Comparison of supraspinatus cross-sectional areas according to shoulder abduction angles

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Abstract. [Purpose] The purpose of this study was to determine the changes in the supraspinatus cross-sectional areas according to shoulder abduction angles, using ultrasonography. [Subjects and Methods] The subjects consisted of 40 individuals (20 males and 20 females). The cross-sectional areas of the supraspinatus of all subjects were measured with ultrasonography at abduction angle of 0°, 30°, 60°, 90°, and 120°. We set four abduction angle levels (I, II, III, and IV), 0° to 30°, 30° to 60°, 60° to 90°, and 90° to 120°, respectively, when determining the largest change in cross-sectional area. [Results] The results revealed that cross-sectional areas of the supraspinatus increased at all levels, but the abduction angle level with the largest increase in cross-sectional area of the supraspinatus was Level III. [Conclusion] The above results indicate that performing exercises at an abduction angle between 60° and 90° will be the most effective for supraspinatus strengthening in clinical practice.

Key words: Rotator cuff, Supraspinatus cross-sectional area, Ultrasonography

INTRODUCTION

The supraspinatus is one of the rotator cuff muscles; it is positioned at the supraspinous fossa and under the trapezius and it abducts the shoulder joints to rotate externally1, 2). The rotator cuff muscles are highly important for dynamic stability of the shoulders, but it is the supraspinatus that plays an important role in dynamic stability during shoulder abduction. The supraspinatus is also the most frequently injured area when the rotator cuff muscles are injured3). Thus, strengthening the supraspinatus is essential to prevent damage to the rotator cuff.

Generally, the full can and empty can positions are recommended as exercises that strengthen the supraspinatus4, 5). Boetechter et al.6) indicated that there was no distinctive difference in muscle activity between the full can and empty can positions. However, few studies have been conducted to determine changes in the cross-sectional areas of the supraspinatus according to abduction angles, suggesting no definite answers concerning which posture and abduction angles are the best for strengthening the supraspinatus.

Jobe and Moyne7) suggested an abduction angle of approximately 90° for the supraspinatus strengthening exercise, while Escamilla et al.8) suggested that muscle activity of the supraspinatus was highest at an abduction angle of 60°. However, in clinical practice, no recommendation for the abduction angle has been made for the supraspinatus strengthening exercise, so various angles have been applied by physical therapists. It would be much easier for physical therapists to determine the criteria for strengthening exercises if they knew which abduction angle of the shoulders incurs the largest cross-sectional area of the supraspinatus. Therefore, the objective of this study was to determine by ultrasonography the changes in the supraspinatus cross-sectional areas according to shoulder abduction angles.

SUBJECTS AND METHODS

Forty subjects at D college participated in the present study (20 males and 20 females). The average ages, heights, and weights of the subjects were 21.3±2.3 years, 165.2±4.2 cm, and 57.6±4.8 kg, respectively. We excluded individuals who had shoulder pain; had cervical, shoulder, or elbow operations; had experienced sprains or strains; or had neurological problems or blood vessel disorders. All included patients understood the purpose of this study and provided written informed consent prior to participation in the study in accordance with the ethical standards of the Declaration of Helsinki.

In order to measure the thickness of the supraspinatus muscle during shoulder abduction, we seated the subjects in chairs without elbow and back rests, and all subjects wore clothes that exposed the right shoulder and scapula. Two researchers and two research assistants were involved.
in measuring each subject. While subjects were sitting comfortably, their waists and backs remained straight, their eyes faced the horizontal plane in front of them, and their foreheads and chins were positioned vertically. Shoulder abduction was conducted in the frontal plane, the elbows of the subjects were extended, and the palms faced the front with the thumbs up.

During abduction, we set four abduction angle levels—Level I (0° to 30°), Level II (30° to 60°), Level III (60° to 90°), and Level IV (90° to 120°)—to measure the thickness of the supraspinatus muscle with a newly manufactured angle plate (100 cm width × 100 cm length) designed for that purpose. The center point of the angle plate was positioned at the axis of the movement of the shoulder joint. In order for the subject to be able to position their abduction at five different angles, one research assistant adjusted the arm of the subject so that it was positioned at the appropriate angle, and the subject maintained the position while the other research assistant monitored the subject’s response. In each abduction step, subjects maintained positions for 10 seconds to permit the recording of ultrasonography images and took a rest for 10 seconds between steps. All subjects practiced three times before the measurement.

While the subjects conducted each level exercise, an ultrasound imaging system (MySono, Seoul, South Korea) and a 7.5-MHz transducer were used to measure muscle thickness. Two experienced researchers with ultrasonography experience participated in the experiment to measure the ultrasonographic image.

Before ultrasonography, the shoulder areas of all subjects were wiped with alcohol gauze, and gels were applied to the supraspinatus region. One researcher positioned the transducer to give the optimized image of the supraspinatus, while the other researcher operated the computer to capture the optimized supraspinatus image. A line was drawn between the acromioclavicular joint and the superior angle to move the transducer in the longitudinal direction, and the transducer was positioned to see the starting point at the left side of the image. The right side of the supraspinatus muscle of all subjects was measured two times for each level, and the best quality image was selected. During measurement, the MySono U6 was positioned behind the back of the subject so that the subject could not see the ultrasonographic image.

The images obtained from ultrasonography were used to measure the supraspinatus muscle thickness by using the National Institutes of Health Image J software (version 1.44 for Windows). For measurement of supraspinatus muscle thickness, a reference line was drawn at the starting point of the muscle at the left side of the image, while vertical lines were drawn 0.5 cm, 1 cm, and 1.5 cm from the reference line. The distance from the boundary between the trapezius and the supraspinatus muscle and between the supraspinatus muscle and the scapular fossa were measured. Average values of the measured muscle thickness were used, and the change rate of muscle thickness was calculated by the formula (muscle thickness at the time of contraction – muscle thickness at the time of rest)/muscle thickness at the time of rest. All measurements were conducted three times, and averages were used as the final result values.

Based on this protocol, a test–retest reliability study was conducted to determine the degree of reliability between the pre- and post-tests of ultrasound measurements of supraspinatus muscle size in normal young adults. Intra-class correlation coefficient (ICC) statistical analysis revealed good to excellent ICCs ranging from 0.74 to 0.93.

The data collected from this study were analyzed using SPSS 17.0, and the average and standard deviation are presented. In addition, repeated measures of analysis of variance was conducted to determine the rate of change in the thickness of the muscle according to abduction angle. The statistical significance level α was set to 0.05.

### RESULTS

Using ultrasonography, the changes in the cross-sectional area of the supraspinatus according to the shoulder abduction angles were measured. The average rate of change in the thickness of the supraspinatus showed that Level III (60° to 90°) exhibited the most statistically significant change (p<0.05) (Table 1).

| Level  | Level I  | Level II | Level III | Level IV |
|--------|----------|----------|-----------|----------|
| Mean±SD* | 0.36±0.32 | 0.67±0.41 | 0.85±0.50 | 0.65±0.39 |

*p <0.05. The mean±SD values are for repeated measures ANOVA.

### DISCUSSION

The shoulder joints consist of ball and socket joints with insufficient stability but very high mobility. Because of their wide movement range, it is important for the shoulder joints to ensure stability and mobility between many ligaments and muscles. The rotator cuff muscle is important for maintaining stability within the range of most movements of the shoulder joint. In addition, the rotator cuff muscle always moves with movement of the shoulder joints, thus playing the role of a dynamic ligament. Because of this, it frequently experiences damage and is one of the main causes of shoulder pain.

The supraspinatus is the most frequent area of damage in the rotator cuff muscle; thus, the supraspinatus strengthening exercise is highly important for the dynamic stability of this muscle. The full can and empty can positions are both recommended as examination methods for the supraspinatus, but we conducted abduction based on the suggestion that the full can position should be used to avoid conflicts in the subacromial space.

While different recommended positions and angles have been reported for the supraspinatus strengthening exercises, the most commonly used angle is 90° abduction and 30°...
horizontal adduction. Abduction at 90° is reported to result in the highest muscle activity of the supraspinatus; however, Escamilla et al. suggested that 60° of abduction result in the highest muscle activity in the supraspinatus. Furthermore, Forbush et al. reported that both the full can and empty can positions at 60° of abduction result in a significant increase in cross-sectional area compared with that at the time of stabilization. Another study recommended less than 60° of abduction for the empty can position to avoid conflict in the subacromial space, but it also recommended consideration of the full can position.

The measurement results in this study comparing abduction angles of 0°, 30°, 60°, 90°, and 120° showed that the largest cross-sectional area of the supraspinatus was found between 60° and 90°. This result is consistent with previous results showing that the muscle activity and cross-sectional area of the supraspinatus were greatest at a 60° abduction angle. We suggest the reason for our results is that the movement of the shoulder joint is minimized at abduction angles between 60° and 90°, so abduction under the stable condition creates stronger torque in the supraspinatus. Therefore, performance of abduction exercises that strengthen the supraspinatus, which is essential to improve the functions of the rotator cuff muscle, is suggested at abduction angles between 60° and 90°. While previous studies have suggested only one angle for abduction, we set a range of angles instead of a single angle to suggest an effective range of movement.

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