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Selective Activation of the Infraspinatus during Various Shoulder External Rotation Exercises

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Abstract. [Purpose] To investigate the selective activation of the infraspinatus muscle while minimizing the use of the posterior deltoid muscles during common shoulder external rotation exercises. [Subjects] Thirty-two able-bodied volunteers (18 males, 14 females; aged 22 to 31 years, mean ± SD, 24.7 ± 3.3 years) were recruited for this study. [Methods] The participants were instructed to perform four exercises: side-lying external rotation; prone abduction with external rotation; sitting external rotation, and sitting with abduction and external rotation exercise. The EMG signal amplitude was measured during each exercise. Surface EMG signals were recorded from the infraspinatus and posterior deltoid muscles. Differences among the exercises were tested using one-way repeated-measures analysis of variance. [Results] EMG activities of the infraspinatus and posterior deltoid muscles in prone abduction with external rotation were significantly higher than in the other exercises. The EMG ratio (infraspinatus/posterior deltoid) was significantly higher in sitting external rotation than in the other exercises. [Conclusion] Based on these findings, sitting with external rotation should be used to minimize posterior deltoid activation and selectively stimulate infraspinatus muscle activity during shoulder external rotation exercise.
Key words: EMG, Infraspinatus, Selective muscle activation

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INTRODUCTION

Shoulder pain is the most common type of musculoskeletal pain in the clinical setting[1)]. Poor neuromuscular control and unbalanced muscle activity of the shoulder joint are major factors related to shoulder musculoskeletal pain, such as shoulder instability, shoulder dislocation, and impingement syndrome[2–4)]. To prevent these injuries, many clinicians and researchers have emphasized selective muscle activity of the infraspinatus during exercise programs and functional activities, because of its critical role in providing dynamic stability and producing external rotation torque at the shoulder joint[5–7)].

The infraspinatus muscle is one of the rotator cuff muscles and provides the primary external force during shoulder movement[8)]. To enhance the strength and endurance of the infraspinatus muscle, shoulder external rotation exercises in various positions are often performed by patients with shoulder instability[9)]. There are several shoulder external rotation exercises for infraspinatus strength, including shoulder external rotation in the side-lying position, shoulder external rotation with 90 degrees abduction in the prone position, shoulder external rotation while sitting, and shoulder external rotation with 90 degrees abduction while sitting[5–7, 9–15)].

Several studies have reported inconsistent results of selective infraspinatus strengthening, with respect to the shoulder joint position. Reinold et al.[7)] compared EMG activity of the infraspinatus among seven shoulder exercises. They reported that the greatest infraspinatus activity was found during the side-lying external rotation at zero degrees abduction. However, other investigators compared prone external rotation at 90 degrees abduction with side-lying external rotation at 0 degrees abduction and reported no significant difference in infraspinatus muscle activity between the exercises[9)].

Higher recruitment of the infraspinatus muscle, compared to the recruitment of posterior deltoid, is dependent on a number of variables, including arm and body position[16)]. A recent tendency in therapeutic protocol is to focus on functional restoration of specific target muscles[17)]. Individuals performing shoulder external rotation exercises tend to engage in excessive posterior deltoid muscle activation more than infraspinatus activation[16)]. To prevent unwanted excessive muscle activity of the posterior deltoid, many researchers have emphasized selective muscle activity of the infraspinatus during common shoulder external rotation exercises[5–7)]. Weakness of the infraspinatus is compensated for by increased activity of the posterior deltoid[16)]. Sahrmann[18)] has suggested that if the posterior deltoid muscle is dominant over the infraspinatus muscle during shoulder external rotation, it would contribute to abnormal anterior gliding of the humeral head. Excessive activation of the posterior deltoid compared to infraspinatus activation during shoulder external rotation led to superior humeral head migration, potentially perpetuating shoulder instability[5, 6, 9]. During external rotation exercise of the shoulder, feedback may be useful to correct unwanted compensation[18].

Though many therapists use external rotation exercise in various positions to promote infraspinatus muscle strength and prevent excessive posterior deltoid muscle activation, there is no information on the effectiveness of particular exercise positions and on how these alter the activation level of related muscles. Many researchers have studied treatment protocols of functional recovery and selective activation of the infraspinatus. However, most studies examined variations in exercise types or positions, and only a few have suggested methods for selective infraspinatus strengthening using various shoulder joint positions during shoulder external rotation exercise.

Purpose of this study was to measure the electromyographic (EMG) signal amplitude (i.e., muscle activity) of the infraspinatus and posterior deltoid muscles during four types of shoulder external rotation exercise. Investigating the effect of the exercise position on the shoulder external rotation exercise should provide beneficial information to the clinician for designing and implementing protocols for shoulder external rotation exercises. We hypothesized that shoulder external rotation exercise in the sitting position would increase the muscle activity ratio (infraspinatus/posterior deltoid) more than other shoulder external rotation exercises.

SUBJECTS AND METHODS

Thirty-two healthy participants (18 males and 14 females) were recruited for this study. The mean age of the subjects was 24.7 ± 3.3 years, their mean weight was 64.6 ± 8.8 kg, and their mean height was 172.3 ± 5.3 cm. Exclusion criteria were as follows: history of cervical, shoulder, or upper back problems, winging scapulae, round shoulder, neurological disease, absence of normal range of movement, and scapulohumeral rhythm (assessed visually). The Inje University Faculty of Health Science Human Ethics Committee granted approval for this study, and all subjects provided their written informed consent prior to participation.

Surface EMG was used to collect the raw EMG data using a Trigno wireless system (Delsys, Boston, MA, USA). The signals were amplified and band-pass filtered (20–450 Hz) before being digitally recorded at 1000 samples/s, and the root mean square (RMS) was then calculated. Two surface electrodes (Trigno sensors; Delsys) were placed on the infraspinatus (4 cm below the spine of the scapula, on the lateral aspect over the infrascapular fossa of the scapula) and the posterior deltoid (lateral border of the spine of the scapula running parallel to the muscle fiber at an oblique angle toward the arm)[19]. The skin was prepared before attaching the electrodes by shaving the site and cleaning with alcohol to reduce skin impedance.

For normalization, 5-s reference contraction data were recorded while subjects performed three trials of maximal voluntary isometric contraction (MVIC) in the manual muscle testing position, as recommended by Kendall et al. (2005)[20]. The infraspinatus muscle was tested by laterally rotating the shoulder joint while stabilizing the humerus in the glenoid cavity during movement. Manual resistance was applied by one of the researchers. The subject was placed in a prone position during testing of the posterior deltoid muscle. The shoulder joint was abducted horizontally with a slight lateral rotation. All of the muscles were tested in the prone position. The first and last second of each MVIC trial was discarded, and the remaining 3 s of EMG data were used in the analysis. Three repetitions of each test were performed, with a 2-min rest interval between repetitions to minimize muscle fatigue. All EMG data were expressed as a percentage of the MVIC (%MVIC).

All subjects reported the right arm to be their dominant arm (the arm preferred when performing eating tasks), and the dominant arm was tested for all subjects. Prior to testing, all subjects were familiarized with the four shoulder external rotation exercises with a 1-kg dumbbell. A goniometer was used to determine when the shoulder was at 60 degrees external rotation. A target bar was placed at this level and provided feedback to the subject when instructed to externally rotate his/her right shoulder while holding a 1-kg dumbbell until the radial border of the wrist touched the bar and to hold the position without elbow flexion for 5 s. We compared four commonly used therapeutic shoulder external rotation exercises. The exercises performed were prone with horizontal abduction and external rotation (PAER)[7, 9, 10, 15], side-lying external rotation (SDER)[7, 9, 10, 12, 13, 15], sitting external rotation (STER)[5–7, 10, 14], and sitting with horizontal abduction and external rotation (SAER)[7, 10]. Each subject performed the four common external rotation exercises in a random order. In PAER, the subject was positioned prone with the dominant arm abducted at 90 degrees and the elbow at 90 degrees of flexion. The subject moved from the start position, lifting the weight toward the ceiling until the wrist joint touched the target bar. For SDER, the subject was placed in the side-lying position with the upper arm aligned parallel to the trunk and the elbow flexed at 90 degrees. From the starting position, the subject lifted the weight toward the ceiling until the wrist joint touched the target bar. For STER, the subject sat with the upper arm aligned parallel to the trunk and the elbow flexed at 90 degrees. From the starting position, the subject moved the arm away from the side, keeping the forearm parallel to the floor until the wrist joint touched the target bar. SAER was performed in the sitting position. The exercise required the subject to abduct the dominant arm at 90 degrees with the elbow flexed 90 degrees. From this starting position, the subject lifted the weight toward the ceiling until the wrist touched the target bar. If subjects substituted an unwanted motion, such as elbow flexion or shoulder horizontal extension during PAER, elbow or shoulder extension during SDER, shoulder or elbow extension during STER, or scapular retraction during SAER, the data were discarded. EMG activity was measured during isometric contraction at the end of exercise for 5 s and the mean was calculated using the middle 3 s of

Table 1. EMG activation expressed as a percentage of maximal voluntary isometric contraction (%MVIC) for each exercise

Mcleus	Exercise, mean ± SD			
	SDER	PAER	STER	SAER
IS	17.73 ± 11.63	30.18 ± 10.39	13.19 ± 9.94	17.00 ± 7.99
PD	8.30 ± 6.40	20.65 ± 11.56	4.91 ± 5.28	10.07 ± 6.52
Ratio	2.75 ± 1.70	1.81 ± 0.92	3.52 ± 2.00	2.08 ± 1.13

Abbreviations: IS, infraspinatus; PD, posterior deltoid; SDER, side-lying external rotation; PAER, prone with horizontal abduction and external rotation; STER, sitting external rotation; SAER, sitting with horizontal abduction and external rotation. *p<0.05

the 5-s period. Three trials were performed with a 1-min rest period between trials, and the mean value of the three trials was used in the data analysis.

The SPSS statistical package (version 18.0; SPSS, Chicago, IL, USA) was used to analyze the significance of differences in activation of the infraspinatus and posterior deltoid muscles during the shoulder external rotation exercises. One-way repeated-measures analysis of variance (ANOVA) was conducted to test for differences between the infraspinatus and the posterior deltoid and in the EMG ratio (infraspinatus/ posterior deltoid) for each %MVIC value of muscle activation during each exercise. The least significant difference (LSD) correction was applied to identify specific differences between exercises. Significance was accepted at values of $p < 0.05$.

RESULTS

Infraspinatus muscle activity was greatest during PAER ($p < 0.05$). The normalized EMG values of infraspinatus during PAER, SDER, SAER, and STER were 30.18 ± 10.39, 17.73 ± 11.63, 17.00 ± 7.99, and 13.19 ± 9.94, respectively. The posterior deltoid EMG value was significantly lower in STER than in PAER, SDER, and SAER ($p < 0.05$). The normalized EMG values of the posterior deltoid during STER, SDER, SAER, and PAER were 4.91 ± 5.28, 8.30 ± 6.40, 10.07 ± 6.52, and 20.65 ± 11.56, respectively.

The EMG ratio (infraspinatus/posterior deltoid) was significantly higher in STER than in PAER, SDER, and SAER ($p < 0.05$). The normalized EMG ratios of STER, SDER, SAER, and PAER were 3.52 ± 2.00, 2.75 ± 1.70, 2.08 ± 1.13, and 1.81 ± 0.92, respectively. The differences in muscle activity during each exercise are shown in Table 1.

DISCUSSION

Shoulder external rotation exercises are often used for rehabilitation of individuals with shoulder pathologies in the physical therapy field[6]. For rehabilitation of patients with shoulder instability, it is necessary to isolate the infraspinatus muscle during shoulder external rotation exercise as much as possible[5–7, 9]. Accordingly, many authors have recommended selective infraspinatus muscle activation during shoulder external rotation exercises[5–7, 9, 14, 15, 21]. However, no study has investigated the selective activation of the infraspinatus muscle or the EMG ratio (infraspinatus/posterior deltoid) during common shoulder external rotation exercises. This study describes shoulder and body positions that isolate the infraspinatus muscle, enabling more precise treatment.

We analyzed and compared the magnitude of infraspinatus and posterior deltoid activities in four commonly used exercises. We found that the infraspinatus muscle had significantly more activity in PAER (30.18 ± 10.39) than in SDER (17.73 ± 11.63), SAER (17.00 ± 7.99), and STER (13.19 ± 9.94). Increased infraspinatus activity in PAER may have caused lengthening of the infraspinatus, altering the force–length relationship. These results are similar to the findings of Blackburn et al.[15], who reported that the highest level of infraspinatus muscle activity occurred when subjects were in the prone position with the shoulder abducted at 90 degrees, in a comparison with side-lying while the upper arm remained adducted at the side of body.

PAER also resulted in the greatest activity in the posterior deltoid. Reinold et al.[7] reported that posterior deltoid activation was greatest in the prone position compared to other shoulder and trunk positions. The prone position lends gravitational force to the posterior deltoid. If the rotator cuff is not functioning properly, the posterior deltoid's full angle compresses the humeral head against the glenoid, accentuating skeletal, tendinous, and labral lesions[22]. Weakness of the infraspinatus and dominant muscle activity of the posterior deltoid may contribute to excessive anterior gliding of the humeral head during shoulder external rotation exercises. Abnormal anterior gliding of the humeral head contributes to permanent shoulder instability[9, 18].

The EMG ratio (infraspinatus/posterior deltoid) was significantly greater in STER (3.52 ± 2.00) than in SDER (2.75 ± 1.70), SAER (2.08 ± 1.13), and PAER (1.81 ± 0.92). Furthermore, STER elicited the least activity in the posterior deltoid muscle. The posterior deltoid was less affected by gravity in the STER position than in the other positions; this may explain why the EMG value for the posterior deltoid was significantly low. The posterior deltoid is involved in shoulder external rotation and shoulder adduction arm movements[23, 24]. The posterior deltoid may contribute to shoulder adduction in STER. Clisby et al.[5] recommended an adduction strategy in external rotation to reduce high posterior deltoid activity. Similarly, Kelly et al.[14] reported that isolation of infraspinatus muscle activity was best achieved with shoulder abduction at 0 degrees, in a comparison with 45 degrees and 90 degrees, in external rotation in the sitting position. However, Kelly et al.[14] compared the EMG activity of the posterior deltoid and infraspinatus in the sitting position, but not in various positions. Based on our results, external rotation at 0 degrees abduction (either sitting or side-lying) may be a better choice for selective infraspinatus strengthening exercise than 90 degrees abduction external rotation exercise. For effective therapeutic exercise, protocols that step up from STER, to SDER, SAER, and PAER would be better for shoulder instability patients.

This study had several limitations. First, our results cannot be generalized to other populations, as all the subjects who participated in the study were healthy young subjects. Second, this study used surface EMG to determine muscle activity, leaving open the possibility of cross-talk from adjacent muscles. Finally, our study measured EMG activity of the infraspinatus and posterior deltoid, but that is insufficient to represent muscle strength directly. Future studies need to develop new exercise methods for selective muscle activity of the infraspinatus.

Our results suggest that STER is superior to PAER, SAER, and SDER in terms of the higher ratio of infraspinatus to posterior deltoid activity with the least amount of posterior deltoid activity. The posterior deltoid muscle showed the lowest activation in STER. Excessive activation of the posterior deltoid is not desirable in early rotator cuff rehabilitation. Therefore, our results suggest that the most effective early-stage rotator cuff rehabilitation for patients with shoulder instability may be STER.

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