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Reliability of ultrasound measures of supraspinatus tendon thickness and subacromial space in judo athletes

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A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background & Study Aim: Ultrasound examination above the shoulder is important in musculoskeletal investigation disorders, i.e. rotator cuff impingement syndrome. Monitoring and diagnostics of shoulder injuries in judo may decrease the development of new injuries and improve the quality of training. The aim of this study was the intra-rater reliability of characteristic ultrasonography measurements of supraspinatus tendon thickness and subacromial space.

Material & Methods: Intra-rater testing was performed on 10 physiotherapy students participated in judo class (mean age 24 years). Sonography was performed using a Honda HS 2200 ultrasound scanner with a 7.5-12.5 linear array transducer (Honda, Japan). Ultrasound images were captured of (1) supraspinatus tendon thickness in short (2) and long (3) axis and (4) subacromial space. Two images were captured, by a single examiner, and then the measurements were analysed on the same images by the same examiner. Interclass correlation coefficient $ICC_{3,2}$ was used to determine the intra-rater reliability of the tendon thickness and subacromial space variables. Measurement error was calculated with the standard error of measure. The minimal detectable change (MDC_{90}) represents the error when a measure was taken twice (change over time).

Results: Intra-rater reliability and error for short axis was ($ICC_{3,2} = 0.989$; SEM = 0.03; $MDC_{90} = 0.10$), long axis ($ICC_{3,2} = 0.980$; SEM = 0.06; $MDC_{90} = 0.17$) of supraspinatus tendon thickness and subacromial space ($ICC_{3,2} = 0.997$; SEM = 0.03; $MDC_{90} = 0.09$). Supraspinatus tendon thickness in short and long axis and subacromial space demonstrated very good reliability when taken by a single examiner. The measurement error in ultrasound measurements is very low.

Conclusions: Ultrasound examination above the shoulder is important in investigation musculoskeletal disorders, i.e. rotator cuff impingement syndrome. Monitoring and diagnostics of shoulder injuries in judo may decrease the risk of new injuries and improve the quality of training. With obtained results, we confirmed the very good reliability and very low measurement error for ultra-sonography performed by the physical therapist.

Keywords: combat sport • musculoskeletal • rehabilitation • shoulder

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Magnetic resonance image scan – *noun* full form of MRI scan [27].

Tissue – *noun* a type of substance that the body is made up of, e.g. skin, muscle or nerves [27].

Tendon – *noun* a sinew or strand of strong connective tissue that attaches a muscle to bone [27].

Pain – *noun* the feeling of severe discomfort that a person has when hurt (NOTE: Pain can be used in the plural to show that it recurs: *She has pains in her left leg.*) [27].

Injure *verb* to hurt someone or a part of the body [27].

Injury *noun* damage or a wound caused to a person's body [27].

Chronic – *adjective* 1. used for describing a disease or condition that lasts for a long time. Compare acute 2. used for describing severe pain [27].

INTRODUCTION

There are many different methods to measure supraspinatus tendon thickness and subacromial space. The measurement can be made by computed tomography, X-rays, magnetic resonance imaging, or ultrasound. Ultrasound is a proven method for examining soft tissues structures, including tendons. It is a well-established, non-invasive and radiation-free method. Azzoni et al. [1] in their research showed that sonographic measurements of subacromial space are very close to those obtained by X-ray.

One of the common musculoskeletal disorders, especially in upper limb region, is shoulder impingement syndrome. Rotator cuff tears are very common and account for an economic burden of $3 to $5 billion per year in the United States [2]. Neer [3] described the syndrome as a mechanical impingement of the rotator cuff tendons beneath the anterior-inferior portion of the acromion occurring when the shoulder is placed in the forwardly flexed and internally rotated position [4]. Most of the patients with shoulder pain show a particular morphology of the anterior prominence of the acromion that reduces the subacromial space [1]. Changes in the size of subacromial space can be a sensitive marker of the rotator cuff dysfunction [5].

In 1972 Neer [3] described II stage of shoulder impingement syndrome concerning supraspinatus tendonitis. He explained that impingement of the supraspinatus leads to supraspinatus tendonitis, what can be caused by intrinsic factors, which is a result of rotator cuff overload and muscle imbalance [6]. Leong et al. [7] pointed that patients with shoulder impingement have significantly thicker supraspinatus tendon. Joensen et al. [8] also found that supraspinatus tendon is thicker in patients with a shoulder impingement, but Cholewinski et al. [5] gave reverse thesis and found that supraspinatus tendon is thinner. This is still not explained, and it needs further research. However many studies indicate the issue of the acromiohumeral distance and most of them showed that subacromial space is smaller in those with subacromial impingement syndrome [1, 4].

Although ultrasound measurement is one of the most common used to detect this issue, but still there is not enough published data regarding its reliability. Leong et al. [7] conducted research suggesting that ultrasound measurement of acromiohumeral distance and supraspinatus tendon thickness is a reliable method.

The aim of this study was the intra-rater reliability of characteristic ultrasonography measurements of supraspinatus tendon thickness and subacromial space.

Findings from this study could establish the reliability of the testing procedures and could also indicate a dependency between supraspinatus tendon and subacromial space (application purpose).

MATERIAL AND METHODS

Participants

The study was conducted on 10 physical therapy students participated in judo class, consisted of 5 men and 5 female with an average age of 23.62 ±0.80 years, average body height of 178.54 ±7.83 m and an average body weight of 74.93 ±10.36 kg. All subjects declared right-hand side as dominant (Table 1).

Twenty images of each shoulder examination were assessed in this study to identify the intra-rater reliability in measuring the supraspinatus tendon thickness (in short and long axis) and subacromial space by ultrasonography. None of the participants reported shoulder pain in the last 6 weeks or a history of shoulder injuries. The study was performed immediately after explaining the purpose and content of the study to the subjects.

Sonography was performed using a Honda HS – 2200 (Honda, Japan) ultrasound scanner with

Table 1. Characteristics of the healthy 10 physiotherapy students participated in judo class.

Variables	Subjects (n = 10)
Age [years]	23.62 ±0.80
Gender:	
Male	5
Female	5
Height [cm]	178.54 ±7.83
Weight [kg]	74.93 ±10.36
Dominant side:	
Right	10
Left	0

a 7.5 (6.0 to 11.0) MHz linear array transducer (HLS – 584M, Honda, Japan). The settings of the ultrasound system were standardised for all the participants and kept constant during all measurements to avoid potential changes in the images. A depth setting of 7.5 cm was used for all images. Depth-gain compensation was built-in in the scanner, meaning that the gain automatically was increased, while the depth increased to compensate for the loss through the tissue scanned. The acoustic power received by the ultrasound transducer 60%.

Ultrasound images were obtained by a single examiner, a licensed physical therapist with training in musculoskeletal ultrasound imaging. Two images were captured, and then the measurements were analysed on the same images by the same examiner. All images were saved on the hard drive of the scanner. Measurements were made with software embedded in the ultrasound scanner and saved on the hard drive of the unit.

Procedure

The measurements included assessment of 1) supraspinatus tendon thickness in short; 2) long axis; 3) subacromial space in the dominant upper extremity; 4) percentage of supraspinatus tendon thickness.

Supraspinatus tendon thickness in short axis (SST-short axis)

The subject seated with their back against a low back chair. The subject's arm was placed posteriorly, placed the palmar side of the hand on the superior aspect of the iliac wing with the elbow flexed and directed posteriorly. The linear transducer was placed on the anterior aspect of the shoulder, and placed perpendicular to the supraspinatus tendon and just anterior to the anterior-lateral margin of the acromion. The transducer was moved medial and lateral and rocked to ensuring the biceps tendon was visualised [9].

Three positions along the tendon were measured for thickness in millimetres (mm) at 10-, 15- and 20 mm lateral to the reference point of the superior and lateral point of hyperechogenicity of the biceps tendon. The tendon borders were defined inferiorly as the first hyperechoic region above the anechoic articular cartilage of the humeral head, and the hyperechoic superior border of the tendon before the anechoic subdeltoid bursa. The three measures (10 mm, 15 mm and 20 mm) were averaged together for a single measure of tendon thickness [4, 10].

Supraspinatus tendon thickness in long axis (SST-long axis)

The subject seated with their back against a low back chair. The subject's arm was placed posteriorly, placing the palmar side of the hand on the superior aspect of the ilium with the elbow flexed and directed posteriorly. The linear transducer will be placed on the anterior aspect of the shoulder, just off the acromion oriented approximately 45° between the sagittal and frontal planes to

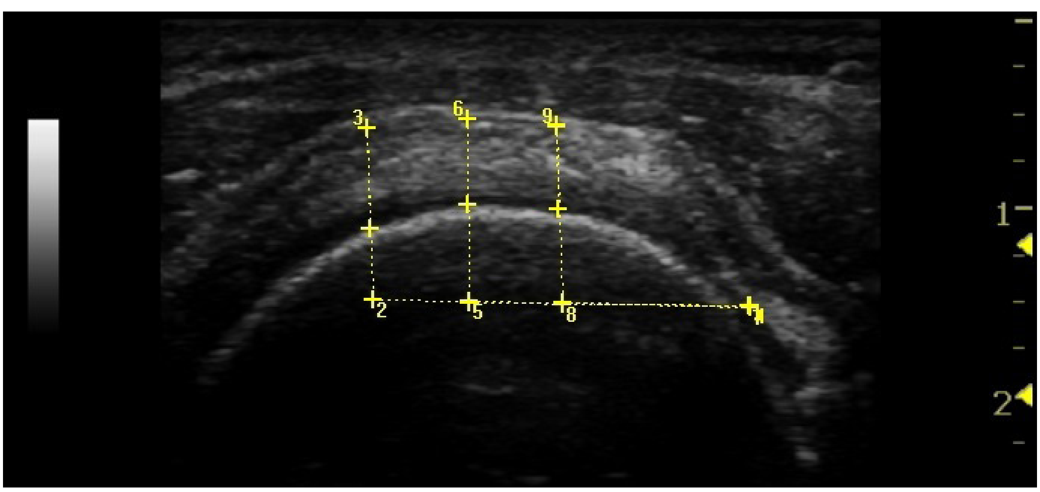

Figure 1. Supraspinatus tendon thickness in the short-axis: the average of three tendon thickness measures 10-, 15- and 20 mm lateral to the biceps tendon.

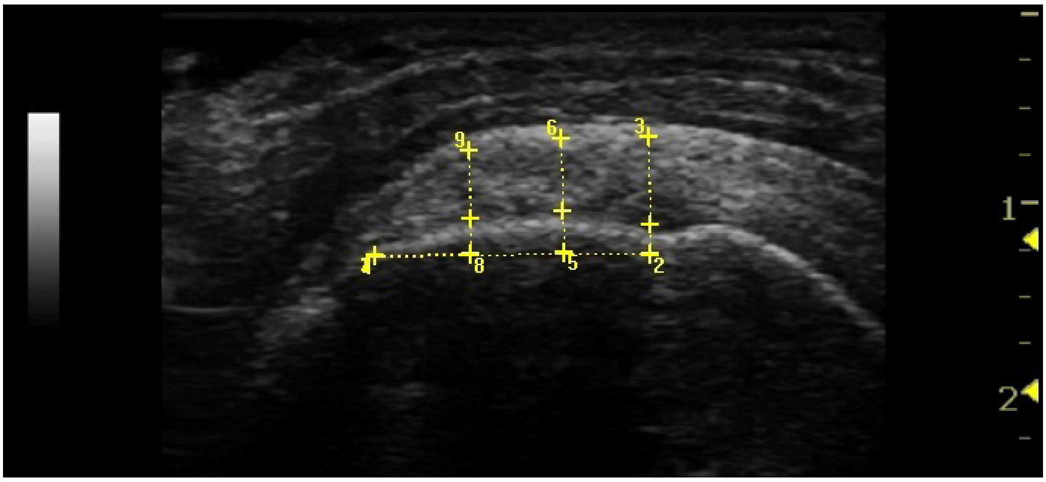

Figure 2. Supraspinatus tendon thickness in the long-axis: the average of three tendon thickness measures 5-, 10- and 15 mm lateral to the greater tuberosity.

obtain a longitudinal view of the supraspinatus. The probe is then moved anterior and lateral until the most distal end of the supraspinatus tendon is visualised just proximal to the greater tuberosity. The supraspinatus tendon in longitudinal view is a beaked-shaped structure with fibrillar pattern and regular margins. Attachment to the greater tuberosity in the healthy tendon is apparent. The probe will be rocked back and forth gently to ensure the transducer is perpendicular to the supraspinatus tendon [9].

Three measurements of tendon thickness were taken at 5-, 10-, and 15 mm proximal to the attachment of the tendon to the reference point of the greater tuberosity. The tendon borders were defined inferiorly as the first hyperechoic region above the anechoic articular cartilage of the humeral head, and the hyperechoic superior border of the tendon before the anechoic subdeltoid bursa. The three measures (5 mm, 10 mm and 15 mm) were averaged together for a single measure of tendon thickness [11].

Subacromial space

The subject was seated with their back against a low back chair. The subject's arm is placed by their side, with the forearm pronated and resting on the thigh, and both feet flat on the floor. The linear transducer was placed on the anterior-lateral aspect of the acromion at the anterior-most aspect [9]. The subacromial space was measured, as the shortest? The linear distance between the edge of the superior aspect of the humeral head and the inferior aspect of the acromion, defined as the subacromial space [10].

Supraspinatus tendon thickness as a percentage of subacromial space (% ratio)

Mean tendon thickness measured was expressed as a percentage of the mean subacromial space using the following formula [10]. The tendon thickness percentage of subacromial space was calculated for supraspinatus tendon in short axis.

$$\%\,ratio = \left[\frac{SST\ tendon\ thickness}{\text{Subacromial space}}\right] \times 100$$

SST – supraspinatus muscle

Data analysis

Interclass correlation coefficient $ICC_{3,2}$ was used to determine the intra-rater reliability of the supraspinatus tendon thickness and subacromial space variables. ICC values are considered very good for values 0.81-1.00, good for 0.61-0.80, moderate for 0.41-0.60, fair for 0.21-0.40, and poor for values below 0.20. Measurement error was calculated with the standard error of measure (SEM), and minimal detectable change (MDC_{90}) represents the error when a measure is taken twice (change over time). SPSS 18 statistical software (SPSS Inc., Chicago, Ill) was used for data analysis.

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

$$MDC = 1{,}96 \times SEM \times \sqrt[2]{2}$$

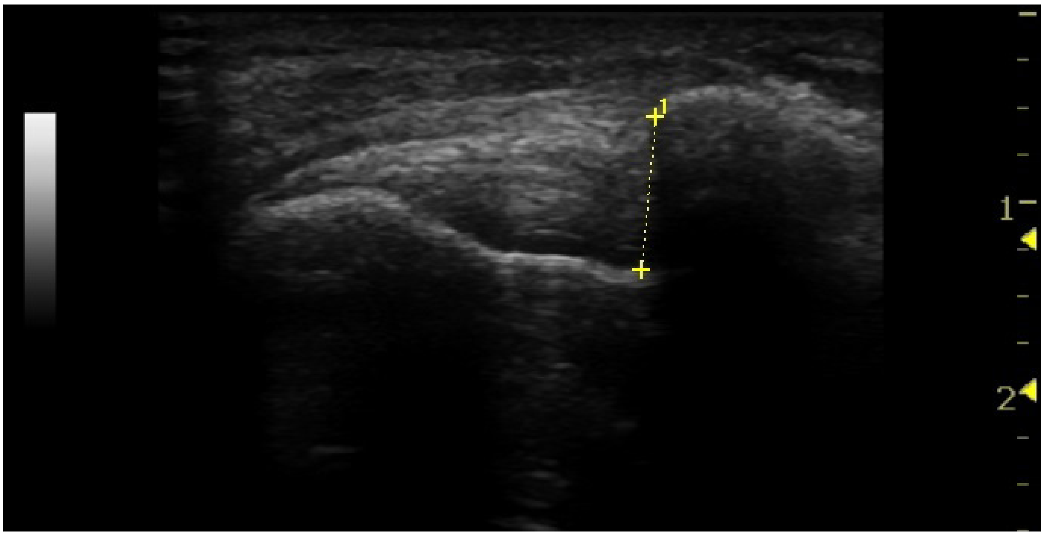

Figure 3. Subacromial space: space between the acromial tip and humeral head.

Table 2. Supraspinatus tendon thickness and subacromial space in 10 healthy physiotherapy students participated in judo class.

US measurements [mm]	Supraspinatus short axis	Supraspinatus long axis	Subacromial space	% ratio
Measure 1	5.44 ±0.26	3.27 ±0.44	10.07 ±0.43	53.70 ±2.71
Measure 2	5.45 ±0.24	3.23 ±0.47	10.08 ±0.42	53.88 ±2.75

Table 3. Intra-rater reliability and statistical analysis of the supraspinatus tendon thickness and subacromial space measurements.

Variale	ICC	95% coefficient interval	SEM	MDC_{90}
Supraspinatus short axis	0.989	0.960-0.997	0.034	0.096
Supraspinatus long axis	0.980	0.960-0.997	0.061	0.169
Subacromial space	0.997	0.990-0.999	0.033	0.091
% ratio	0.989	0.957-0.997	0.323	0.895

RESULTS

Average of supraspinatus tendon thickness in short axis was 5.44 ±0.26 mm at the initial evaluation and 5.45 ±0.24 mm several days later (Table 2). The intra-rater $ICC_{3,2}$ was 0.989 (95% CI: 0.960 to 0.997). The measurements error represented by SEM and MDC_{90} was 0.034 and 0.096 respectively (Table 3). Average of supraspinatus tendon thickness in long axis was 3.27 ±0.44 mm during first measure and 3.23 ±0.47 mm during the second examination (Table 2). The intra-rater $ICC_{3,2}$ was 0.980 (95% CI: 0.960-0.997) with SEM = 0.061 and MDC_{95} = 0.169 (Table 3). Average of subacromial space was 10.07 ±0.43 mm at the initial evaluation and 10.08 ±0.42mm several days later (Table 2).

The intra-rater $ICC_{3,2}$ was 0.997 (95% CI: (95% CI: 0.960-0.997).The measurements error represented by SEM and MDC_{90} was 0.033 and 0.091 respectively (Table 3). The percentage of supraspinatus tendon thickness was 53.70 ±2.71% and 53.88 ±2.75% respectively (Table 2). The intra-rater $ICC_{3,2}$ was 0.989 (95% CI: 0.957-0.997) with SEM = 0.323 and MDC_{95} = 0.895 (Table 3).

DISCUSSION

Recently the importance of rehabilitative ultrasound imaging (USI) for musculoskeletal rehabilitation has significantly increased. Current applications of US in rehabilitation are focused on two main areas of musculoskeletal imaging: rehabilitative USI (RUSI) and diagnostic imaging. This involves the need for standardisation of imaging and measurement procedures [12]. What is consistent with our findings, rehabilitative ultrasound imaging can be performed by physiotherapists to evaluate muscle and related soft tissue morphology or function while subjects tasks, and to assist in the application of therapeutic interventions. It can also be a useful tool to provide biofeedback during treatment [13].

Schneebeli et al. [14] investigated the intra- and interrater reliability of RUSI to measure supraspinatus thickness and cross-sectional area. The aim of their study was to establish the reliability of measurements performed by two physiotherapists. They showed a high to very high intra-rater reliability for the thickness for both raters. Considering the high correlation in intra-rater reliability, they established that RUSI can be a reliable tool for measuring supraspinatus muscle morphology. Our research also confirmed this conclusion.

Rathi et al. [15] also aimed to evaluate the reliability of shoulder US performed by a physiotherapist. Their results showed good intra-rater reliability (ICC: 0.86-0.98), and because of that, they stated that the US is recommended to investigate the stabilising role of rotator cuff muscles.

According to Docimo et al. [16], shoulder complaints are the third (after back and neck disorders) most common reason for musculoskeletal consultation in primary care. Rotator cuff muscles, together with supraspinatus, are very often subjected to a therapeutic intervention. Given the reliability of US to assess changes in muscle architecture, physiotherapists, as well as other clinicians, can use RUSI in the clinical practice. This assumption is in line with our idea to scientifically investigate this matter.

Katayose and Magee [17] showed that the use of diagnostic ultrasound can give reliable information regarding the morphological state of the supraspinatus. Therefore, it can be useful in the objective evaluation of pathological conditions of investigated muscle. The decreasing function of supraspinatus may be a factor of pathological abnormality in the shoulder region.

O'Connor et al. [18] aimed to quantify inter-observer variation in a US shoulder examination between radiologists with different levels of experience. They found a good agreement (kappa >0.60, p<0.01) between the experienced operators for investigated structures of the shoulder region, with no significant agreement between the experienced operators and the less experienced operator in several categories (kappa Ľ 0.18-0.21). According to their paper, sonography of the rotator cuff is a reproducible diagnostic test, although highly dependent on the operators' experience levels. Therefore, it indicates the need for a more clearly defined sonographers training, to precise definitions of abnormalities in the rotator cuff. Even slight modification in the probe or patient positioning can modify the result of the examination.

The wide-ranging reported accuracy for US detection of full-thickness rotator cuff tears achieves values between 57-100% for sensitivity and respectively 50-100% for specificity [19]. Ultrasonography is an inexpensive, painless, and non-invasive and relatively quick method of diagnosis and examination of the shoulder region. It has similar accuracy to the MRI examination to evaluate the soft tissues within rotator cuff tendons and muscles [20].

Sheel et al. [21] proved 81% of the overall agreement between US and MRI for the shoulder. The relatively good agreement with most detected pathologies was proved. As the conclusion, they stated that the musculoskeletal US is a reliable technique with moderate to good inter-observer reliability. Although they emphasised the role of raining and standardisation of musculoskeletal US, as necessary to achieve higher inter-observer reproducibility. MRI is considered the gold standard for identifying the ageing-related chronic changes in musculoskeletal structures. Swen et al. [22] investigated the accuracy of US for the assessment of full-thickness rotator cuff tears. They confirmed the same sensitivity for sonography and MRI (0.81), and emphasised advantages of US, because of its low cost and availability.

In contradiction with previous findings, Naredo et al. [23] showed that musculoskeletal ultrasound has a moderate to good inter-observer reliability. Corresponding values were only fair-to moderate, even for an operator with great experience. In their opinion there is a need for further agreement on the scanning technique or diagnostic criteria, to improve repeatability of musculoskeletal ultrasonography.

The operator dependence remains one of the perceived major limitations for the use of ultrasonography in pathology diagnosis. The investigator needs to place the probe on the right site at the correct angle. There have been much research emphasising the role of examiner experience in performing the US. Le Corroller et al. [24] proved, that sonography has a high level of inter-rater reliability for full-thickness rotator cuff tears and lower inter-rater reliability for partial-thickness and intratendinous rotator cuff tears, depending on operator's experience. Rutten et al. [25] also showed that the major disadvantage of US, including the sonography of the shoulder, is a high rater dependence.

For statistical analysis of our data, we used the intraclass correlation coefficients (ICC). It is the most common and recommended method of analysis to enable comparison between reliability studies [26]. Future research will be focused on shoulder tendon characteristics in elite judokas and changes of ultrasonographic indicators as the effect of training and fights.

CONCLUSIONS

Ultrasound examination above the shoulder is important in musculoskeletal investigation disorders, i.e. rotator cuff impingement syndrome. Monitoring and diagnostics of shoulder injuries in judo may decrease the development of new injuries and improve the quality of training. With obtained results, we confirmed the very good reliability and very low measurement error for the US performed by the physical therapist.

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