Background: No studies have looked at the rotator cuff dimensions in the young healthy population using ultrasonography. Our aim is to define the ultrasound dimensions of the rotator cuff in the healthy young adult population and explore correlations with other patient characteristics.

Methods: Thirty male and 30 female healthy volunteers (aged 18-40 years), with no shoulder problems, underwent ultrasound assessment of both shoulders by a musculoskeletal radiologist. The dimensions of the rotator cuff, deltoid, and biceps were measured in a standardized manner.

Results: A total of 120 shoulders were scanned. The mean maximum width of the supraspinatus footprint was 14.9 mm in men and 13.5 mm in women (P < .001). The mean thickness of the supraspinatus tendon was 4.9 mm in women and 5.6 mm in men. The mean thickness of the subscapularis was 4.4 in men and 3.8 mm in women and for the infraspinatus was 4.9 mm in men and 4.4 mm in women. There was no correlation between height, weight, biceps, or deltoid thickness with any tendon measurements. Apart from supraspinatus tendon thickness, the difference between dominant and nondominant shoulders in the same sex was not significant for any other tendon dimensions.

Conclusion: This study has defined the dimensions of the rotator cuff in the young healthy adult, which has not been previously published. This is important for the documentation of normal ultrasound anatomy of the rotator cuff and also demonstrates that the asymptomatic contralateral shoulder can and should be used to estimate the expected dimensions.

Level of evidence: Anatomic Study, Imaging.

Keywords: Rotator cuff; dimensions; adults; normal; gender; ultrasound

Shoulder pain is the second most prevalent cause of musculoskeletal pain in the community, behind only low back pain.22 It has been estimated that every year approximately 1% of all adults consult their general practitioner with new-onset shoulder pain.18,20 Rotator cuff pathology is reported to be the most common cause for painful shoulder...
episodes, accounting for up to 70% of cases.20 Accurate diagnosis of shoulder conditions is difficult because the clinical findings are often shown to have poor correlation with the actual pathology.8,10

Magnetic resonance (MR) arthrography is the most sensitive and specific technique for diagnosing rotator cuff tears.7 Ultrasound is accurate and the most cost-effective method to identify full-thickness tears and, to a lesser extent, partial-thickness tears, comparable to MR imaging (MRI) in sensitivity and specificity.7,21 According to recent systematic reviews,7,25 ultrasound had a sensitivity of 92% to 96% and a specificity of 93% to 94.4% for diagnosing full-thickness tears. For partial-thickness tears, the sensitivity was 66% to 84% and specificity was 89% to 93.5%. One of the criteria used to diagnose a rotator cuff tear is thinning of the tendon.5,11,24,30,31 It is based on knowing the normal dimensions of the rotator cuff and trying to visualize a decrease in tendon thickness.

Although there is an abundance of literature on the pathologic appearances and frequencies of rotator cuff pathology, a detailed literature review has revealed no previous studies looking at the cuff dimensions in a young healthy population using ultrasonography. Specifically, there is no evidence of correlation with sex, hand dominance, weight, height, and other ultrasound measurements. Defining the normal parameters for the rotator cuff will help clinicians make a comparison between normal and pathologic conditions.

The aim of this study is to define the dimensions of the supraspinatus tendon and other rotator cuff muscles in a healthy young adult population and compare them with the contralateral shoulder. Correlations with sex, height, weight, dominance of hand, and other muscle dimensions will also be established.

Materials and methods

Inclusion and exclusion criteria

All healthy adults aged between 18 and 40 years, who had no significant medical conditions and had no shoulder problems, were considered eligible to participate in the study. Anyone with significant comorbidities or who had undergone previous shoulder surgery was excluded. Volunteers who had or had experienced pain in their shoulder or who were limited in their daily activities due to shoulder problems in the preceding 4 weeks were also considered ineligible to participate in the study.

Recruitment

The first 60 volunteers (30 men and 30 women) from among the staff and students of our institution who met the eligibility criteria formed the study population. Each volunteer included in the study underwent an ultrasound assessment of both shoulders in a private consultation room by a musculoskeletal radiologist (S.B.R.).

Data collection

Demographic details, including age, height, weight, hand dominance, sports activities, comorbidities, and smoking and drinking habits were collected for each individual.

One experienced consultant musculoskeletal radiologist (S.B.R.) who routinely performs ultrasound assessment of shoulders did all of the measurements. Both shoulders were scanned in each individual sequentially. A GE Logiq E9 (GE Healthcare, Chalfont St. Giles, UK) ultrasound scanner with a 10- to 15-MHz linear array transducer was used for all assessments. The scan was performed with the individual sitting on a couch and facing the examiner.

The following structures were visualized in sequence, and measurements were taken as described for each structure. To minimize bias, all measurements were taken with reference to bony landmarks.

1. Tendon of long head of biceps
2. Subscapularis
3. Supraspinatus
4. Subacromial bursa
5. Infraspinatus
6. Deltoid

The biceps tendon was identified first, and its maximal thickness was measured in the transverse view at the highest point of the groove with the forearm resting supine on the lap. With the arm in external rotation, the thickness of subscapularis tendon was measured just medial to the attachment at the lesser tuberosity (Fig. 1).

The maximal mediolateral width of the supraspinatus footprint at its insertion was measured in the coronal view of the tendon, with the arm in internal rotation. Two further measurements were made to assess the thickness of supraspinatus tendon in the same view. The first was made at the medial edge of footprint and the second was at the midpoint of the footprint (Fig. 2). In addition, the thickness of supraspinatus tendon on the sagittal view was done at a fixed point 15 mm posterior to the biceps tendon (Fig. 3).

The thickness of the subacromial bursa was measured on the coronal view in the same plane as the thickness of the supraspinatus tendon. Infra- and Supraspinatus tendon thickness was measured at the level of the posterior border of the acromion, and thickness of deltoid muscle was measured at the anterolateral edge of acromion.

Figure 1 Thickness of the subscapularis tendon on ultrasound imaging.
Interobserver and intraobserver agreement

For a subset of 10 participants (5 men and 5 women), repeat measurements were taken by the initial observer at 4 weeks after the first measurement and by a second observer who was also an experienced consultant musculoskeletal radiologist (R.W.).

Statistical analysis

Differences in measurements between men and women and hand dominance were determined by performing t tests. Paired t tests were used to compare dominant and nondominant arms for each participant. For comparisons of dominant arms between men and women a 2-sample t test was conducted. The Pearson correlation coefficient was calculated to measure the strength of association between the tendon measurements and the height and weight of the individuals. Differences were considered significant at the 5% level if the P values were <.05. Bland-Altman plots were constructed to measure intraobserver and interobserver agreement. All analyses were performed using R software (The R Foundation for Statistical Computing, http://www.r-project.org/).

Results

Scans were done of 120 shoulders from 60 participants (30 men and 30 women); of these, 55 were right hand-dominant and 5 were left hand-dominant. Participants’ age, height, weight, and hand dominance are reported in Table I.

The mean maximum mediolateral width of the supraspinatus insertion onto the humerus in the coronal plane (footprint) was 14.9 mm in men and 13.5 mm in women (Fig. 4). The mean thickness of the supraspinatus tendon varied from 4.9 mm in women to 5.6 mm in men at the medial edge of its insertion and between 3.6 and 4.2 mm, respectively, at the midpoint of its insertion.

Table I  Study participant characteristics by sex

<table>
<thead>
<tr>
<th>Participant characteristics</th>
<th>Females (n = 30)</th>
<th>Males (n = 30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>26.7 (21-39)</td>
<td>29.9 (23-39)</td>
</tr>
<tr>
<td>Height, m</td>
<td>1.63 (1.50-1.78)</td>
<td>1.80 (1.70-1.95)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>60.6 (45-77)</td>
<td>81.4 (67-100)</td>
</tr>
<tr>
<td>Body mass index, kg/m²</td>
<td>24.96 (17-31)</td>
<td>22.73 (22-33)</td>
</tr>
<tr>
<td>Hand dominance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right-handed</td>
<td>28</td>
<td>27</td>
</tr>
<tr>
<td>Left-handed</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

* Continuous data are shown as the mean (range) and categoric data as the number of participants.
nondominant shoulders. The footprint for the dominant arm was measured at 13.4 mm in women compared with 14.9 mm in men \((P < .001; t\) test). For the nondominant arm, women had a footprint dimension of 13.5 mm compared with 14.9 mm in men \((P < .001; t\) test). However, the difference between the dominant and nondominant arm among men and women was not significant. The mean difference in supraspinatus footprint dimensions between the dominant and nondominant arms was 0.03 mm in men \((P = .867; \text{paired } t\) test) and 0.09 mm \((P = .607; \text{paired } t\) test) in women.

The thickness of the supraspinatus tendon was significantly different between the dominant and nondominant arms in men and women. The difference in thickness was 0.5 mm \((P = .003; \text{paired } t\) test) in men and 0.3 mm \((P = .005; \text{paired } t\) test) in women at the medial edge of the footprint and was 0.27 mm \((P = .007; \text{paired } t\) test) in women at the middle of the footprint.

For all other tendon measurements, a significant difference was found between men and women for dominant and nondominant sides, but no significant difference between the dominant and nondominant sides was found among the same sex (Table II).

**Correlation**

Bland-Altman plots\(^2,3\) were constructed for measuring the intraobserver (Fig. 5) and interobserver (Fig. 6) agreement. Agreement was analyzed by plotting the differences in the 2 sets of measurements against the mean values of these measurements. The Bland-Altman plots are consistent with the hypothesis that 95% of the differences between the assessments were within ±1.96 standard deviations of the mean of the differences (“limits of agreement”), denoting good agreement between the 2 sets of measurements.\(^2,3\)

**Discussion**

This study has demonstrated for the first time the mean and range of dimensions of the rotator cuff in the young healthy adult. Although a statistical difference was found between

<table>
<thead>
<tr>
<th>Table II</th>
<th>Descriptive statistics for the average measurements for male and female participants in the study*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Female ((n = 30))</td>
</tr>
<tr>
<td>Rotator cuff</td>
<td></td>
</tr>
<tr>
<td>Subscapularis</td>
<td>3.8 \± 0.5 (2.8-4.7)</td>
</tr>
<tr>
<td>Supraspinatus</td>
<td></td>
</tr>
<tr>
<td>Coronal view</td>
<td></td>
</tr>
<tr>
<td>Medial edge of FP</td>
<td>5.0 \± 0.6 (3.9-6.4)</td>
</tr>
<tr>
<td>Middle of FP</td>
<td>3.7 \± 0.5 (2.6-4.8)</td>
</tr>
<tr>
<td>Max width of FP</td>
<td>13.4 \± 1.2 (11.3-16.6)</td>
</tr>
<tr>
<td>Sagittal view</td>
<td>4.7 \± 0.6 (3.6-6.1)</td>
</tr>
<tr>
<td>Infraspinatus</td>
<td>4.4 \± 0.4 (3.6-5.2)</td>
</tr>
<tr>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Biceps tendon</td>
<td>2.9 \± 0.4 (2.2-3.9)</td>
</tr>
<tr>
<td>Deltoid muscle</td>
<td>6.1 \± 0.8 (4.6-8.0)</td>
</tr>
<tr>
<td>SASD bursa</td>
<td>1.0 \± 0.2 (0.6-1.5)</td>
</tr>
</tbody>
</table>

\(FP\), Footprint; \(SASD\), subacromial-subdeltoid.

* Data are shown as the mean ± standard deviation, and the range for each measurement is shown in parentheses. All measurements are in millimeters.

No significant correlation was found between the height or weight of the individual and any of the tendon measurements \((P > .05\) for all tests). Deltoid muscle dimension and biceps dimensions did not have any correlation to the thickness of the rotator cuff tendons \((P > .05\) for all tests).
the dimensions of women and men, it has demonstrated that except for thickness of the supraspinatus tendon at the footprint, the dimensions between dominant and nondominant hands are not statistically significantly different. This is important, because it means that an asymptomatic contralateral shoulder can be used as a guide to estimate normal dimensions of the affected shoulder.

Partial-thickness tears are classified arthroscopically using the Ellman grading,9 which is based on a supraspinatus thickness of 10 to 12 mm just proximal to its insertion on to the humerus. However, there is no evidence for using this as a reference range. Although the gross anatomy of the supraspinatus has been documented,27 and the tendon thickness has been reported as 3\(\pm\)0.07 mm (range, 0.2-0.4 mm) in elderly cadaveric specimens,16,23 that the integrity of the rotator cuff decreases with age has been well established.17 Milgrom et al17 showed that there is a very significant difference in the incidence of rotator cuff tears in individuals aged older than 50 years compared with someone aged between 30 and 39 years (\(P<.001\)). Besides, another study showed that the muscle volume and the cross-sectional area of the rotator cuff muscles were 1.6 times higher in living humans, primarily due to age and dehydration effects.13 Therefore, these data are unlikely to reflect what would be found in young healthy adults.

Ultrasound has been used to measure the thickness of the supraspinatus tendon in asymptomatic adults1,4,6,12,19,28,29 and also to calculate the cross-sectional area of the supraspinatus within its fossa in the asymptomatic patient.14,15 The mean diameter of the supraspinatus tendon has been recorded by ultrasound in these studies as between 4.0 and 6.25 mm.1,6,19,28,29 It was approximately 5.2 to 5.6 mm in the elite baseball athlete29 and was increased in patients with diabetes1 and amyloidosis.12 However, these studies assessed the tendon at different points and none of them at the point referred to by Ellman,9 which is most critical to the surgeon as the point where rotator cuff tears occur.

Our study has documented the width of the supraspinatus footprint in a younger population that is most likely to sustain a partial-thickness tear. This information will be helpful in determining the percentage of the tendon involved in a partial-thickness tear at arthroscopy. Although there is a wide range in the data, our study has shown that the contralateral shoulder can and should be used as a control in almost all circumstances, supporting the argument for always performing bilateral shoulder ultrasound assessments.

Our study has some limitations. All of the volunteers for our study were chosen from our institution; however, there are no reasons to believe they are any different from the general population.

Ultrasound is highly user-dependent.5,25,26 Previous studies using ultrasound to measure the thickness of tendons have shown that even with well-defined protocols, substantial interobserver and, to a lesser extent, intrasubject intervisit variation exists.19 In our study, the Bland-Altman plots show good agreement for interobserver and intraobserver measurements, supporting the use of ultrasound to image the shoulder.

All of the measurements were made in a younger age group that is unlikely to have rotator cuff pathology, and because the rotator cuff is known to display thinning with advancing age, these data cannot be extrapolated to other age categories.5

Conclusion
This study has shown the normal dimensions of the rotator cuff for subscapularis, supraspinatus, and infraspinatus in young adults. However, there is a wide range in the dimensions, which makes using classifications based on an average size difficult. This has not previously been published and aids clinicians and radiologists in the evaluation of the shoulder. It reassures us of the reliability of shoulder ultrasound measurements and emphasizes the utility and appropriateness of routine screening of the other shoulder as a control.

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