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Original Article

Relative and absolute reliability of ultrasound measurements for the thickness of the soft tissue around the shoulder joint of young normal subjects

Nobuhisa Ohya, MS[1)*], Takumi Yamada, PhD[2)], Yoshinao Satoh, MS[3)], Hirobumi Kawamura, PhD[4)]

[1)] *Shonan University of Medical Sciences: 16-48 Kamishinano, Totsuka-ku, Yokohama-shi, Kanagawa 244-0806, Japan*
[2)] *Tokyo Metropolitan University, Japan*
[3)] *Tokyo Metropolitan Rehabilitation Hospital, Japan*
[4)] *Konan Women's University, Japan*

Abstract. [Purpose] The purpose of this study was to examine the reliability of ultrasound measurements by analyzing the relative reliability and absolute reliability when measuring soft tissue thickness around the shoulder joint. [Subjects and Methods] Eleven healthy young adults (22 shoulders) participated in this study. Thickness of the supraspinatus tendon, subacromial bursa, and biceps tendon was measured on both shoulders. This protocol was performed twice in the same day. The relative reliability of ultrasound measurement was evaluated using the intraclass correlation coefficient for determining the degree of consistency and agreement between two measures. The absolute reliability of the ultrasound measurement was evaluated using the standard error of measurement, minimum detectable change, and Bland-Altman analysis. [Results] Ultrasound measurements exhibited high relative reliability: intraclass correlation coefficients for the supraspinatus tendon, subacromial bursa, and biceps tendon thickness were demonstrated to be 0.91, 0.82, and 0.90, respectively. Bland-Altman analyses revealed no significant systematic bias between the repeated measurements for the supraspinatus tendon, subacromial bursa, and biceps tendon thickness. [Conclusion] These findings suggest that ultrasound measurement for the supraspinatus tendon, subacromial bursa, and biceps tendon thickness exhibited good relative reliability and no systematic errors were detected regarding their absolute reliability.

Key words: Supraspinatus tendon thickness, Subacromial bursa thickness, Biceps tendon thickness

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INTRODUCTION

Adhesive capsulitis can be classified into three phases: freezing, frozen, and thawing. Patients with the freezing phase are predominantly treated by drug therapy or injection therapy, or both. In many cases, patients experience imperfect treatment effects, which lead to prolonged disease duration of adhesive capsulitis. Binder et al. reported that 40% of adhesive capsulitis patients who had surpassed the average of 44 months from onset experienced residual symptoms[3)]. Hand, et al. reported that 41% of adhesive capsulitis patients who had surpassed the average of 4.4 years from onset experienced either pain or disability in completing daily activities[1)]. The duration of adhesive capsulitis can be shortened by early initiation of therapy after the cause of disease is identified by a physical therapist.

*Corresponding author. Nobuhisa Ohya (E-mail: nobuhisa.ohya@sums.ac.jp)

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The mechanism of onset of adhesive capsulitis remains controversial. Slide disorder in the second shoulder joint, slide disorder of the biceps tendon (BT) in the intertubercular sulcus, and rotator interval disorder have been associated with its onset[2, 4]. Soft tissues, such as the supraspinatus tendon (SST), subacromial bursa (SAB), and BT are thought to be associated with the onset of adhesive capsulitis. For effective treatment of adhesive capsulitis, a physical therapist must objectively evaluate the condition of the soft tissue that caused the disease. The main effect of treatment for the freezing phase of adhesive capsulitis is evaluated by pain, as the condition of the soft tissue that caused this disease cannot be objectively evaluated. Arthrography, computed tomography, magnetic resonance imaging (MRI), and ultrasonography can be used to objectively evaluate the condition of a patient and the effect of treatment. In particular, ultrasonography can be used to simply and immediately scan soft tissue. The spatial and temporal resolution of this technique over a small range is superior to that of MRI in measuring soft tissue. When using ultrasonography to assess adhesive capsulitis patients, detecting subacromial bursitis in the early period of the disease is important. Similarly, it is important to observe the internal structures of the rotator cuff, BT, and tendon synovial sheath[5]. Many studies have reported the use of ultrasonography in adhesive capsulitis patients for the assessment of qualitative changes and diagnosis[6–8]. However, few of them have attempted to use this technique to assess treatment effects in adhesive capsulitis patients[9].

SST thickness of the critical zone on ultrasonography was different between the painful side and the non-painful side in patients with adhesive capsulitis[10].Tendon swelling is interpreted as a focal or more often diffuse increase in tendon thickness[8]. During the freezing phase in adhesive capsulitis patients, swelling can be observed via ultrasonography as an increase in soft tissue thickness. A small number of studies have evaluated the use of ultrasonography to measure the thickness of soft tissue around the shoulder joint. SST thickness[11–15], supraspinatus muscle belly thickness[16], SAB thickness[17], and BT thickness[14, 15] have been investigated. The reliability of ultrasound measurements has been reported by many studies, including those measuring lumbar multifidus thickness[18] and the distance of the interval between the tibia and femur[19]. However, few studies have examined the reliability of ultrasonography measurements of soft tissue thickness around the shoulder joint[12–14]. The reliability of these measurements has typically been examined by the intraclass correlation coefficient (ICC). ICC assesses relative reliability but cannot examine absolute reliability that defines the quantity of the measurement errors[20]. Absolute reliability indicates how much dispersion and error the measurement contains. Errors can be classified into systematic bias or random error. Test and inferential statistics can be nullified by systematic bias that occurs during the planning or study phases. Bland-Altman analysis is one of the methods used to confirm the presence of systematic bias, and assess the details by examining the quantity and type of error between two measurements[21]. A random error can be classified as biological variation or a measurement error. The random error of the absolute reliability is examined by standard error of measurement and minimal detectable change.

The present study was performed to measure the thickness of the soft tissue around the shoulder joint of young normal subjects by ultrasonography. In addition, the reliability of these measurements was examined by assessing relative and absolute reliability.

SUBJECTS AND METHODS

Eleven students were recruited from a technical school and a university physical therapy course. All participants declared their right hand as dominant, and the mean age was 22.8 ± 2.7 years (means ± SD). Exclusion criteria were as follows: shoulder joint pain, humeral proximal edge bone fracture, clavicle bone fracture, shoulder blade bone fracture, traumatic shoulder joint front dislocation, acromioclavicular joint dislocation, rheumatoid arthritis, shoulder arm syndrome, cervical spine lesion, peripheral neuropathy due to diabetes, central nerve obstacle, calcific tendinitis, rotator cuff tear, a BT tear, and shoulder impingement syndrome. Written informed consent was provided by all participants. Ethical approval was obtained from the Faculty of Health Sciences of Tokyo Metropolitan University (14014).

Soft tissue thicknesses were scanned by one physical therapist. The examiner had fifteen years of clinical experience including 30 cases of ultrasonography. SST (major axis) and BT (minor axis) were scanned twice in both shoulders by ultrasonography. The thickness of SST and SAB was measured from the SST (major axis) image. Ultrasonography for the same subject was performed on the same day. A second ultrasound of SST, SAB, BT was performed at intervals of about 1 minute after the first scan.

Ultrasonography was performed using a Hitachi EUB-7500 ultrasound machine with an 8–12 MHz linear transducer. SST was scanned with subjects in a sitting position. The subject's head was in the neutral position, with shoulders and elbow in the neutral position and full extension, respectively. The transducer was placed parallel to the scapular spine. Subsequently, the proximal transducer was placed on the acromion, and the distal transducer was placed on the superior facet (SF) of the greater tubercle (Fig. 1A). BT was scanned with subjects in a sitting position. The subject's head was in the neutral position, with shoulders and elbow in the neutral position and full extension, respectively. The transducer was placed in the intertubercular sulcus. Subsequently, the transducer was moved up and down to the position at which the subscapularis muscle appears (Fig. 1B). Each soft tissue thickness measurement of SST, SAB, and BT was analyzed using ImageJ analysis software (National Institutes of Health, Bethesda, MA, USA). Measurements of soft tissue thickness around the shoulder joint are often analyzed for the maximum of each thickness[13–15]. Soft tissue thickness was analyzed by the succeeding methods in the present study because previous studies were vague[13, 14]. SST and SAB thicknesses were measured as the perpendicular line distance from

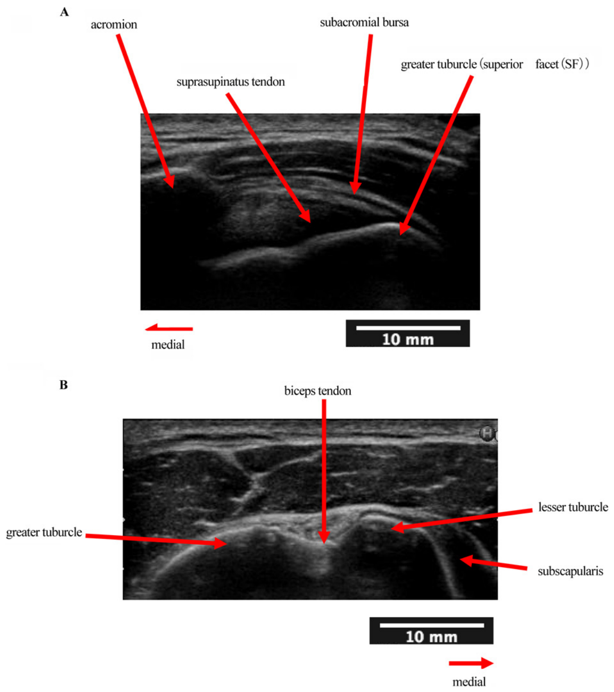

Fig. 1. Image by ultrasonography
(A) Image of a supraspinatus tendon and a subacromial bursa by ultrasonography. The transducer was placed parallel on the scapular spine. Then proximal transducer was placed the acromion, distal transducer was placed the superior facet (SF) of the greater tubercle.
(B) Image of a biceps tendon by ultrasonography. The transducer was placed the intertubercular sulcus. Then the transducer was moved up and down to the place where subscapularis muscle appears.

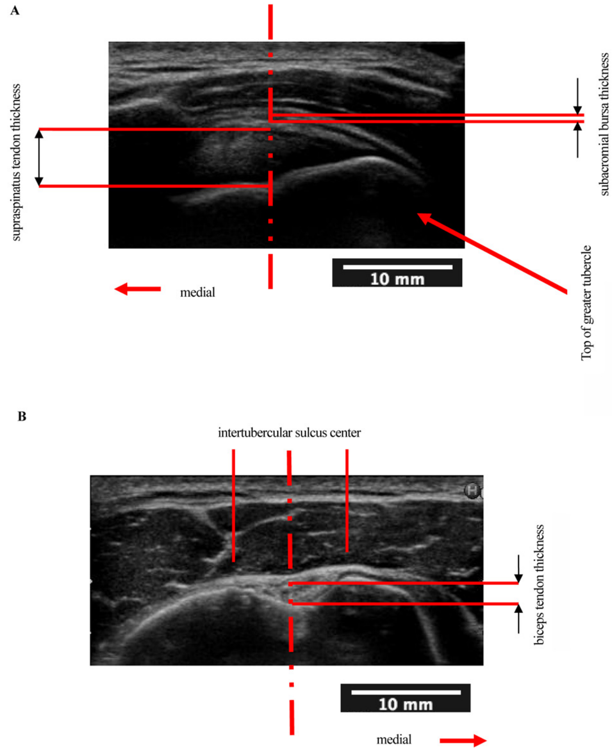

Fig. 2. The ultrasound measurement of thickness
(A) The ultrasound measurement of the supraspinatus tendon (SST) thickness, the subacromial bursa (SAB) thickness. SST, SAB thickness was measured for perpendicular line distance from the first change point of the inclination angle from the top of the greater tubercle.
(B) The ultrasound measurement of the biceps tendon (BT) thickness. BT thickness was measured for perpendicular line distance from the intertubercular sulcus center.

the first change point of the inclination angle from the top of the greater tubercle (Fig. 2A). BT thickness was measured according to the perpendicular line distance from the intertubercular sulcus center (Fig. 2B). SST, SAB, and BT thicknesses were measured by the assessors themselves.

Statistical analyses were conducted with IBM SPSS 17.0 statistics software. Level of statistical significance was set at 0.05. Descriptive statistics were presented as the mean (standard deviation) for continuous data and as numbers for discrete baseline characteristics.

The relative reliability of the ultrasound measurements of SST, SAB, and BT thickness was determined by calculating the ICC[22]. An ICC of >0.80 indicated great to good reliability, 0.70–0.79 indicated normal reliability, and <0.60 indicates re-work reliability[23].

Systematic bias was assessed by Bland-Altman analysis[21, 22]. Bland-Altman analysis was constructed by plotting the test-retest difference ($\bar{d}$) for two measurements versus the test-retest mean for two measurements. Bland–Altman analysis indicates the presence or absence of systematic bias in a visual and statistical manner[22, 25, 26]. The 95% confidence interval (CI) of mean difference ($\bar{d}$) of two measurements, which was used to determine the presence of systematic bias, was calculated as follows[22, 25–27]:

$$95\%\ \text{CI of } d = \bar{d} \pm t\sqrt{(SD\,\bar{d}^{\,2}/n)}$$

where SD $\bar{d}$ is the standard deviation for all the observations from test sessions 1 and 2, n is the sample size, and t is the value obtained from the t-table with degrees of freedom. If 0 is included within the 95% CI, no significant systematic bias between the measurements can be inferred[24–26]. When a systematic error was not recognized, standard error of measurement (SEM) and minimal detectable change (MDC) were calculated. SEM was calculated as follows[26–28]:

$$SEM = SD\,\bar{d} \times \sqrt{(1-ICC)}$$

Table 1. Characteristics of the participants

Characteristic	Participants
Gender	
Male	7
Female	4
Age (years)	22.8 ± 2.7
Supraspinatus muscle tendon thickness	
Right (mm)	4.73 ± 0.8
Left (mm)	4.47 ± 0.6
Subacromial burse thickness	
Right (mm)	0.66 ± 0.3
Left (mm)	0.66 ± 0.2
Biceps tendon thickness	
Right (mm)	2.21 ± 0.6
Left (mm)	2.31 ± 0.6

Table 2. Relative and absolute reliability of a supraspinatus tendon, an subacromial bursa, a biceps tendon by ultrasound measurement (n=22)

Soft tissue	ICC (95%CI)	SEM	MDC_{95}	Bland-Altman Analysis		
				d	SDd	95%CI of d
SST	0.91 (0.80–0.96)	0.09	0.26	0.07	0.31	−0.07–0.21
SAB	0.82 (0.63–0.92)	0.07	0.18	0.03	0.16	−0.04–0.10
BT	0.90 (0.79–0.96)	0.08	0.23	0.01	0.26	−0.10–0.13

ICC: Intraclass Correlation Coefficient; 95%CI: 95% confidence interval; SEM: standard error of measurement; MDC: Minimal Detectable Change; MDC_{95}: 95%CI of MDC; SST: supraspinatus tendon; SAB: subacromial bursa; BT: biceps tendon

The MDC is calculated as MDC, which is the CI of 95% of the MDC. MDC_{95} was calculated as follows[19, 27–30]:

$$MDC_{95}=SEM \times 1.96 \times \sqrt{2}$$

The MDC indicates the limit area that the amount of change in repeated two measurements results from measurement error[29]. If the change of measurement is within MDC, the measurement error between repeated measurements can be inferred. If the change of measurement is greater than MDC, the true change between repeated measurements can be inferred[30].

RESULTS

Detailed characteristics of the participants and the soft tissue thickness around the shoulder joint are shown in Table 1. SST thickness values were as follows: right, 4.73 ± 0.8 mm and left, 4.47 ± 0.6 mm. SAB thickness values were as follows: right, 0.66 ± 0.3 mm and left, 0.66 ± 0.2 mm. BT thickness values were as follows: right, 2.21 ± 0.6 mm and left, 2.31 ± 0.6 mm.

The results of the relative reliability of SST, SAB, and BT thickness are shown in Table 2. The relative reliability of SST, SAB and BT thickness was rated as excellent (ICC=0.91; 95% CI=0.80–0.96), good (ICC=0.82; 95% CI=0.63–0.92), and excellent (ICC=0.90; 95% CI=0.79–0.96), respectively.

The results of the absolute reliability of SST, SAB and BT thickness are shown in Table 2. The 95% CIs of SST, SAB, and BT thickness were −0.07–0.21, −0.04–0.10, and −0.10–0.13, respectively. SEMs of SST, SAB, and BT thickness were 0.09, 0.07, and 0.08, respectively. $MDCs_{95}$ of SST, SAB, and BT thickness were 0.26, 0.18, and 0.23, respectively.

DISCUSSION

In the present study, standard methods were used to evaluate the relative and absolute reliability of ultrasound measurements of SST, SAB, and BT thickness. Ultrasound measurements in the present study exhibited good relative and absolute reliability, demonstrating a high degree of agreement between the 1st and 2nd measurements, small measurement error, and lack of systematic bias.

Establishing the reliability of a tool for the adequate measurement of SST, SAB, and BT thickness is an essential prerequisite before the tool is adopted as a standard measurement in patients with acute adhesive capsulitis.

The ICCs of SST, SAB, and BT thickness were 0.91, 0.82 and 0.90, respectively. When relative reliability was evaluated using the criteria outlined by Kuwahara et al., SST, SAB, and BT thickness were rated as good to great[23]. Therefore, the relative reliabilities of ultrasound measurement for SST, SAB, and BT thickness were demonstrated to be high. Our data for SST thickness were consistent with values reported in previous studies. Supraspinatus (tendon) thickness data from a healthy adult (ICC=0.91; 95% CI=0.80–0.97)[16] and a university student from Hong Kong (ICC=0.92; 95% CI=0.90–0.98)[12] indicated excellent reliability. In the present study, a detailed landmark was not set when scanning SST, SAB, and BT via ultrasonography. By contrast, in previous studies, the supraspinatus (tendons) was scanned after a landmark was set[13, 17]. SST and infraspinatus tendons are in close proximity to the greater tubercle of the humerus. Therefore, when SST was scanned alone by ultrasonography, it was necessary to scan on the SF of the greater tubercle. If a detailed landmark was set before scanning SST via ultrasonography, it was very difficult to scan the SF of the greater tubercle. The shoulder joint consists of plural joints, including the glenohumeral, acromioclavicular, sternoclavicular, and scapulothoracic joints. It is difficult to attain the same alignment of the shoulder joint in all subjects. Therefore, the SST on the SF of the greater tubercle was scanned via the monitor of the ultrasonography device. The result of relative reliability in the present study demonstrated good relative reliability; therefore, it is thought that the ultrasound measurement by the method of this study was effective.

Bland-Altman statistics for the ultrasound measurement of SST, SAB, and BT thickness indicated no significant systematic bias between the repeated measurements. The mean differences between the two testing sessions were all close to 0 and the 95% CI included 0. It is difficult to resolve a systematic bias by repeated measurements under the same conditions. Test and inferential statistics are nullified by a systematic error that occurs during the study planning and experimental phases[31]. The present study had no significant systematic bias. SEM and MDC_{95} assess measurement errors between repeated measurements and determine whether changes occur between these repetitions. In the present study, the $MDCs_{95}$ of SST, SAB, and BT thickness were 0.26, 0.18, and 0.23, respectively. If the changes in repeated measurements for SST, SAB, and BT thickness were >0.26, 0.18, and 0.23 mm, respectively, the change was real within the 95% CI. Acute adhesive capsulitis patients experience swelling at the onset. A treatment effect may be indicated if the changes in SST, SAB, and BT thickness, as detected by ultrasound measurement, were more than the MDC_{95} values for acute adhesive capsulitis patients. The results of reliability testing in the present study showed that ultrasonography may be a useful measurement tool for assessing the condition of acute adhesive capsulitis patients and the effects of treatment. Ultrasonography has many advantages, including the ability to scan soft tissue simply and immediately. Therefore, we suggest that physical therapists evaluate acute adhesive capsulitis patients via ultrasound measurements to determine the severity of their condition and assess treatment effects. As a result, the disease duration of adhesive capsulitis patients may be reduced.

The present study had some limitations. First, the validities of the measurement for SST, SAB, and BT thickness were not examined. These should be examined by another measurement system, such as MRI. Second, the small number of participants adversely affected the power of the study. Finally, this study only evaluated healthy young adults. The final objective of the present study is to form a standard ultrasound measurement in patients with acute adhesive capsulitis. As the majority of patients with adhesive capsulitis are elderly, the reliability of ultrasound measurements should be examined in elderly individuals in the future.

The present study examined the reliability of ultrasound measurement for the SST, SAB, and BT thickness. The results demonstrated that the relative reliability of these measurements ranges from good to great, and a systematic error was not detected in absolute reliability testing. These examinations of reliability suggest that it is possible to use ultrasound measurements as an evaluation for the condition of acute adhesive capsulitis patients and to assess treatment effects.

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