A Comparison of Levels of Muscle Activity Based on Stabilization Exercise Methods Applied to Patients with Rotator Cuff Tendon Tears

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Abstract

For normal shoulder joint movements, sternoclavicular articulation, the acromioclavicular joint, the glenohumeral joints, and the scapulothoracic joints should be coordinated. For remedial program after arthroscopic surgery for rotator damage, muscle exercise for the rotator should be regarded as an important factor, and clinical approaches should be adopted to promote muscle control and balance. This study was conducted on 30 patients in their 30s and 40s who underwent arthroscopic surgery for supraspinous muscle tendon rupture 4–6 weeks prior; such rupture represents one of the most common types of rotator cuff tear. Four types of remedial treatments—rowing in prone position, Superman 'T', prone supported on elbow and pushup with hands—were used to measure the muscle activity of the upper trapezius, lower trapezius, and serratus muscle. Considering all these factors, it was determined that each exercise method led to different muscle activities. No ideal exercise method was found to reduce the muscle activity of upper trapezius muscle and increase that of the lower trapezius and serratus muscle. Therefore, it is considered that each stabilization exercise should be applied in a selective manner based on the patient's condition and a doctor's diagnosis.

Keywords: Rotator cuff, EMG, Stabilization exercise

1. Introduction

Shoulder joints have the greatest scope for exercise in the body; anatomically, they are composed of thin glenoid cavities, and these often cause instability between the acromion and humeral head. Such instability can be addressed by strengthening the muscles or ligaments surrounding the shoulder joint [1]. In particular, balance between muscles provides stability to this joint. In addition, shoulder joint muscles produce coordinated activities in association with various other joints to maintain and control mobility [2].

In a given population, about half of the individuals experience shoulder pain in their lifetime [3]. One of the most common causes of such pain is rotator damage [4]. When this condition worsens, it leads to rotator cuff tearing. The rotator is composed of the supraspinous, infraspinous, subscapular, and teres minor muscles. Rotator cuff tears are most frequently observed in supraspinous muscles [5]. They are caused by internal and external factors; internal causes include problems in the rotator itself, resulting from changes in blood supply, collagen fibers, and the physical properties of topical organization. In contrast, external causes include the environment and external stimuli caused by morphological abnormalities in the acromial arch, excessive tensile force, and abnormalities in motor mechanics [6]. Symptoms of rotator cuff tearing include

omarthralgia, myatrophy, weakening of the shoulder joint muscle, and oppressive pain in the anterolateral part of shoulder joints, which all cause difficulties in everyday activities [7].

Methods of conservative therapies for rotator cuff tears include painkillers, nonsteroidal anti-inflammatory drugs, intraarticular injection, physical therapy, and exercise treatment [8]. When the condition is not improved by such conservative therapies, rotator cuff repair is usually carried out to relieve pain, recover functions, and prevent further rupture [9]. Remedial exercise is necessary after the surgery. When range of motion is limited, recovering the range of joint motion should take precedence [10]. In addition, muscles composing the shoulder joints should be strengthened [11]. The decline in shoulder muscle strength resulting from full-thickness tearing of the rotator cuff leads to a 19-33% decline in movement of abduction muscle strength and a 22-23% decline in external rotation for isolated supraspinous muscle injury. Itoi et al. (1997) reported that muscle weakness of the shoulder joints is observed in patients with rotator cuff tears, while Kibler et al. (2006) stated that for the shoulder functions to be recovered [12-13]. In addition, Sahrmann (2002) reported that shoulder joint damage and abnormal scapular movements have more to do with imbalances in muscle activities and less to do with weakened scapulothoracic joint muscles; Sahrmannargued in particular that that excessively activated upper trapezius muscles affect abnormal scapular movements [14]. Furthermore, abnormal muscle activities in the serratus muscles are observed in many patients with shoulder joint damage. Reduced muscle activities in the serratus muscles are found in baseball players with glenohumeral and joint instability, workers with shoulder joint collision syndrome, and swimmers with shoulder joint pain. The reduced muscle activity is related to with abnormal scapula movements [15-16]. For these reasons, balance of the scapular stabilizing muscle should be considered for therapeutic exercise programs designed to prevent and treat functional disorders of the shoulder joints. To this end, closed-chain exercises are usually conducted for upper arm exercise treatment programs [17]. Closed-chain exercise is frequently used in exercise treatment programs to help patients to maintain the dynamic stability and correct posture of the joints, as this provides more proprioceptive senses by stimulating afferent receptors surrounding the joints, coordinating and contracting various muscles through mechanical pressure on the articular surface, enhancing, endurance and strengthening muscle power [18].

According to Ahn (2011), remedial exercise programs enhance the muscle functions and power of patients with rotator cuff tears after arthroscopic surgery [19]. Moreover, Oh (2011) stated that during the 12-week period of the program in a study, participants' subjective pain was reduced significantly over time (4, 8, 12 weeks), joint working range was increased, and the deficiency ratio determined by the muscle test for normal muscles was reduced [20]. Likewise, for remedial program after arthroscopic surgery for rotator damage, muscle exercise for the rotator should be regarded as an important factor, and clinical approaches should be adopted to promote muscle control and balance. However, few studies have been conducted on muscle activity analysis and muscle balance for each exercise method adopted in many clinical studies. In this regard, the present study was designed to analyze muscle activity for each shoulder's remedial exercise motion after arthroscopic surgery for rotator damage and identify proper shoulder remedial exercise motions.

2. Study Subjects and Methods

2.1. Study Subjects

This study was conducted on 30 patients in their 30s and 40s who had undergone arthroscopic surgery for supraspinous muscle tendon rupture 4–6 weeks prior. Patients with neurological manifestations in the cervical vertebrae and lumbar vertebrae, pain

caused by a vascular problem, fracture, wounds, rheumatoid arthritis, or medical disease, as well as patients who suffered from acute pain and therefore could not conduct the exercise, were excluded from the study. The subjects were fully informed of the research purpose and methods before starting the study. The study was conducted from June 9 to July 30, 2015 with participants who fully understood and agreed to take part in the study.

2.2. Study Methods

In the study, four types of remedial exercises-rowing in prone position, Superman 'T', prone supported on elbow, and pushup with hands-were used to measure muscle activities of the upper trapezius, lower trapezius, and serratus muscles. For rowing in prone position, subjects were asked to lie on their stomachs with their involved arm hanging over the side of the table, hold a 1 kg dumbbell in the hand with the elbow straight, and slowly raise the arm while bending the elbow. For Superman 'T', subjects were asked to lie on a gym ball, facing down, with the involved arm hanging straight to the floor and the palm facing down, shoulder joints flexed at 90 degrees (horizontal abduction), and elbow joints flexed at 90 degrees. For prone supported on elbow, subjects were asked to lie on the bed on their stomachs and lift their body off the ground, supporting their upper body with their elbows directly under the shoulder and their forearms flat on the ground. Meanwhile, they maintained their body in a straight line from the shoulder. For pushup with hands, subjects started in a normal pushup position with both hands on a balance ball. Their shoulders were directly above their hands. Then, they were asked to flex their elbow joints. The subjects were fully informed of the exercise methods before starting the exercises.

To carry out electromyography (EMG) measurements, the laboratory temperature was kept at 25°C. Moreover, to reduce skin resistance, hair where the electrodes were to be placed was shaved using a razor, and the surface of the skin was rubbed with sandpaper to remove dead skin cells. For collection of EMG signals, three muscle areas where electrodes were to be placed were marked with a pen. The trapezius muscle is located between the C7 processusspinosus and the acromion. The lower trapezius muscle is located in the one-fourth from the thoracic vertebrae to the scapula when the arm is fully flexed on a sagittal plane. The serratus muscle is between the area below the armpit and the forefront of the latissimusdorsi muscle. To locate the correct point, the arm was raised over the head and the fore part of latissimusdorsi muscle, located at the bottom of the scapula, was contracted. The muskelbauch, where the maximum muscular contraction was observed, was found. Activated electrodes and reference electrodes were attached according to the location of muscular fibers, and ground electrodes were attached on each muscle inner and outer of the electrodes. Each electrode was placed with 2 cmapart[21]. For the EMG measurement, Ag/AgCl Meditrace (Kendall[®], Canada) surface electrodes were used. Every motion was repeated three times to calculate the mean value, which was used as the measurement value.

Analog EMG signals collected on two channels of Bagnoli DE3-1 surface electrodes were sent to the MP100 system to be converted into digital signals. On a PC, AcqKnowledge 3.71 software was used to filter and process other signals. The sampling rate of the EMG signal was 512 Hz, and a 20–250 Hz band pass filter and 60 Hz notch filter were used. The Bagnoli DE3-1 EMG electrodes comprised double differential amplifiers.

The SPSS (Ver.18.0) statistical program was used to analyze data in this study. Oneway analysis of variance (ANOVA) was used for significance testing of the data from each exercise data, and LSD was used for the post hoc test. The significance level was set at α <.05.

3. Results

This study aimed to examine muscle activity of the upper trapezius, lower trapezius, and serratus muscles by carrying out rowing in the prone position, Superman 'T', prone supported on elbow, and pushup with hand exercises, which are widely used as remedial exercises after arthroscopic surgery for supraspinous muscle tendon rupture. The results are described below.

	Ex 1	Ex 2	Ex 3	Ex 4	F	р
UT (%)	20.57±15.78	59.77±25.76	10.43±4.34	9.30±5.12	35.230	$.000^{*}$
LT (%)	88.13±42.52	82.13±40.47	25.66±35.20	23.18±28.82	13.438	$.000^{*}$
SA (%)	14.48±18.71	9.35±7.79	48.71±22.88	57.37±36.86	15.188	$.000^{*}$

Table 1. Comparison of RMS among Each Exercise

p<.05, Ex 1: rowing in prone, Ex 2: Superman 'T', Ex 3: prone supported on elbow, Ex 4: pushup position w hand, UT: Upper Trapezius, LT: Lower Trapezius, SA: Sarratus anterior

Significant differences were found for the muscle activities of the upper trapezius muscle depending on the exercise method (p<.05). The lowest muscle activity was observed for the pushup with hand position, and the post hoc test showed a significant difference between pushup position with hands and Superman 'T' (p<.05). Statistically significant differences were also found when comparing Superman 'T' with rowing in prone position and prone supported on elbow (p<.05).



Figure 1. RMS of Upper Trapezius Compared to Each Exercise

Ex 1: rowing in prone, Ex 2: Superman 'T', Ex 3: prone supported on elbow, Ex 4: pushup position w hand

Statistical differences were found for the muscle activity of the lower trapezius muscle depending on the exercise methods (p<.05). The highest muscle activity was observed for rowing in prone position, and the post hoc test showed a significant difference with prone supported on elbow and pushup position with hands (p<.05). Superman 'T' exhibited a statistically higher muscle activity than prone supported on elbow and pushup position with hands (p<.05). However, no significant differences were found between rowing in prone position and Superman 'T' or between prone supported on elbow and pushup position with hands (p>.05).



Figure 2. RMS of Lower Trapezius Compared to Each Exercise

Ex 1: rowing in prone, Ex 2: Superman 'T', Ex 3: prone supported on elbow, Ex 4: pushup position w hand

Significant differences were found for the muscle activity of serratus muscle depending on the exercise method (p<.05). The highest muscle activity was observed for pushup position with hands. The post hoc test showed no significant differences between rowing in prone position and Superman 'T', and no statistically significant differences were found between prone supported on elbow and pushup position with hands(p>.05). However, significant differences were found between rowing in prone / Superman 'T' and prone supported on elbow. Moreover, significant differences were found between rowing in prone position/Superman 'T' and pushup position with hands (p<.05).



Figure 3. RMS of Sarratus Anterior Compared to Each Exercise

Ex 1: rowing in prone, Ex 2: Superman 'T', Ex 3: prone supported on elbow, Ex 4: pushup position w hand

4. Discussion

For normal shoulder joint movements, sternoclavicular articulation, the acromioclavicular joint, the glenohumeral joints, and the scapulothoracic joints should be coordinated [22]. The stability of shoulder joints can be complemented by the rotator. which stabilizes the head of the humerus by working with the deltoids when the arms are moving [23]. Since the rotator is combined with the articular capsule, it is also called the active ligament. The rotator is connected by one continuous band near a stopped position; thus, the contraction of each muscle affects a neighboring tendon, and this should be considered for the treatment of rotator when some part of a tendon is torn[24]. Scapular stabilizers also provide stability to glenohumeral and joints. They work with rotator muscles, including the serratus, upper trapezius, and lower trapezius muscle to rotate the scapulaupward [23]. When the scapula is rotated upward, the lower trapezius and serratus muscles work first. At an earlier stage, the serratus and upper trapezius muscle, as well as fibers in the lower part of the serratus muscle work together to rotate the scapula upward [23]. In particular, the serratus muscle plays an important role in exercising and controlling the scapula. The lever arm, which rotates the scapula upward is longer than other scapulothoracic joint muscles. For this reason, these muscles serve as agonistic muscles for the movement of the scapula, preventing prevent scapula winging [25].

The pathology of shoulder joints and abnormal movement of the scapula have to do with imbalanced muscle activities rather than weakened muscles [14]. For the scapula to function properly, the muscles attached to the thoracic vertebrae and the scapula should have a normal muscle power, recruitment pattern, and proper length. Scapulothoracic musculature plays a major role in the movement of the scapula. To minimize abnormal

stresses on the biceps tendon attaching to the shoulder joint, it should coordinate well with the humerus [14]. Therefore, for patients suffering from imbalances in the trapezius muscle/serratus muscle, exercise designed to selectively strengthen the serratus while maintaining the activation of trapezius to increase the balance between the two muscles will be reduced should be selected instead of exercises that promote the activity of the scapulothoracic muscles.

Sahrmann (2002) argued that scapula control damage occurs due to a weakened, lengthened, or shortened serratus muscle or changes in the timing of scapula exercises related to humerus exercises [14]. Wilk and Arrigo (1993) argued that if serratus muscle problems lead to abnormal activities of the scapula, the joints—including the glenohumeral joint—will be affected, as well as forces and arrangements related to movements surrounding joints [26]. Cools *et al.* (2007) argued that reduced activity of the serratus muscle, increased activity of the upper trapezius muscle, and imbalances in upper and middle/lower trapezius muscle cause abnormal movements of the shoulder joints, leading to rotator cuff tears [27][28]. Therefore, to treat patients with rotator cuff tears, it is important to address imbalances of the trapezius and serratus muscles to ensure that the scapula can fully rotate upward.

This study was conducted on 30 patients in their 30s and 40s who underwent arthroscopic surgery for supraspinous muscle tendon rupture 4–6 weeks prior; such rupture represents one of the most common types of rotator cuff tear. Four types of remedial treatments—rowing in prone position, Superman 'T', prone supported on elbow and pushup with hands—were used to measure the muscle activity of the upper trapezius, lower trapezius, and serratus muscle.

In the results, statistically lower muscle activity was observed for the upper trapezius muscle when conducting rowing in prone position compared to Superman 'T', while statistically higher muscle activity was observed for the lower trapezius muscle compared to the effectiveness of prone supported on elbow and pushup with hands. However, lower muscle activity was observed for the serratus muscle when compared to the effectiveness of prone supported on elbow and pushup with hands. Significantly higher muscle activity was observed for the lower trapezius muscle when conducting the Superman 'T' compared to prone supported on elbow and pushup with hands. In contrast, higher muscle activity was observed for the upper trapezius muscle when conducting rowing in prone position, prone supported on elbow, and pushup with hands. In addition, since statistically low muscle activity was observed for the serratus muscle when conducting prone supported on elbow and pushup with hands, these two exercises cannot be regarded as effective. Statistically lower muscle activity was observed for the upper trapezius muscle when conducting prone supported on elbow and pushup with hands, while statistically higher muscle activity was observed for the serratus muscle compared to the effectiveness of rowing in prone position and Superman 'T'. However, statistically lower muscle activity was observed for the lower trapezius muscle compared with the effectiveness of rowing in prone position and Superman 'T'.

Considering all these factors, it was determined that each exercise method led to different muscle activities. No ideal exercise method was found to reduce the muscle activity of upper trapezius muscle and increase that of the lower trapezius and serratus muscle. Therefore, it is considered that each stabilization exercise should be applied in a selective manner based on the patient's condition and a doctor's diagnosis.

The limitations of the study were that the number of patients was small and that the study results cannot be generalize, since the research only included patients who had undergone arthroscopic surgery for supraspinous muscle tendon rupture 4–6 weeks prior to the study. In addition, only four types of stabilization exercise methods were used for comparison, and EMG was conducted for specific muscles. Single measurements were used for the study, so the treatment effectiveness was not compared, and follow-up measurement over time was not conducted. Thus, we were unable to observe the potential

long-term effects of the exercises. Based on the findings of the study, more research needs to be done on various diagnoses, exercise methods, and muscles related to this topic.

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