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Original Article

Evaluation of the tissue thickness of the supraspinatus and biceps long head tendons using ultrasound among elderly patients with unilateral adhesive capsulitis in the freezing phase

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Abstract. [Purpose] This study aimed to clarify the changes in the tissue thickness of the abnormal supraspinatus and biceps long-head tendons among elderly patients to select the treatment targets and evaluate the treatment effects in the freezing phase of adhesive capsulitis. [Participants and Methods] Thirty-two elderly patients with unilateral shoulder pain underwent ultrasound of the supraspinatus and biceps long-head tendons, pain evaluation, and orthopedic testing. Both the supraspinatus and biceps long-head tendons were classified as normal, abnormal, and other groups. Participants with negative orthopedic test results were assigned the "normal group". Participants with positive orthopedic test results and resting and night pain were assigned the "abnormal group". Differences in tissue thickness were calculated from the differences between the symptomatic and non-symptomatic sides. [Results] The thickness of the supraspinatus and biceps long-head tendons was significantly higher in the abnormal than in the normal group. [Conclusion] This study clarified the changes in tissue thickness of the abnormal supraspinatus and biceps long-head tendons among elderly patients to select the treatment targets and assess the treatment effects in the freezing phase of adhesive capsulitis. The study results suggest the usefulness of ultrasound for selecting the treatment targets for analgesia and assessing the treatment efficacy in cases of adhesive-capsulitis freezing phase.
Key words: Ultrasonography, Shoulder joint, Thickness difference

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INTRODUCTION

Adhesive capsulitis (AC), frozen shoulder, stiff shoulder, and retractable capsulitis are terms used to refer to the condition of pain and stiffness in the glenohumeral joint to active and passive movements[1)]. AC may arise spontaneously without an obvious preceding cause, or it may be associated with a local or systemic disorder[2)]. The pathophysiological condition with synovitis around the biceps long head tendon (BT), contracture of the rotator interval, inflammation of the subacromial bursa, rupture of the supraspinatus tendon (SST), coraco-humeral ligament thickening, and the anterior capsule, as a combination of synovial inflammation and capsular fibrosis has been described[2–5)]. AC is classified according to three phases as follows: freezing, frozen, and thawing phases. In the freezing phase, pain occurs both during rest and at night; in the frozen phase, pain is almost completely absent at rest, although some pain is experienced at night; and in the thawing phase, pain occurs only during activity and almost no pain is experienced during rest or at night[6)].

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Corticosteroid injections, patient education, therapeutic ultrasound, heat, electroacupuncture, stretching, and joint mobilization have been described for the treatment of AC[7–14]. Interventions used to manage AC are usually tailored to the phase of the condition. Hence, it is important to focus on the early phase and how to relieve the pain[15]. Conservative options, such as education and oral painkillers, injections, and physical therapy, including mobilization, ultrasound examination, acupuncture, heat, laser, and electroacupuncture, were found to be the most common non-surgical treatment options for the early painful phase (the freezing phase) by UK health care professionals[16]. Although physical therapy is often the first line of management for shoulder pain, its efficacy has not been established to date[17]: one of the reasons considered for this phenomenon is that the treatment is performed without selecting the soft tissue that causes the pain. If the soft tissue to be treated is selected, it may be possible to shorten the duration of the complaint by performing appropriate treatment on that soft tissue in the freezing phase of AC.

Magnetic resonance imaging (MRI) is a standard imaging approach for shoulder disorders, and reliable signs of AC on MRI correlate with clinical impairment. However, MRI requires magnetic resonance compatible hardware and a relatively long examination time and has other limitations, including high cost. Arthroscopy provides an accurate assessment of the joint capsule; however, because of its invasive nature, its use is limited for diagnostic purposes. Further, high-resolution ultrasound has been widely used as a suitable imaging option for musculoskeletal problems, as it is noninvasive, inexpensive, and easy to perform bilaterally in specific positions[18]. Several orthopedic tests are available to detect abnormalities in the soft tissue surrounding the shoulder joint. The full can test detects a rupture of the SST[19], the speed test detects a rupture of the BT[20], and the Yergason test detects a lesion of the BT[21]. If the orthopedic test is positive, the soft tissue is suspected to be abnormal. AC causes severe pain due to a type of intra-articular inflammation[22]. The mean joint capsule thickness in patients with AC correlated with pain intensity[23]. The abnormal condition of the soft tissue around the shoulder joint may cause severe pain, including resting and night pain, and the tissue thickness of this abnormal condition of the soft tissue around the shoulder is greater than normal. Based on these facts, this study hypothesizes that the tissue of the abnormal SST and BT is thicker than that of the normal ones on ultrasonography. In the freezing phase of AC, if the tissue causing severe pain can be detected by ultrasonography, it is possible to select the treatment target for pain relief and objectively judge the treatment effect on the tissue. Ultrasonography of patients with AC has shown changes in tissue thickness of the coracohumeral ligament, inferior capsule, inferior glenohumeral ligament, and rotator interval[18, 24–26]. These reports do not presuppose selection of treatment targets or judge treatment effect. This study aimed to clarify the change in tissue thickness of abnormal SST and BT in the elderly to select treatment targets and evaluate the treatment effect in the freezing phase of AC.

PARTICIPANTS AND METHODS

This observational cross-sectional study was conducted following the requirements of "The Strengthening the Reporting of Observational Studies in Epidemiology" (STROBE)[27]. This study was conducted after obtaining approval from the Research and Safety Ethics Committee of the Tokyo Metropolitan University, Arakawa Campus (approval number: 14014). It was conducted in accordance with the Declaration of Helsinki. The participants' verbal and written informed consents were obtained before their inclusion in the study. The study population comprised 32 elderly patients (8 males, 26 females) aged between 69 and 79 years, and data were collected between August 2017 and March 2018. The inclusion criteria were participants who reported shoulder pain and stiffness of more than one month's duration, with localized pain over one shoulder. In contrast, the exclusion criteria included a history of fractures of the proximal humerus, clavicle, or scapula; traumatic anterior shoulder dislocation; acromioclavicular joint dislocation; rheumatoid arthritis; shoulder-arm syndrome; peripheral neuropathy due to cervical spine lesions; central nervous system disorder; calcific tendonitis; rotator cuff tears; and rupture of BT. The test was administered using ultrasound examination equipment (examiner A; EUB-7500, Hitachi Medical, Tiyoda-ku, Tokyo, Japan) (examiner B; Noblus, Hitachi Aloka Medical, Mitaka-shi, Tokyo, Japan), with a 10-MHz linear probe. The probe was held perpendicular to the skin surface, which was gently touched to avoid pressing the muscles. Two examiners performed the ultrasonographic evaluations. Examiner A is a physical therapist with 15 years of clinical experience and a history of 50 cases involving ultrasound examinations of the shoulder joints in clinical practice. Examiner B is an orthopedic surgeon with 20 years of clinical experience and a history of 30 cases involving ultrasound examinations of the shoulder joints in clinical practice. Tissue thickness was evaluated using the ultrasonic device in the SST (long axis) and BT (short axis). The ultrasound image was projected on the device monitor, without setting landmarks on the body. The imaging method was performed according to the methods previously described by Ohya et al[28]. During SST and BT imaging, the participants were instructed to sit on a chair with the arm in a neutral position. SST imaging (long axis) was performed by placing the probe near the center of the acromion, parallel to the spine of the scapula. In BT imaging (short axis), the probe was moved up and down around the intertubercular groove and applied at the site where the nodule was trapezoidal and the subscapularis muscle was visible. In each participant, the measurement was performed twice for each tissue by the same examiner. Further, the tissue thickness of the SST and BT was measured using Image J image analysis software (United States National Institutes of Health, Bethesda, MD, USA), and the measurements were performed using the approach described by Ohya et al[28]. A vertical line was drawn from the initial change point of the inclination from the apex of the greater tubercle attachment with the SST, and the thickness of this line was considered the SST thickness (Fig. 1a). In contrast, the thickness in the direction perpendicular to the center of the intertubercular groove was defined as the BT

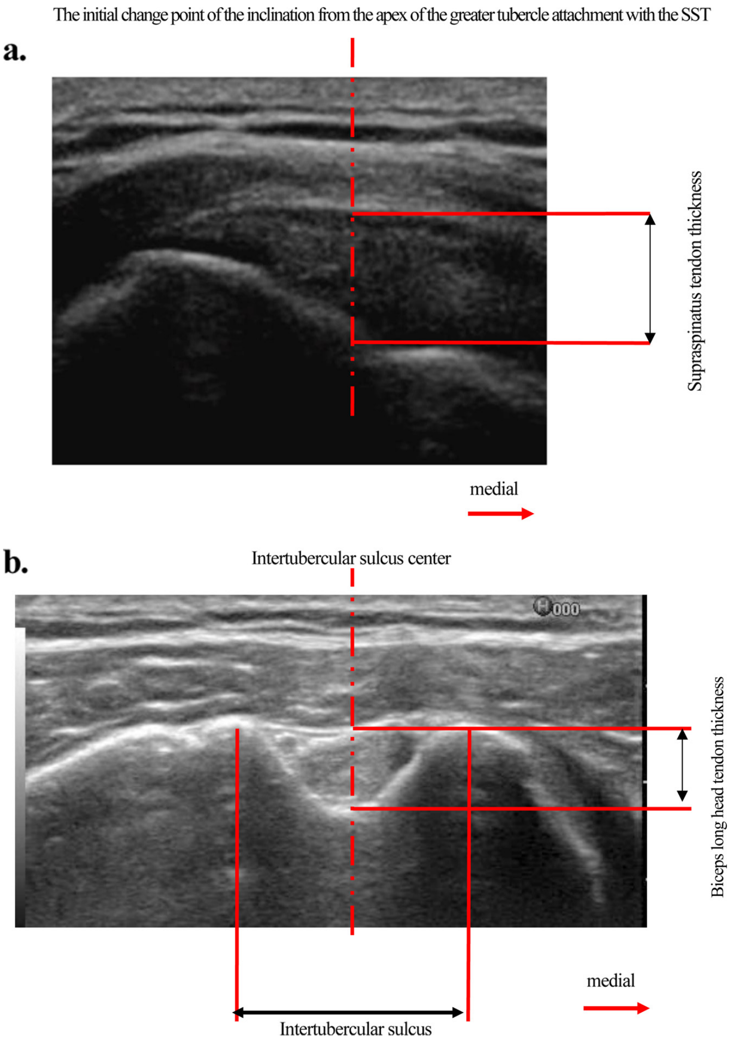

Fig. 1. Ultrasound measurement of thickness. a. Measurements of the thickness (black arrows between the red sections) of the supraspinatus tendon (SST); b. Measurement of the thickness (black arrows between the red sections) of the biceps long head tendon.

thickness (Fig. 1b). All measurements were performed by the same examiner who conducted the image acquisition. The pain test measured resting and night pain using the visual analog scale (VAS). The orthopedic tests included the full can and drop arm tests for the evaluation of the SST and Speed's and Yergason's tests for the BT.

Statistical analyses were performed using the Statistical Package for the Social Sciences software for Windows, version 23 (IBM Corp., Armonk, NY, USA). The statistical significance level was set at $p<0.05$. The mean values (standard deviations [SDs]) were used for descriptive statistics of continuous data, while numbers were used for initial values, which were discrete data. The relative reliability of evaluations of the thickness of SST and BT by ultrasonography was examined using the intraclass correlation coefficient (ICC)[29]. The Bland–Altman analysis was performed by plotting the mean ($\bar{d}$) of the differences between the two measurements against their mean (d). This method is used to ascertain the presence of systematic errors in measured values, visually or statistically[30–32]. The standard error of measurement (SEM) and minimum detectable change (MDC) were calculated. The MDC values were calculated as MDC_{95}, which is the 95% confidence interval (CI) of the MDC[33–37].

The participants were classified into the normal group, abnormal group, and others. If both orthopedic tests were negative, they were assigned to the "normal group". Further, participants whose one or more of the orthopedic tests was positive and those who had resting and night pain were assigned to the "abnormal group". Those who tested positive in one or more of the orthopedic tests and did not have resting and night pain were assigned to the "other" category (Fig. 2a, b). In this study, participants with resting and night pain were treated as corresponding to the freezing phase of AC. The thickness differences were calculated as the difference between the symptomatic and non-symptomatic sides. As the sample's normality and equal variance had been confirmed, the Student's t-test was used to assess the differences in tissue thickness of the SST and BT between the abnormal and normal groups. A p-value ≤0.05 was considered statistically significant.

RESULTS

The abnormal group included the following:—SST: 12 participants (6 evaluated by examiner A and 6 by examiner B); and BT: 8 participants (3 evaluated by examiner A and 5 by examiner B). The normal group included the following—SST: 14 (10 evaluated by examiner A and 4 by examiner B); and BT: 21 participants (14 evaluated by examiner A and 7 by examiner B) (Table 1).

The ICC (1.1) of SST thickness was 0.99 (95% CI, 0.95–0.99) for examiner A and 0.98 (95% CI, 0.95–0.99) for examiner B. Conversely, the ICC of BT thickness was 0.98 (95% CI, 0.96–0.98) for examiner A and 0.96 (95% CI, 0.92–0.98) for examiner B.

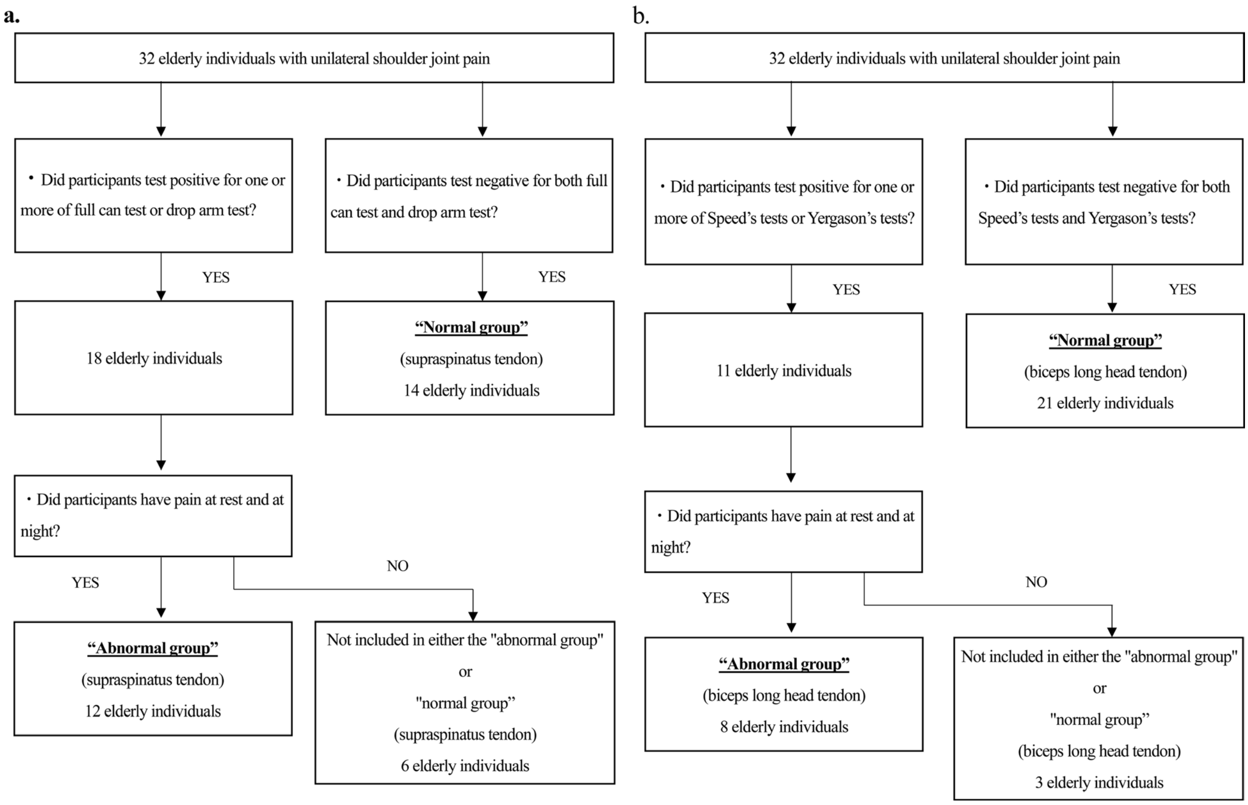

Fig. 2. Grouping of the abnormal and normal groups. a. Grouping of the supraspinatus tendon cases; b. grouping of the biceps long tendon cases.

Table 1. Characteristics of the participants

Tissue assessed	Group	Examiner	Participants	Average age (years)
Supraspinatus tendon	Abnormal group	Examiner A	6	75.7 ± 3.2
		Examiner B	6	70.7 ± 3.9
		Total	12	73.2 ± 4.3
	Normal group	Examiner A	10	77.2 ± 9.2
		Examiner B	4	75.3 ± 1.7
		Total	14	76.6 ± 7.8
Biceps long head tendon	Abnormal group	Examiner A	3	75.7 ± 4.5
		Examiner B	5	74.2 ± 1.6
		Total	8	74.8 ± 2.8
	Normal group	Examiner A	14	76.6 ± 7.6
		Examiner B	7	68.4 ± 4.2
		Total	21	73.9 ± 7.7

Errors can be broadly divided into systematic and accidental. Accidental errors are further sub-divided into biological differences between individuals and measurement errors (occurring during measurement), with the SEM tests revealing the absolute reliability of the measurement error. The SEM values for SST and BT thicknesses were 0.02 and 0.04 mm, respectively, for examiner A and 0.04 and 0.05 mm, respectively, for examiner B. The MDC_{95} values for SST and BT thicknesses were 0.06 and 0.11 mm, respectively, for examiner A and 0.11 and 0.14 mm, respectively, for examiner B. In this study, the results of the Bland–Altman plot analysis indicated that 95% CI of ($\bar{d}$) values for the SST and BT thicknesses included zero elements.

The thickness difference between the symptomatic and non-symptomatic sides in the SST and BT was 0.68 (SD 0.14) and 0.56 (SD 0.15) mm, respectively, in the abnormal group and 0.06 (SD 0.12) and 0.01 (SD 0.12) mm, respectively, in the normal group. Both thickness differences between the symptomatic and non-symptomatic sides in the SST and BT were found to be significantly higher in the abnormal group than in the normal group ($p<0.01$; Table 2).

DISCUSSION

This study clarified the change in tissue thickness of abnormal SST and BT in the elderly to select treatment targets and evaluate the treatment effect in the freezing phase of AC. In this study, ultrasound measurements of the SST and BT thickness were highly reproducible, with high relative and absolute reliabilities and small measurement error. Moreover, no systematic errors were found. Both thickness differences between the symptomatic and non-symptomatic sides in the SST and BT were significantly larger in the abnormal group than in the normal group.

In this study, the ultrasonography evaluation was conducted on the device monitor, without setting landmarks on the body. In previous studies[28, 38, 39)] conducted using the same method, the relative and absolute reliability of the SST and BT thickness by ultrasonographic evaluations were both good. The method of measuring the tissue thickness of the SST and BT by ultrasonography used in this study appeared to be a reliable measurement method. It is suggested that degenerative changes commonly occur in the supraspinatus because the blood supply of this tendon is irregular and that ruptures and calcification of the tendon occur due to local cell death secondary to decreased blood supply[40)]. Anatomically, the BT enters the glenohumeral joint through the intertubercular groove of the humerus and passes under the rotator interval, which is the resistance attenuation part of the rotator cuff. The BT is extremely vulnerable to age-related factors after middle age, and inflammation onset from the BT is thought to easily spread to adjacent areas. An MRI study of AC revealed a high rate of effusion in the BT sheath[41)]. According to these facts, the SST and BT are tissues that are likely to be in an anatomically abnormal state. A previous study of SST ultrasonography reported that the thickness of the SST in patients with AC was not significantly different from that of the control group (patients of the same age with no shoulder-related complaints)[42)]. In a previous study[42)], patients with AC of the three phases (freezing, frozen, and thawing) were mixed; thus, it is considered that the results were different from those in this study. Patients with AC underwent ultrasonography. Compared with unaffected shoulders, the frequency of increased tissue thickness at the rotator interval and BT effusion in the affected shoulders was found to be higher in the freezing phase than in the frozen and thawing phases[18)]. An MRI study showed that the shoulder joint capsule thickness in the humeral portion of axillary recess was positively correlated with the intensity of pain[23)]. Especially in the freezing phase, which is a severe pain phase of AC, the thickness of the SST and BT in this abnormal state is considered to increase more than that in the normal state and in the asymptomatic side. Based on these facts, the result that the thickness difference of the SST and BT of the abnormal group corresponding to the freezing phase of AC was significantly larger than that of the normal group in this study was valid.

In terms of physical therapy research on AC, treatment targets remain unclear, and very few studies have clearly identified treatment targets[9, 10, 13, 43)]. In this study, the finding that the cause of resting and night pain in the freezing phase of AC may be related to the abnormal condition of the SST and BT diagnosed by ultrasonography appears to be important. If the change in measurement is greater than the MDC_{95}, the true change between repeated measurements can be inferred. In the freezing phase of AC, if the difference in tissue thickness between the symptomatic and non-symptomatic sides of the SST and BT

Table 2. Differences in tissue thickness between the abnormal and normal groups

Name of tissue	Group	Number of participants	Difference in tissue thickness (mm)	p
Supraspinatus tendon	Abnormal group	12	0.68 ± 0.14	*
	Normal group	14	0.06 ± 0.12	
Biceps long head tendon	Abnormal group	8	0.56 ± 0.15	*
	Normal group	21	0.01 ± 0.12	

*$p<0.01$, $p \leq 0.05$ is statistically significant.
"Abnormal group": This comprised participants with positive results in one or more of the orthopedic tests and who had resting and night pain.
"Normal group": This comprised participants with negative results in both orthopedic tests.
The differences in tissue thickness were calculated as the difference between the symptomatic and non-symptomatic sides.

by ultrasonography is ≥MDC_{95}, it is considered that the SST and BT may be treatment targets. In the freezing phase of AC, if the difference in tissue thickness of the SST and BT before and after treatment is ≥MDC_{95}, it would appear that there is a treatment effect.

There are three important limitations to this study. First, the tissue that is abnormal due to AC and is causing pain includes not only the SST and BT, but also the capsule, coracohumeral ligament, and subacromial bursa[2–5]. In this study, the thickness of the SST and BT by ultrasonography was only significantly larger in the abnormal group than in the normal group. It has only been shown that it may be involved in pain in the freezing phase of AC. In the future, it will be necessary to verify whether changes in thickness are involved in the pain in the freezing phase of AC for the capsule, coracohumeral ligament, and subacromial bursa. Second, the age composition of participants in this study was 69–79 years, which is different from the target age of 40–65 years for AC, as indicated by the American Physical Therapy Association[44]. The SST has been shown to increase tissue thickness with age[42, 45, 46]. However, since both the normal and abnormal groups included individuals aged 69–79 years, it appears that the results also apply to the generalized model of individuals aged 40–65 years. Third, our findings suggest that measuring the tissue thickness of the SST and BT via ultrasound is useful in selecting treatment targets for analgesia as well as assessing the treatment efficacy in the freezing phase of AC. However, this was not assessed clinically in our study; therefore, further studies are warranted to establish the appropriate use of ultrasonography for patients in the freezing phase of AC.

In conclusion, the difference in thickness between the symptomatic and non-symptomatic sides in the SST and BT was significantly larger in participants enrolled in the abnormal group than in those enrolled in the normal group. The study results suggest the usefulness of ultrasonography in selecting treatment targets for analgesia and assessing the treatment efficacy in the freezing phase of AC.

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There are no sources of funding and conflicts of interest to be disclosed in this study.

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