 196 piezoelectric crystals. “SonoMB® multi-beam imaging” was applied to increase resolution and improve visualization. Images were captured in grey scale of 256 shades. All patients underwent a single session of standardized ultrasound assessment of both shoulders(Teefy et al., 2000),(Corazza et al., 2015), whereas

only the dominant arm was assessed for the asymptomatic participants. The assessment was performed by a single examiner with advanced training in ultrasound imaging and over 5-years of experience.

Three measurements of tendon thickness (mm) were taken for each tendon and an interval of one minute was provided between measurements, with the participant being encouraged to move freely during this time. The examiner was blinded to all measurements (values were obscured by placing a cover over the ultrasound screen, and a research assistant registered the data), and was blinded to the affected versus unaffected side in the symptomatic participants. The procedure proposed by the European Society of Musculoskeletal Radiology(Beggs et al., 2015) was followed to position the participants. Additionally, when the tendon integrity evaluation was carried out to assess for exclusion criteria, standard views I, II and III (according to the modified 5-grade Wiener and Seitz classification) were accepted(Wiener and Seitz, 1993), whereas types IV and V did not met the eligibility criteria for this study and were excluded.A full-thickness tear of the rotator cuff was defined as the inability to visualize the rotator cuff due to complete avulsion and retraction under the acromion, or as a focal defect in the rotator cuff created by a variable degree of retraction of the torn tendon edges(Teefy et al., 2000).

*Supraspinatus*

The supraspinatus tendon thickness was evaluated using the modified Crass or Middleton position, with the patient's palm placed over his/her iliac wing or "back pocket" with the elbow flexed and directed medially(Figure 1)(Beggs et al., 2015). The transducer was placed over the anterior aspect of the shoulder, perpendicular

to the supraspinatus tendon and just anterior of the anterior-lateral margin of the acromion. A transverse glide was then performed at the site to determine the exact position where the observer evaluated the tendon thickness at its maximum(Beggs et al., 2015)(Corazza et al., 2015).Measurements were taken 2 cm laterally from the biceps tendon(Schmidt et al., 2004), from the top to the bottom (Figure 1).

Figure1:Left:Position of the transductorfor the evaluation of supraspinatus. Right: Supraspinatus tendon thickness measurement.

*Long head of bicepsbrachii(LHB)*

The patient's forearm was placed with the elbow flexed to 90° in slight internal rotation, with the palm facing upward and medially (Figure 2). This position allows the bicipital groove to be brought to an anterior position, allowing clear visualization of the tendon within the grove. The transducer was placed over the bicipital groove to visualize a transverse scan of the tendon(Beggs et al., 2015; Corazza et al., 2015) and tendon thickness was measured from the top to the bottom at the distal end of the rotator cuff (Figure 2)(Schmidt et al., 2004).

Figure2:Left: Position of the transductor for the evaluation of the long head of biceps brachii. Right: Long head of biceps brachii tendon thickness measurement.

*Subscapularis*

The transducer was placed along the axial plane in the same position used to visualize the bicipital groove when evaluating the long head of biceps brachii

tendon (Figure 3). The patient was asked to rotate the forearm externally, keeping the palm up and the elbow strictly close to the iliac crest(Beggs et al., 2015; Corazza et al., 2015). The tendon thickness was measured from the top to the bottomat a distance of 2 cm medial to the biceps tendon(Figure 3)(Schmidt et al., 2004).

Figure3: Left: Position of the transductor for the evaluation of subscapularis. Right: Subscapularis tendon thickness measurement.

**Data analysis**

The average of three measures for each tendon was calculated and used for analysis. Normality of the data was explored using the Kolmogorov Smirnov test for the group of participants with shoulder pain (affected and non-affected side), and the Shapiro-Wilk test for the control group. Comparisons between the affected and non-affected side of the participants with shoulder pain were calculated using paired sample t-tests whereas the comparison between the symptomatic and asymptomatic group were determined using independent sample t-tests. When normality was violated, comparisons were made using non parametric tests for related and/or independent samples.

Correlations between tendon thicknesses and shoulder pain-function (SPADI) were analyzed using Pearson's and Spearman correlation coefficients. A weak correlation was defined as values between 0.3 and 0.5; moderate between 0.5 and 0.7; and strong if the correlation coefficient was than 0.7 (Mukaka, 2012)A p-value $<0.05$ was considered statistically significant. To calculate the intra-rater

reliability of the ultrasound variables, the intraclass correlation coefficient (ICC) was calculated for the three repeated measures. A reliability coefficient less than 0.50 was considered “poor” reliability; “moderate” between 0.50 and 0.75, “good” between 0.76 and 0.90; and “excellent” over 0.90(Portney and Watkins, 2000).

## RESULTS

The final sample size consisted of 62 patients and 40 pain-free participants since 11 patients did not meet the inclusion criteria.

*Sample characteristics*

Demographic characteristics are shown in Table 1 and the ICC for the repeated measurements is shown in Table 2. The intra-rater reliability for most of the tendons was excellent.

| | | Participants with shoulder pain | Asymptomatic participants | p |
|---|---|---|---|---|
| AGE, years (SD) | | 46.24 (1.32) | 46.42 (1.11) | 0.92 |
| GENDER | FEMALE | 41 | 19 | |
| | MALE | 21 | 21 | 0.12 |
| SPADI (0-100)(SD) | | 57.05 (18.93) | - | |
| Chronicity of Symptoms | | 3-6 months = 6*<br>6-12 months = 19*<br>>12 months = 35* | | |

Table 1**:** Age, gender and duration of symptoms of the participants, and score on the Shoulder Pain and Disability Index (SPADI) for the patient group.

SD: Standard deviation

*: number of participants

| Group | **Participants with shoulder pain** | | | | **Asymptomatic participants** | |
|---|---|---|---|---|---|---|
| | Affected side | | Non-affected side | | | |
| | ICC (95CI) | SEM/MDC95 | ICC (95CI) | SEM/MDC95 | ICC (95CI) | SEM/MDC95 |
| Supraspinatus | 0.98 (0.97-0.99) | 0.01/0.02 | 0.96(0.94-0.97) | 0.02/0.05 | 0.81(0,71-0.89) | 0.00/0.01 |
| Bicepsbrachii | 0.91(0.86-0.94) | 0.03/0.08 | 0.94(0.90-0.96) | 0.02/0.05 | 0.83(0.73-0.90) | 0.02/0.05 |
| Subscapularis | 0.97 (0.95-9.98) | 0.03/0.08 | 0.97(0.95-0.98) | 0.02/0.05 | 0.96(0.93-.98) | 0.01/0.03 |

Table 2: Intraclass correlation coefficient for supraspinatus, biceps brachii and subscapularis tendonultrasound measurements.

SEM: standard error of measurement

MDC95: minimal detectable change

The tendon thickness measurements for each group are presented in Table 3. As seen from these data, the thickness of each tendon was equivalent across all groups. The level of association between tendon thickness and shoulder pain-function (SPADI) was almost inexistent, and no statistically significant for all comparisons.

| | Affected side | Associationwith SPADI (p) | Non-affected side | Asymptomatic participants |
|---|---|---|---|---|
| Supraspinatus | 5.21 (4.97 to 5.46) | 0.07 (0.56) | 5.13 (4.88 to 5.38) | 5.18 (4.97 to 5.39) |
| Bicepsbrachii | 3.15 (2.98 to 3.38) | -0.05 (0.73) | 3.35 (3.04 to 3.65) | 3.23 (3.08 to 3.37) |
| Subscapularis | 5.04 (4.84 to 5.2) | -0.15 (0.25) | 5.06 (4.82 to 5.30) | 5.11 (4.86 to 5.36) |

Table 3:Mean values (95% CI) of tendon thickness, expressed in millimetres.

The mean differences between groups for each measure of tendon thickness are presented in Table 4 which shows that there were no significant differences between groups.

| | Affected-Non affected side | p | Affected side-Asymptomatic participants | p | Non Affected side-Asymptomatic participants | p |
|---|---|---|---|---|---|---|
| Supraspinatus | 0.11 (-0.16 to 0,38) | .42 | 0.03 (-0.1 to 0.37) | .85 | -0.05 (-0.40 to 0.30) | .78 |
| Bicepsbrachii | -0.14 (-0.43 to 0,15) | .92 | -0.04 (-0.30 to 0.22) | .64 | -0.05 (-0.4 to 0.31) | .47 |
| Subscapularis | 0.00** (-0.25 to 0.24) | .97 | -0.06 (-0.38 to 0.25) | .89 | -0.11 (-0.27 to 0.51) | .68 |

Table 4:Mean differences (95% CI) in supraspinatus, biceps brachii and subscapularis tendon thicknesses between groups

*: statistically significant (p>0.05)

## DISCUSSION

This study applied ultrasonography to investigate the thickness of supraspinatus, long head of biceps brachii and subscapularis tendons measured on the symptomatic and asymptomatic shoulder in patients with chronic unilateral shoulder pain, as well as on the dominant arm in asymptomatic individuals. The results revealed no difference in tendon thickness, between the symptomatic patients´shoulder and controls or between the symptomatic and asymptomatic side in the patient group. There was also no significant association between rotator interval tendon thickness and shoulder pain-function.

This is the first comprehensive study exploring tendon thickness assessed with ultrasound in such populations and the first to explore the association between shoulder tendon thickness and perceived pain and function. The tendon thickness values obtained from the asymptomatic subjects in this study were similar to those previously reported by Karthikeyan et al.(Karthikeyan et al., 2014), which reported a thickness of the supraspinatus tendon between 4.9 mm and 5.6 mm, of the subscapularis tendon between3.8 to 4.4 mm and a thickness of the biceps brachiitendon between 2.9 to 3.4mm when measured on the dominant shoulder of their healthy volunteers. Similarly, Schmidt et al(Schmidt et al., 2004)reported mean values of 4.6 mm for the supraspinatus, 4.2 mm for the subscapularisand2.6 mm for the biceps.

In the symptomatic group, the mean values of supraspinatus tendon thickness measured in the affected shoulder were similar to values reported by Cholewinski et al(Cholewinski et al., 2008), who found a mean thickness of 5.6 mm for the rotator cuff. Other studies, however, have documented greater tendon thickness in patients with shoulder impingement syndrome(Leong et al., 2012; Michener et al., 2013). These differences could be explained by the use of different ultrasound measurement techniques varying positions for evaluation of the tendon. For example, Michener et al(Michener et al., 2013)measured the supraspinatus tendon by taking an average of three measurements performed 10, 15 and 20 mm laterally to the long biceps tendon, while Leong et al(Leong et al., 2012)performed the measures at 10, 20 and 30 mm lateral to the biceps tendon. Moreover, Leong et al enrolled participants who were younger than those in the current study, which may have also contributed to the differing results (Leong et al., 2012).The current study is the first to measure the thickness of the subscapularis and long head of bicepsbrachii tendon in people with shoulder pain and thus no comparative values exist.

In contrast to the current findings, Cholewinski et al. found significant differences in tendon thickness between the symptomatic and the asymptomatic shoulders in subjects with shoulder pain(Cholewinski et al., 2008).This could be attributed to different factors such as the different inclusion criteria applied in both studies, and the difference in the duration of symptoms. Changes in tendon morphological properties, driven by central and/or systemic conditions, could also explain the

lack of side-to-side difference in the patient group in the current study, as has been studied in Achilles tendinopathy(Docking et al., 2015).

When comparing differences in tendon thickness between symptomatic tendons and the control group, the presented findings are in line with Michener et al(Michener et al., 2013).However they also studied the occupation ratio (the ratio between supraspinatus thickness and the acromiohumeral distance), reporting a larger occupation ratio in those with shoulder pain, which shows both intrinsic (thickening) and extrinsic (decreased acromiohumeral distance) mechanisms occurring in the tendon. These results suggest that non-traumatic chronic shoulder pain does not alter the thickness of the tendons, with the thickening of the tendon possibly being rather an early traumatic or mechanical loading response.

Previous studies have shown a lack of correlation between symptoms (e.g., pain, disability) and tendon thickness in patients with full rotator cuff tears(Curry et al., 2015; Dunn et al., 2014; Wylie et al., 2016), and also after a rotator cuff repair(Tham et al., 2013), which is in agreement with the results from the present study since we only observed non-significant associations between rotator interval tendon thickness and shoulder pain-function. However, others studies advocate that the increase in the size of the tear appears to be highly correlated with pain(Moosmayer et al., 2010; Tashjian, 2012).In line with the poor association reported in our study, the acromiohumeral distance only shows a small association with shoulder pain-function in people with chronic shoulder pain(Navarro-ledesma et al., 2017).

This study has a number of strengths, including similar demographic characteristics of our two groups and it is the first to report the rotator interval tendon thicknesses in these different populations. Moreover, a careful screening for exclusion criteria was carried out using ultrasound imaging assessment following established guidelines(Wiener and Seitz, 1993), recommended patient positioning (Beggs et al., 2015; Corazza et al., 2015), and precise and highly reliable tendon thickness measurements(Auliffe et al., 2017; Schmidt et al., 2004). However, the present study has some limitations that should be recognized. First, the person taking the measurements was aware that the subject was either a patient or an asymptomatic control. Second, the rotator cuff interval is not only composed of tendons but also of ligaments, which were not measured in this study.

The presented findings have relevant clinical implications. Based on our results, the tendon thickness cannot explain differences in pain perception, and should not be used as an indicator of shoulder pain-function in chronic conditions. However, changes in tendon thickness after treatments have to be longitudinally analyzed to study its usefulness as an indicator of improvement. Currently, little effort is made to detect the minimum change in shoulder tendon morphology by ultrasound, (e.g. ultrasound quantification(Pozzi et al., 2017), elastography(Lee et al., 2016)) however more studies are needed to correlate such changes with those occurring in pain-function and in cell populations, which have been shown to be altered in tendinopathy conditions leading to chronic degeneration and pain(Dakin et al., 2015; Thomopoulos et al., 2015).Previous work has shown that the elastic properties of the patellar tendon, measured by supersonic shear imaging, are

different between painful and non-painful sides in athletes with unilateral patellar tendinopathy (Zhang et al., 2014). It may be that tendon structural differences are more apparent in younger populations, while no differences occur in older populations or people with chronic pain, however more studies are necessary to explore these hypotheses.

In conclusion, no difference in shoulder tendon thickness was observed between the symptomatic and asymptomatic shoulder in people with chronic unilateral shoulder pain and no difference was observed between these patients and asymptomatic control subjects. Furthermore, the correlations between the thickness of the rotator interval tendons and shoulder pain-function were non-significant. Other tendon properties, such as elastic properties, and cell populations, should be explored in future studies as possible factors than can be altered by the presence of chronic pain.

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