Reliability and Validity of Thickness Measurements of the Supraspinatus Muscle of the Shoulder: An Ultrasonography Study

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Context: The supraspinatus is the most commonly affected muscle with rotator-cuff pathology and necessary for stability of the humeral head in the glenoid fossa. Rehabilitative ultrasound imaging (RUSI) of skeletal muscles provides a safe and clinically accessible measure of intact human muscle function at rest or during contracted states. The ability to perform accurate assessment of supraspinatus function has not been studied and may be of value in assessment and treatment. Objectives: To determine the validity and reliability of measures obtained using RUSI for assessing supraspinatus muscle at rest and contracted conditions. Design: Reliability and validity Setting: Outpatient physical therapy clinic. Subjects: 15 asymptomatic subjects age 30–49 y. Intervention: The supraspinatus muscle was measured at rest and contracted with a 0.9-kg weight with the arm positioned in 45° of abduction in the plane of the scapula. Repeated ultrasound images of the supraspinatus were collected by 3 physical therapists on 2 separate days. Main Outcome Measures: Reliability was assessed with the intraclass correlation coefficient (ICC) and standard error of the measurement (SEM). Validity was tested by comparing mean difference between active and passive states for all 3 raters on both days. Results: All ICC values were found to be at .9 or above. In addition, for all days and raters, the active condition was significantly thicker than the passive condition (P < .001). Conclusions: Thickness measures of the supraspinatus using RUSI, during passive and active conditions, demonstrate high interrater and intrarater reliability and can easily distinguish between active and passive states. These findings suggest that RUSI may provide an appropriate quantitative measure for changes in the thickness of supraspinatus that are important for determining improvement or deterioration in muscle function.

Keywords: muscle thickness, rehabilitative ultrasound imaging

Rotator-cuff problems, including impingement and associated tendinitis, account for nearly one-third of physician visits for shoulder-pain complaints. The supraspinatus is the most commonly affected muscle in patients with rotator-cuff pathology and plays a key role in stabilizing the humeral head on the glenoid fossa during arm elevation.

Rehabilitative ultrasound imaging (RUSI) is used to measure various aspects of muscle morphology, such as muscle thickness, cross-sectional area, and volume. Ultrasound measurements of thickness are closely related to cross-sectional area, which has been correlated with the ability of a muscle to produce force. RUSI assists in monitoring treatment effectiveness and providing visual feedback when teaching patients to properly engage musculature, most notably in reeducation of the deep abdominal muscles. Muscle-thickness change, as measured by RUSI, has also been highly correlated with EMG activity in the lumbar multifidus.

RUSI of skeletal muscles, although less sophisticated in terms of resolution than MRI and CT, offers the advantages of providing a safe, cost-effective, portable, and clinically accessible measurement of muscle to determine whether differences in a passive state or during isometric contraction contribute to muscle dysfunction. A feature unique to RUSI is its dynamic capability of scanning in real time, which makes it superior to MRI and CT for evaluating mobile structures such as tendon, nerves, and muscles. These advantages make it highly attractive for directing appropriate physical therapy treatment decisions, as has been demonstrated in patients with low-back disorders.

The assessment of rotator-cuff function/dysfunction is typically performed in a resting (passive) state by diagnostic ultrasound or MRI. It is difficult to perform accurate dynamic assessment of supraspinatus function...
except with clinical tests, the results of which tend to lack high sensitivity.

The purpose of this study was to assess the validity and reliability of RUSI as a tool for measuring passive and active conditions in the supraspinatus muscle in a population of healthy subjects.

Methods

Participants

Participants were 15 asymptomatic subjects (8 men, 7 women) with a mean age of 37 ± 18 years, a mean height of 173 ± 11 cm, and a mean body mass of 72 ± 12 kg. Inclusion criteria were having full active pain-free range of motion of the cervical and thoracic spine and shoulders. Exclusion criteria included neuromuscular or musculoskeletal disorders of the cervical or thoracic spine and shoulders; history of significant neck or shoulder pain, arm trauma, pain or surgery of the neck or shoulder; pregnancy, or metal implants in the upper body.

Subjects were recruited from the employees of Therapeutic Associates, Inc (TAI), Eugene, OR, and their family members and friends. All subjects signed informed consent after receiving a detailed explanation of the procedure of the study. The University of Oregon’s institutional review board approved the protocol for the study.

Procedure

Before testing, subjects completed an intake form of their medical history, and a licensed physical therapist with orthopedic clinical specialization performed a screen of the cervical and thoracic spine and upper extremities to rule out neuromuscular or musculoskeletal problems. Subjects were asked to use their dominant arm during the study for consistency. Dominance was defined as which upper extremity was used for throwing and writing.

Position.

Subjects were seated next to a high/low table in a straight-back chair with lumbar support (folded towel) and feet supported. They were asked to place their arm on a fabricated support, modified with additional padding to accommodate for various trunk and arm lengths, in a supported position resting at 45° of abduction in the plane of the scapula at 30° (Figure 1).

Instrumentation. Three ultrasound images of the supraspinatus (Figure 2) in a passive and in a contracted state were collected by each of 3 physical therapists on 2 separate days, 1 week apart. The therapists were trained by the first author (who has 7 years of clinical experience with RUSI) and additionally with certified ultrasound technicians employed by a local radiology group. RUSI images were recorded in B mode using a Biosound Esaote Aquila real-time ultrasound unit (Indianapolis,
Reliability and Validity of Supraspinatus Measures

Figure 2 — Resting and contracted state of supraspinatus as measured by rehabilitative ultrasound imaging.

IN) using an 8-MHz linear probe and on-screen calipers for all measurements.

**Measurements.** Resting measures of muscle thickness (diameter) were made just proximal to the spine of the scapula in the midposition (belly of the supraspinatus) in the sagittal plane to determine cross-section measures. This position was determined on-screen by finding the thickest part of the muscle medial to the acromion (measuring the greatest distance from the inside of the fascial borders) and is consistent with the distal portion of the muscle belly proximal to the musculotendinous junction. Probe angle was adjusted based on the size and shape of the individual’s muscle for best image. Once the measurement in a passive state had been recorded, within 15 seconds, the patient was asked to do an isometric hold of a 0.91-kg weight in the same position without arm support as the high-low table was lowered to leave the arm unsupported. Measurement of the muscle in the same position was measured by and recorded by a fourth physical therapist, then stored. The arm was resupported, and a 1-minute rest period was given between the 3 trials per examiner. Subsequently, the second and third therapists repeated the same procedures with a 5-minute rest between examiners (for a total of 9 trials per condition). Data were averaged over the 3 trials for each rater. Order of the testing by examiners was randomized. Subjects returned for a second visit 1 week after the first study, and the same procedure of testing was repeated.

**Statistical Analysis**

Our dependent variable, muscle thickness, was analyzed using SPSS 21.0 software (IBM, Armonk, NY). Reliability for both the active and the passive condition was assessed with the intraclass correlation coefficient (ICC) and standard error of the measurement (SEM). An ICC (3,3) model was used for both interrater (within session) and intrarater (between sessions) reliability. Validity was tested by comparing active and passive conditions for all 3 raters on both days. This is an example of the known-groups method as defined by Portney and Watkins. A total of 6 paired t tests were run with an appropriate Bonferroni correction to account for multiple comparisons. The alpha level was set at .05.

**Results**

With respect to reliability, all between-raters and between-sessions ICC values were found to be at the $r = .9$ level or above, with corresponding SEM values ranging from 0.07 to 0.12 mm (Table 1). With respect to validity, for all days and raters, the active condition was significantly thicker than the passive condition ($P < .001$; Figure 3). In fact, for all 90 individual data points ($6 \times 15$ subjects per test), there was only 1 instance in which the passive condition was found to be thicker than the active condition.

**Discussion**

The purpose of the current study was to investigate the reliability and validity of measurements of supraspinatus muscle contraction using RUSI. Thickness measures of the supraspinatus during passive and active conditions demonstrated high interrater and intrarater reliability, with all ICC values above .90 and SEM values of 0.12 cm and below for all conditions. All ICC values are well above the threshold of .75, indicating good reliability. In addition, all ICC values are above the .90 level recommended for clinical measurements. In addition, this technique could easily distinguish between active and passive states ($P < .001$). These findings suggest that RUSI may provide an appropriate quantitative measure for documenting change in the thickness of supraspinatus that is important for determining improvement or deterioration in muscle function for those with muscle pathology. This has been recognized in the lumbar spine as noted differences in the segmental atrophy of multifidus with discal pathology. Muscle regeneration was not automatic after resolution of back pain and required training to restore function and reduce recidivism of low-back events.
Table 1  ICC and SEM Values for Active and Passive Conditions

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<td>Between days</td>
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<td>Rater 2</td>
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<td>Between raters</td>
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Figure 3 — Active and passive conditions between raters for days 1 and 2.
Measurements of muscle architecture by ultrasonography have been validated using MRI as the criterion measure. Studies that have looked at the validity of cross-sectional-area measurements with RUSI in comparison with MRI have found similar results for supraspinatus and other muscle groups. Muscle parameters are more difficult to measure during dynamic tasks and in older or patient populations; however, this was not measured in the current study. Despite these limitations, the literature supports the validity of RUSI for measuring muscle morphology.

If clinicians are to rely on RUSI to monitor changes in muscle size with treatment of painful or injured soft-tissue structures, it is important that they first determine the reliability of their clinical measurement system. We opted to use 3 individual measures per examiner because of differences between single and multiple trials demonstrated with RUSI examining for intertester reliability of multifidus. An average of 3 trials produced higher interrater reliability scores. Our findings included high ICC values for within-day and between-days measurements of both intrarater and interrater reliability. This is clinically relevant as to the type of further research to be done on same-day changes (eg, immediate effects of thoracic manipulation) and long-term training intervention (eg, the effects of using RUSI for training as a biofeedback mechanism).

Our findings demonstrate a significant increase of muscle thickness during the performance of supraspinatus contraction using a 0.9-kg resistance. This suggests that RUSI may provide a quantitative measure of change in the thickness of supraspinatus muscle. Normal and altered patterns of muscle architectural changes at passive states and with movement have demonstrated clinically relevant information using RUSI. Differences in thickness of trunk musculature of healthy individuals and low-back-pain patients provide patterns of this architectural difference, with decreased muscle thickness and substantial fatty atrophy of multifidus in patients with lumbar-disc pathology. This may be highly relevant in the diagnosis of rotator-cuff pathology when found in the supraspinatus and infraspinatus and compares favorably with MR imaging. Other clinical studies investigating the use of RUSI across a broad spectrum of patients with shoulder disorders are required before more definitive clinical conclusions can be drawn.

RUSI could be used as a clinical measure of individual supraspinatus muscle thickness, provided the user follows the measurement protocol used in the current study. By use of RUSI, the validity of a clinical examination may increase when detecting muscle atrophy, hypertrophy, and symmetry between affected and nonaffected sides. In addition, RUSI may be a valuable supplement in evaluation of the treatment effect and improve the ability to distinguish more clearly between speedy recovery and the high risk of long-standing and recurrent complaints. Future research is required to determine the clinical utility of this approach.

References