We have established a reference standard for the cross-sectional area (CSA) of supraspinatus as measured by diagnostic ultrasound. The influence of hand dominance and of ageing on the CSA was also assessed. We examined 72 subjects aged from 20 to 79 years. Standard values of the CSA were determined with a high measure of interobserver reliability. Although the CSA on the dominant side was significantly larger ($p < 0.001$) by $0.16 \text{ cm}^2$ ($95\% \text{ CI 0.072 to 0.249}$) than that on the non-dominant side, this difference had no clinical significance. The CSA of supraspinatus decreased significantly with ageing.

The main techniques for acquiring a diagnostic image in anatomical and morphological studies of muscle are MRI, CT and diagnostic ultrasound. MRI is non-invasive and is reported to be the best method of obtaining clear images of soft tissue.$^{1,2}$ Many of the anatomical and morphological studies on muscles such as quadriceps femoris have been performed using MRI,$^{3-12}$ but it is expensive and not always available. Although examination by CT requires less time than MRI, it is an ‘invasive’ technique in that potentially harmful x-rays are used. Thus, cost, availability and potential harmful effects must be considered before any of these methods can be used for the clinical evaluation of muscle morphology.

By contrast, diagnostic ultrasound is not invasive, expensive or complicated in application, but it does have some disadvantages in regard to the clarity of the image, the reliability of interpretation and limitation of the image by the size of the examination probe. Diagnostic ultrasound cannot ‘see’ the image behind high-echo tissue such as bone. Possible target areas are limited by the size of the probe and the echo level of the surrounding tissue. Several recent studies, however, have reported its use in assisting clinical management.$^{13-20}$ Others have also shown its value in the anatomical and morphological assessment of muscles such as quadriceps femoris, tibialis anterior and multifidus.$^{11,21-26}$ These are all located in front of bone and close to skin as is supraspinatus, which is also of adequate size for the diagnostic ultrasound probe. Thus, diagnostic ultrasound may be of value in the measurement of atrophy of this muscle.

Our aim was to establish standard reference values for the cross-sectional area (CSA) of supraspinatus as measured by diagnostic ultrasound in several age groups of sedentary males without shoulder symptoms. We also discuss the differences between dominant and non-dominant arms and among different age groups.

**Subjects and Methods**

We recruited 72 sedentary male Japanese volunteers from staff and students at Sapporo Medical University and related institutes in Sapporo. Older individuals were enrolled from a Seniors Club in Sapporo. They all gave their signed informed consent to participate in the study. None had shoulder symptoms. The criteria for inclusion of an asymptomatic shoulder were a normal range of active movement, no symptoms in the neck or shoulder, no previous surgery to the shoulder or neck and no difficulty in using the upper limbs in daily activities. We excluded those who undertook regular sporting activity using the upper limbs in an attempt to eliminate activity level as a factor influencing the CSA. Dominance was determined using the Edinburgh Handedness Inventory$^{27}$ and in all subjects the right hand was dominant. They were assigned to one of six age groups with 12 in each: 20 to 29, 30 to 39, 40 to 49, 50 to 59, 60 to 69 and 70 to 79 years. Table I gives the details of the subjects.

**Measurement of CSA using diagnostic ultrasound.** We acquired diagnostic ultrasound images using a 7.5 MHz transducer. The same probe and system (Aloka Echo Camera SSD-1000, Aloka Co, Japan) were used for all measurements. The subjects were examined seated with the shoulder in the neutral position, the arm by the side and the palm facing inwards. A section of supraspinatus through
the midpoint of the spine of the scapula was observed. We determined this site using a metal tape and by measuring from the posterior edge of the acromion to the medial edge of the spine of the scapula. The probe was set on the surface of the skin over supraspinatus at this midpoint at an angle of between 30° and 40°. This section is not commonly used for general assessment of the shoulder by diagnostic ultrasound, but we thought that it was more appropriate for the evaluation of the CSA of supraspinatus because the point of movement could easily be identified.

We used B-mode imaging which demonstrates a cross-sectional slice of the muscle (Fig. 1) and obtained the same angle of slice for each subject. Both shoulders were measured three times and the mean of these taken for each side. The analogue image data were converted to digital form using the TIFF format, and stored in a Macintosh computer (Model G3 450MHZ). From these digital data, measurements of the CSA were analysed using the NIH Image program which is available on the Internet at http://rsb.info.nih.gov/nih-image/.

Statistical analysis. The mean, SD and 95% confidence interval (CI) for the CSA of supraspinatus in each group were recorded. Since the CSA was measured on three scans, the interscan reliability was analysed using intraclass correlation coefficients. Repeated-measures ANOVA was performed to investigate the difference in the CSA among the six age groups and between dominant and non-dominant sides. In addition, multiple regression analysis of the CSA in regard to age, height and weight was performed separately for each side to estimate the effect of these factors. For each analysis, significance was achieved if p < 0.05.

Results

The interobserver measurement of reliability of the three scans was 0.94 on the right and 0.93 on the left side. Table II gives the mean and 95% CI values of the CSA of supraspinatus in each group. Repeated-measures ANOVA showed that there was a statistically significant difference in the CSA of supraspinatus in the six age groups (F = 1086.6; d.f. 1/5; p < 0.000) and between dominant and non-dominant sides (F = 16.7; d.f. 1/5; p < 0.009). Multiple regression analysis showed on both left and right sides that

<table>
<thead>
<tr>
<th>Age group (yr)</th>
<th>Number</th>
<th>Left</th>
<th>Right</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 to 29</td>
<td>12</td>
<td>7.54 (6.93 to 8.14)</td>
<td>7.67 (7.03 to 8.29)</td>
<td>0.13 (-0.09 to 0.35)</td>
</tr>
<tr>
<td>30 to 39</td>
<td>12</td>
<td>7.32 (6.72 to 7.92)</td>
<td>7.55 (6.83 to 8.27)</td>
<td>0.23 (-0.02 to 0.47)</td>
</tr>
<tr>
<td>40 to 49</td>
<td>12</td>
<td>7.12 (6.60 to 7.64)</td>
<td>7.43 (7.00 to 7.85)</td>
<td>0.31 (0.06 to 0.56)</td>
</tr>
<tr>
<td>50 to 59</td>
<td>12</td>
<td>6.73 (6.21 to 7.26)</td>
<td>7.77 (6.20 to 7.33)</td>
<td>0.03 (-0.21 to 0.28)</td>
</tr>
<tr>
<td>60 to 69</td>
<td>12</td>
<td>6.53 (6.14 to 6.92)</td>
<td>6.62 (6.16 to 7.08)</td>
<td>0.09 (-0.01 to 0.19)</td>
</tr>
<tr>
<td>70 to 79</td>
<td>12</td>
<td>6.22 (5.84 to 6.60)</td>
<td>6.40 (6.09 to 6.71)</td>
<td>0.18 (0.03 to 0.33)</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>6.91 (6.70 to 7.12)</td>
<td>7.07 (6.85 to 7.30)</td>
<td>0.16 (0.07 to 0.25)</td>
</tr>
</tbody>
</table>

Fig. 1

B-mode ultrasound image of supraspinatus.
Age (p < 0.003 and p < 0.002, respectively) and weight (p < 0.008 and p < 0.006, respectively) were significant predictors of the CSA of supraspinatus after adjusting for the other variables, but that height was not (p = 0.16 and p = 0.38, respectively; Tables III and IV). It also showed that the CSA of supraspinatus decreases for each additional year of age, and increases for each additional kilogram of weight.

**Discussion**

Previous studies by Veeger et al \(^{28}\) and Poppen and Walker \(^{29}\) using direct measurement on cadavers reported values for the CSA of 5.21 ± 1.76 and 6.21 cm\(^2\), respectively. They did not distinguish between right and left sides.

In our study the mean CSA for all the subjects was 7.07 ± 0.94 cm\(^2\) and 6.91 ± 0.90 cm\(^2\) for the right and left side, respectively, which is larger than the values listed above. The main reason for the discrepancy is that the observation slices were at different sites. In the previous two studies the slices were reported to be perpendicular to the muscle fibres on the largest CSA of the muscle belly by direct observation of the specimen. In our study direct observation was not possible and it was decided to use a slice perpendicular to the spine of the scapula, which is easier to determine clinically. This may have been at a slight deviation from the perpendicular, which would give a larger value for the CSA. The previous studies also had fewer subjects and did not examine gender, activity or hand dominance or the effect of height or age. In our study the slice was as close to the perpendicular as possible and used clearly palpable reference points such as the medial and posterior edges of the spine of the scapula.

The reliability of the measurement of the CSA of supraspinatus using diagnostic ultrasound was high, with an intraclass correlation coefficient (ICC) of 0.93. Rankin and Stokes \(^{30}\) reported a high reliability of measurement between scans on the same day (ICC = 0.94) and on different days (ICC = 0.92) for the CSA of tibialis anterior, which is similar to our findings. This suggests that the measurement of the CSA of supraspinatus can be used as a reliable clinical parameter.

We found a statistically significant difference (p < 0.001) between dominant and non-dominant sides. The CSA of the dominant (right) side was significantly larger than that of the non-dominant. The estimated mean difference between the two sides was 0.16 cm\(^2\) (95% CI 0.07 to 0.25) and similar differences were observed in all six age groups (Table II). The inclusion and exclusion criteria which we used included some limitations on the level of activity of our subjects. The influence of hand dominance on the CSA of supraspinatus in sedentary males with no shoulder symptoms is very small. Although the mean difference between the dominant and non-dominant side was statistically significant the difference was not large enough to be clinically significant.

ANOVA showed significant differences among the six age groups, and multiple regression analysis a significant decrease in CSA with ageing. The CSA is also influenced by the weight of the subject. On the left side, on average, it decreased by 0.017 cm\(^2\) per year’s increase in age, and increased by 0.031 cm\(^2\) per kilogram increase in body weight, and on the right by 0.017 cm\(^2\) and 0.036 cm\(^2\), respectively. These findings suggest that ageing is one of the primary factors which influences the CSA. Our findings showed that the CSA in the 70- to 79-year age group was 83.4% on the right and 82.5% on the left of those in the 20- to 29-year age group. Young, Stokes and Crowe \(^{31}\) in a study of the CSA of quadriceps reported a decrease of 25% in the 80-year age group compared with those over 90 years.

Our study was not longitudinal in that it did not determine changes in the CSA of supraspinatus in the same individuals over time. It examined different age groups at one period. Milgrom et al \(^{32}\) using ultrasound reported that the prevalence of partial- or full-thickness tears of the rotator cuff increased markedly after 50 years of age in asymptomatic adults. They indicated that lesions of the rotator cuff are a natural aspect of ageing and are usually asymptomatic. We did not examine our subjects for tears of the rotator cuff, which may be a limitation of this study. Decreasing function of supraspinatus may be a factor in the increased incidence of pathological abnormality in the shoulder as age advances.

We have shown that the use of diagnostic ultrasound can give reliable information regarding the morphological state of supraspinatus, and these findings may be useful in the objective evaluation of pathological conditions of supraspinatus.
References


