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The comparison of the shoulder muscle activation in patients with rotator cuff tear under an abduction brace among the three postures

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ABSTRACT

Background: Immobilization using an abduction brace is essential for the relaxation of the rotator cuff and scapular muscles and the prevention of a retear in patients with rotator cuff tear after arthroscopic rotator cuff repair (ARCR). However, thus far, the comparison of the scapular muscle activities has not been compared among different postures under an abduction brace in patients after ARCR.

Objectives: The purpose of our study was to compare the scapular muscle activities among the supine position, sitting position, and walking under an abduction brace before and after ARCR

Study Design: Observational, repeated measures study.

Methods: Twelve patients with full-thickness rotator cuff tears were studied. The mean patient age was 64.7 years. The scapular muscle activations of the ipsilateral limbs were measured using surface electromyography in three postures: supine position, sitting position, and walking. The integrated electromyography relative values of the upper trapezius, anterior deltoid, middle deltoid, and biceps brachii were compared preoperatively and at two weeks after ARCR.

Results: The trapezius, biceps brachii, and middle deltoid in the walking showed significantly higher integrated electromyography relative values than those in the supine position, preoperatively and at two weeks after surgery. The anterior deltoid in the sitting position had significantly higher integrated electromyography relative values than those in the supine position.

Conclusions: Postures affected the scapular muscle activities in ARCR patients under an abduction brace. Understanding the influence of posture on the scapular muscle activity after ARCR will help rehabilitation accurately and appropriately.

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Background

Rotator cuff tears remain a significant clinical problem. 65% of total rotator cuff tears were found to be asymptomatic. [1,2] Arthroscopic rotator cuff repair (ARCR) is an accepted and widely used treatment for rotator cuff tears to decrease pain and to recover normal range of motion to allow a return to work. [3]

Electromyography (EMG) has been used to measure shoulder muscle activation objectively during both isometric and functional tasks, and to guide postoperative rehabilitation progression following rotator cuff repair. [4,5] Previous studies have reported on the muscle activation of the shoulder muscles using electromyography. [6-16]

Some researchers have also evaluated the muscle activation of the shoulder muscles using electromyography for rotator cuff tears. [5,6,17-23] EMG data analysis showed significantly increased subscapularis activity in the rotator cuff repair patients during active external rotation. [18] Symptomatic patients demonstrated greater activation of the supraspinatus, infraspinatus, and upper trapezius during shoulder elevation compared with asymptomatic patients. [21] Increased activation of deltoid was required to compensate for lost supraspinatus abduction torque. [19] Alenabi et al. [6] described that active arm elevation should be directed toward flexion and scaption and postponed abduction to prevent high level of activity in this muscle.

Patients who were performed ARCR need to apply an abduction brace for several weeks to prevent a retear of the repaired rotator cuff. Rehabilitation with an abduction brace after ARCR is essential to prevent a retear of the repaired rotator cuff and to rest the scapular muscles. Several previous studies have reported the correlation between changes in the posture and the scapular muscle activity. [13-15] Miyakoshi et al. [14] showed that trunk posture affects scapular kinematics and muscle activity during external rotation. Krause et al. [13] suggested that EMG activity of the shoulder and trunk muscles was dependent on body position. However, no study has yet evaluated whether postures affect scapular muscle activities in patients with rotator cuff tears treated by ARCR under an abduction brace.

The purpose of this study was to evaluate the scapular muscle activities under an abduction brace in patients treated by ARCR and to compare the scapular muscle activities among the supine position, sitting position, and walking. Our hypothesis was that postures affect scapular muscle activities in patients with rotator cuff tears under an abduction brace.

Methods

1. Subjects

Twelve patients (7 males, 5 females) with full-thickness rotator cuff tears received primary ARCR at hospitals between January 2019 and November 2019. The mean patient age was 64.7 (range, 44 to 82) years old, height was 162.8 ± 10.7 cm, and weight was 64.7 ± 14.2 kg. The tear size of rotator cuff tears was evaluated using preoperative magnetic resonance images. The tear size was classified using Cofield classification of rotator cuff tears as follows: small tear < 1cm; medium tear 1-3cm; large tear 3-5cm; massive tear > 5cm (Table 1).

The inclusion criteria were a full-thickness tear of the supraspinatus tendon with or without a combined full-thickness tear of any other rotator cuff tendon, primary ARCR using the suture bridge repair technique, and age ≥20 years old. In order for the study to be considered observational, the orthoses must have been provided to the study participants as a part of their clinical treatment and not by the investigators for the purposes of the study. The exclusion criteria were a partial-thickness tear of any of the rotator cuff tendons, age <20 years old, isolated subscapularis tear, revision surgery, rheumatoid arthritis, tumor, fracture, and infection.

All patients gave their informed consent prior to being included into the study. The study was approved by the Institutional Review Board of ○○○ ○○○○ (No. ○○○○-○○○).

2. Measurement method

An abduction brace (medi SAS 45; Bayreuth ,Germany) was fixed to the waist and the contralateral shoulder by two belts. The ipsilateral shoulder was immobilized in abduction with a removable wedge. The elbow was also immobilized. During the tests, the ipsilateral shoulder was kept in the scapula plane position (30° abduction and 30-45° horizontal abduction. The shoulder muscle activation of the ipsilateral limbs was measured under the abduction brace under three conditions: supine position, sitting position, and walking (Figure 2). The position of the abduction brace was adjusted by the therapist for each patient to the scapula plane position (30° abduction and 30-45° horizontal internal rotation). The patient's upper limbs were placed on cushions to stabilize the patient's upper limbs, and the patient was set to maintain the scapula plane position. The patient was placed in a resting sitting position with the soles of both feet floating and the patient looking forward. The patient walked on a flat, straight, 16-m-long path. A running section and a following section were set up at both ends of the straight line, with the middle 10 m used as the measurement section. The participants were instructed to walk at their most comfortable walking speed.

3. Electromyogram analyses

Surface electromyography (EMG Master; Mediarea Support Inc., Okayama, Japan) was used to measure the scapular muscles (upper trapezius, biceps brachii, anterior deltoid, and middle deltoid muscle) of the affected shoulder joint. A bipolar silver/silver chloride electrodes (Blue Sensor P-00-S, Ambu Inc., Linthicum, USA) was used as the electrode. After sufficient pre-treatment of the skin, the interelectrode center was set at 3 cm. The electrodes were placed at the anterior part of the anterior deltoid muscle three lateral fingers down from the anterior margin of the acromion, the middle part of the deltoid muscle at the midpoint of the line connecting the tip of the acromion and the rough surface of the anterior deltoid muscle, the upper trapezius at the line connecting the seventh cervical spinous process (C7) and the acromion, 2 cm outside and 2 cm below C7, and the long head of the biceps brachii longus muscle at the center of the ventral part of the muscle, along the myofiber. Grounding electrodes were placed at the acromion and the olecranon. The sampling frequency was set at 1 kHz.

Table 1

Patient data (n =12)	
Sex (Male/ Female)	7 / 5
Age (years)	64.7 ± 12.9
Height (cm)	162.8 ± 10.7
Weight (kg)	64.7 ± 14.2
BMI (kg/m^2)	24.3 ± 4.3
Cofield Classification	small: 2, medium: 5, large: 5

Mean ±SD

BMI: body mass index

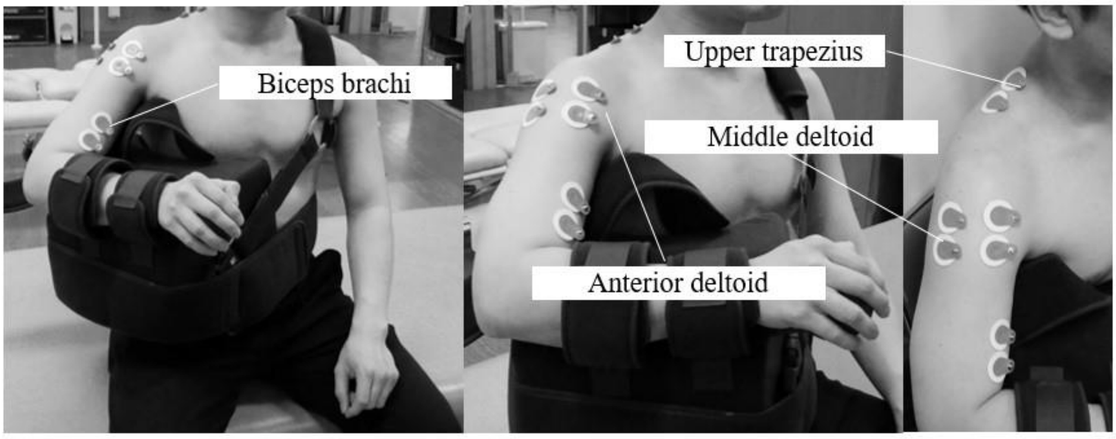

Figure 1. Electrode mounting area

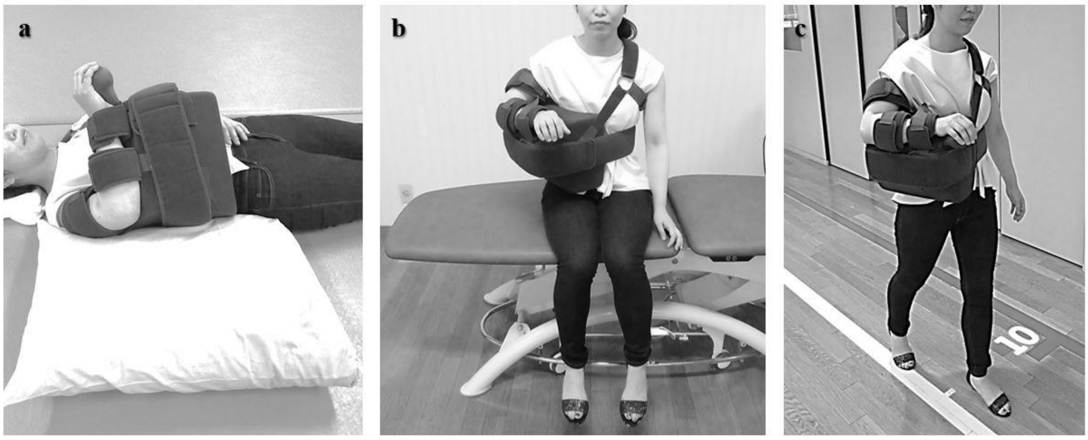

Figure 2. Postures under an abduction brace:
(a) supine position, (b) sitting position, (c) walking

All EMG signals were filtered using a high-pass Butterworth filter with a cut-off frequency of 15 Hz to remove motion artifacts. Subsequently, full-wave rectification processing using the spreadsheet software program which is a custom made spreadsheet (Excel, Microsoft, Inc.,Redmond, WA, USA) with an integrated EMG (IEMG) analysis was performed. First, for the surface electromyogram analysis, the IEMG relative values were obtained from the IEMG of each muscle in the supine position, and the relationship of the IEMG relative values among postures and the IEMG relative values was examined by changing the measurement conditions in the sitting position and while walking. A foot switch sensor I-Scan pressure sensors (Tekscan, Inc., MA, USA) was attached to the heel of the measurement side in order to identify one walking cycle during the measurement.

Regarding the measurements, each limb position was measured three minutes after the electromyography electrodes were applied. The measurement time was set at 10 s. For the walking posture, one gait cycle was assessed using the foot switch signal, and the gait cycle time of each subject was converted to 100%. The IEMG analysis was performed by subtracting the walking cycles at five locations from the four walking cycles of each subject. This analysis was performed at 10% increments for each walking cycle.

The muscle activity of the scapular muscle among the three postures was evaluated preoperatively and at two weeks postoperatively. The assessments were the comparison of the IEMG relative values for the four scapular muscles among the three postures. The testing was conducting both pre and post operatively wearing the same abduction brace.

4. Statistical analyses

The values are presented as the means and standard deviation (SD). The IEMG values of each muscle in the sitting position and walking were compared with the IEMG in the supine position (control group) using Steel's test. The IEMG relative values of each muscle among the three postures were evaluated preoperatively and at two weeks after ARCR. Values of $p<0.05$ were considered statistically significant. A power analysis was conducted a priori with different data. The power assessment using a significance level of 5% and a power of 80% indicated a required sample size of 12.

Results

Preoperatively, the trapezius, biceps brachii, and middle deltoid in the walking showed significantly higher IEMG relative values than those in the supine position (p=0.0182, p=0.0009, p=0.0073), with a median increase of 352%, 145%, and 180%, respectively (Figure 3). No significant differences were found in the four muscles between the supine position and sitting position.

At two weeks after surgery, the trapezius, biceps brachii, and anterior and middle deltoid in the walking showed significantly higher IEMG relative values than those in the supine position (p=0.0368, p=0.0033, p= 0.0180, p=0.0071), with a median increase of 303%, 131%, 86%, and 178%, respectively (Figure 4). No significant differences were found in the anterior deltoid muscle among the three postures preoperatively.

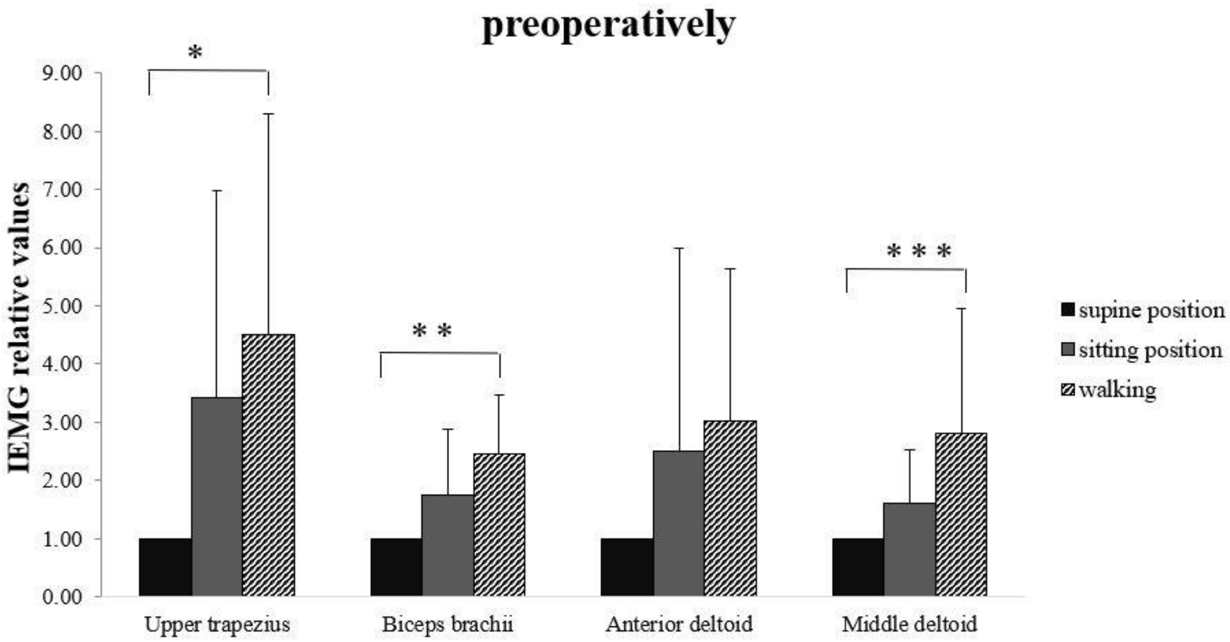

Figure 3. IEMG relative values preoperatively.
The trapezius, biceps brachii, and middle deltoid in the walking showed significantly higher IEMG relative values than those in the supine position (*p = 0.0182, **p= 0.0009, ***p=0.0073; Dunnett's test). No significant differences were found in the four muscles between the supine position and sitting position. No significant differences were found in the four muscles between the sitting position and walking.

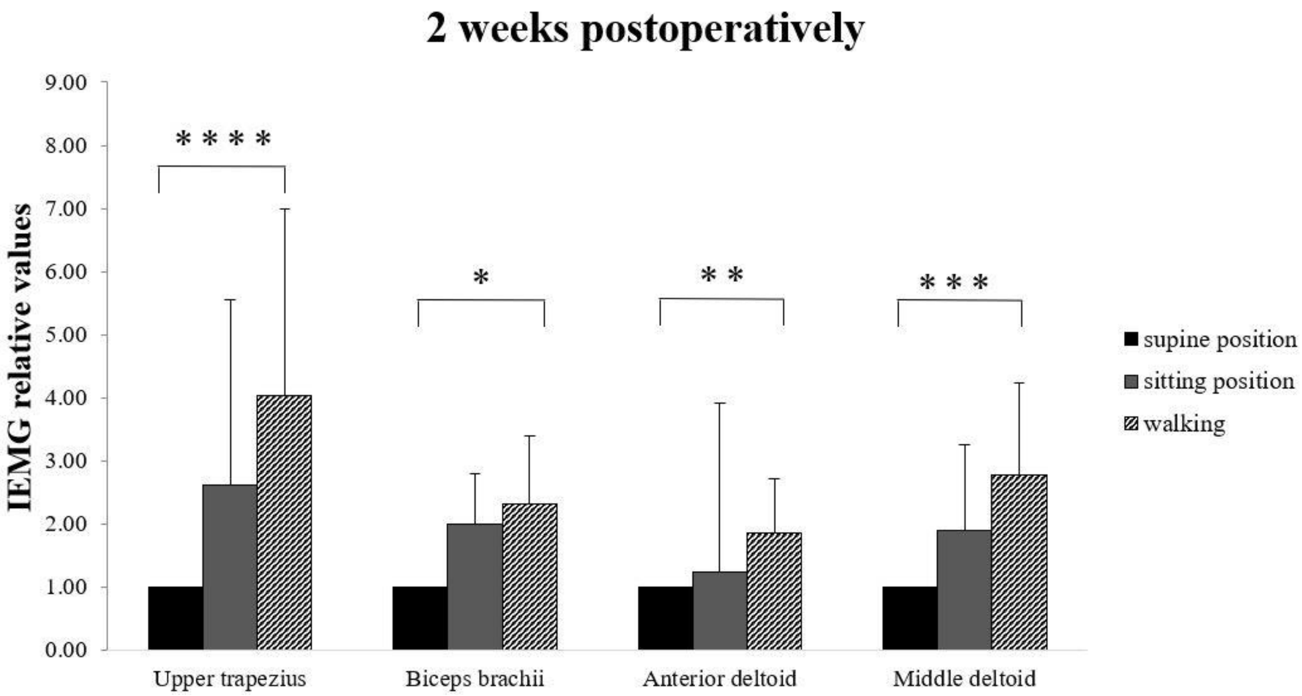

Figure 4. IEMG relative values at two weeks postoperatively.
The trapezius, biceps brachii, and anterior and middle deltoid in the walking showed significantly higher IEMG relative values than those in the supine position (*p = 0.0368, **p= 0.0033, ***p= 0.0180, ****p= 0.0071; Dunnett's test)

Discussion

The major finding of this study was that the trapezius, biceps brachii, and middle deltoid had significantly higher IEMG relative values during walking than in the supine position preoperatively and at two weeks after surgery. Therefore, postures affected the scapular muscle activities in patients with rotator cuff tear under an abduction brace. To our knowledge, this is the first study to compare the scapular muscle activities among different postures under an abduction brace in patients with rotator cuff tears.

The changes in the scapular muscle activity due to posture were thought to be due to the effect of gravity. The deltoid and biceps brachii connect the humerus and scapula, and the trapezius connects the scapula and vertebral body. The origin of the deltoid is the lateral third of the clavicle, acromion, and spine of the scapula, and the insertion of the deltoid is the deltoid tuberosity of the humerus. The origin of the long head of the biceps brachii is the supraglenoid tubercle of the scapula, and the insertion is the tuberosity of the radius. The origin of the short head of the biceps brachii is the tip of the coracoid process of the scapula, and the insertion is the tuberosity of the radius. The origin of the superior trapezius is the external occipital protuberance and the spinous processes of the C7-T12 vertebrae, and the insertion is the lateral third of the clavicle, acromion, and spine of the scapula. [24]

When walking, the humerus moves downward due to gravity. Subsequently, the deltoid and biceps muscles are stretched, which may result in increased muscle activity as a stretch reflex. While walking, the scapula also moves downward, and the upper mitral muscle is stretched, which may result in increased muscle activity due to the stretch reflex. [25,26] With the upper limb immobilized with an abduction orthosis, the muscle activity of the mitral, deltoid, and biceps muscles of the upper limb was subsequently altered. This antigravity position may affect the hyperactivity of the upper trapezius, biceps, and anterior deltoid muscles of the upper extremities. Patients who undergo ARCR are able to walk immediately after surgery, and relaxation exercises and lifestyle guidance are necessary starting the next day to reduce the muscle activity of the scapula.

Several previous studies have described the correlation between changes in the posture and the scapular muscle activity. [13-15] In resisted isometric shoulder external rotation exercises, the EMG values of the infraspinatus were reported to be greatest in the side-plank position. To strengthen the infraspinatus, the side plank is preferred over the standing or side-lying position. [13] Miyakoshi et al. [14] evaluated the effect of different trunk postures during external rotation. The difference in trunk posture affected the scapular kinematics and muscle activity of the scapular muscles during active shoulder external rotation at 90° of abduction. Nakamura et al. [15] noted that the muscle activities of the serratus anterior, anterior deltoid, and infraspinatus were higher in the sitting position than in the standing position when a load of 7% of the body weight was applied in both the sitting and standing positions. They concluded that the scapular muscle activity was modified relative to changes in the body posture and resistance intensity. Some researchers have evaluated the shoulder muscle activity in patients with rotator cuff tears. [5,6,17-23] Fritz et al. [18] evaluated the muscle activation of the shoulder after the repair of the supraspinatus muscle compared to that in healthy shoulders. EMG data analysis showed significantly increased subscapularis activity in the rotator cuff repair patients during active external rotation. Hawkes et al.[19] measured fatigability of shoulder muscles in healthy controls and patients with massive rotator cuff tear. The results suggested that increased activation of deltoid was required to compensate for lost supraspinatus abduction torque. Kelly et al. [21] compared the shoulder muscle activation in patients with symptomatic and asymptomatic rotator cuff tears. Symptomatic patients had greater activation of the supraspinatus, infraspinatus, and upper trapezius during shoulder elevation than asymptomatic patients. They concluded that symptomatic patients continue to fire paradoxically torn rotator cuff tendons and are forced to rely on the scapular muscle substitution during elevation maneuvers.

Regarding previous studies on the shoulder muscle activities under an abduction brace, [6,12,21] the effect of resistance exercises on the muscle activity of an upper limb under an abduction orthosis supported elbow and wrist flexion/extension in the horizontal plane, with weights of up to 4 lb, minimally activated the rotator cuff muscles while potentially preventing muscle disuse of other upper limb musculature. It was also noted that elbow, wrist, and finger movements could minimally activate the rotator cuff muscles when the shoulder was immobilized with an orthosis.[12]

Several limitations associated with the present study warrant mention. First, only four muscles (upper trapezius, biceps brachii, anterior deltoid, and posterior deltoid) were examined. The muscle activity of the supraspinatus and infraspinatus muscles, serratus anterior, and the lower trapezius muscles should also be investigated in the future. Second, only an electromyographic analysis was evaluated, and the kinematic data are insufficient. Third, this study was conducted only in patients with rotator cuff tears, without any comparison with healthy individuals. Further investigations will be necessary to compare the scapular muscle activity between patients with rotator cuff tear and healthy volunteers under an abduction brace.

Conclusion

In conclusion, the upper trapezius, biceps brachii, and middle deltoid had significantly higher IEMG relative values while walking then in the supine position preoperatively and at two weeks after surgery. Understanding the influence of postures on the scapular muscle activity after ARCR will allow clinicians to perform rehabilitation accurately and appropriately.

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