

Comparison of Diagonal Shoulder Exercises with and Without Distal Wrist and Finger Movement

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| Abstract |

PURPOSE: The aim of this study was to investigate the effects of distal movement on shoulder muscle activation during diagonal pattern of exercises.

METHODS: Seventeen healthy male participants volunteered to participate. Five muscles of shoulder were investigated during standing performance of diagonal shoulder exercises with and without visual trace. Two patterns of the diagonal exercises were used as diagonal 1 flexion and extension (D1F-E), and diagonal 2 flexion and extension (D2F-E). Two way repeated measures analysis of variance was used, which the factor was the presence of distal movement and exercise variations.

RESULTS: The average muscle activity values of the lower trapezius and anterior deltoid are higher with the D2F-E, compared to the D1F-E ($p < .05$). The distal movement effect was observed within included all muscles except the lower trapezius, which the values are significantly greater in

exercise with distal movement ($P < .05$). All significant increase of the muscles during the exercise with distal movement condition showed over 0.9 for the observed power in present study.

CONCLUSION: Present result suggested that the diagonal pattern of exercise with distal movement has additional advantages of activating the scapulothoracic muscle as well as glenohumeral muscles. In addition, the D2F-E exercise pattern is effective for activating lower trapezius and anterior deltoid muscles.

Key Words: EMG, PNF, Distal firing

I. Introduction

Selecting proper exercises for improving strength of shoulder muscles are essential for both athletes and patients with shoulder injuries to achieve better shoulder performance (Tucker et al., 2010; Ebaugh et al., 2006). Balanced activities of the glenohumeral and the scapulothoracic musculatures induce the appropriate position of the humerus against the glenohumeral fossa during functional arm elevation (Ebaugh et al., 2006). Due to the multi-axial movements of the shoulder,

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diagonal movements of the glenohumeral joint are often used for strengthening the musculature in exercises program (Youdas et al., 2012; Andersen et al., 2010). Proprioceptive neuromuscular facilitation (PNF) interventions suggest two spiral-diagonal elevations associated with the shoulder joint, which have been designated diagonal 1 flexion and extension (D1F-E), and diagonal 2 flexion and extension (D2F-E). The D1F-E involves flexion, adduction, and external rotation for arm elevation, and extension abduction, and internal rotation for arm depression. The D2F-E involves flexion, abduction, and external rotation of the shoulder for arm elevation, and extension, adduction, and internal rotation for arm depression (Adler et al., 2008).

Some studies have investigated the muscle activities of the upper extremities associated with diagonal pattern of arm elevation (Park & Yoo., 2014; Ekstrom et al., 2003). A study suggested that the diagonal flexion pattern of arm elevation was effective for activating scapulothoracic muscles (Ekstrom et al., 2003), and the other report showed that the exercise was effective for activating both the upper trapezius and the lower serratus anterior in subjects with winged scapulae (Park & Yoo., 2014). Youdas et al. (2012) compared muscle activities of the trunk and shoulder in diagonal flexion pattern of exercises, and elevation within the scaption plane. They concluded that three exercises were appropriate to activate the shoulder musculature and diagonal pattern of exercises had the advantage of activating the trunk musculature. However, there is a lack of information on the muscle activities of upper extremity-related diagonal extension pattern of arm depression.

Although the practical application of diagonal exercise is considered as both the flexion and extension diagonal pattern, there were a few studies which investigated the muscle activities around scapulothoracic and glenohumeral joint during both the flexion and extension diagonal pattern of exercises (Witt et al., 2011). Witt et al. (2011)

reported selective activation of the scapulothoracic musculature could be accomplished by each pattern of diagonal exercise. Although the study reported positive effects of each diagonal exercises, there is still a lack of empirical data on the recruitment of the shoulder and scapular muscles when performing both the diagonal flexion and extension exercise simultaneously.

According to the clinical literature associated with the PNF approach, the exercises should not only focus on functional diagonal patterns of movement to improve muscular activity but should also combine sensory stimuli to improve neuromuscular control and maximize the effects of the exercise (Adler et al., 2008). Recent finding investigated the effects of the distal movement associated with shoulder muscular activities, which suggested that distal movement could increase the proximal shoulder and scapular muscle activities (Alenabi et al., 2014). However, the study examined muscle activities in immobile shoulder status, so that there is a necessity to evaluate the muscular activities during dynamic exercise procedure.

We hypothesized that using distal movement with wrist and finger in diagonal pattern of exercise might increase shoulder and scapulothoracic muscle activity (Youdas et al., 2012; Witt et al., 2011). If a distal movement were not to increase muscle activity, it may be questionable to adopt this to maximize the effects of strengthening upper extremity muscles. Thus, we investigated the effects of distal movement on muscle activities in the upper extremity during the diagonal pattern of shoulder elevation exercises.

II. Method

1. Subject

This study was performed with 17 men, aged 20–24 years (22.65 ± 1.32 , mean \pm SD), whose mean heights and weights were 175.85 ± 5.14 cm and 70.02 ± 9.39 kg,

respectively. The inclusion criteria were university students who were physically active with a body mass index not exceeding 25. Participants who had a body mass index (BMI) of 25 or higher were excluded due to the potential influence of fatty tissue on our ability to measure sEMG activity (Park et al., 2013). Subjects with a history of upper or lower extremity injuries or diseases that could affect exercise performance were excluded. Approval from the Ethics Committee was obtained prior to beginning data collection. Each participant provided informed consent prior to participation in the study. Thirteen participants were required for present study design, which set as 80% of power, 0.6 of effect size (η^2), and 0.05 of alpha level.

2. Measurement device

Surface electromyography (sEMG) data were collected using a wireless EMG system (Delsys, Boston, MA, USA). The sEMG signals were sampled with a 2000 Hz frequency. Five surface electrodes were attached parallel to the muscle fibers on the dominant right side (1) on the upper trapezius (UT), (2) on the lower trapezius (LT), (3) on the serratus anterior (SA), (4) on the anterior deltoid (AD), and (5) on the infraspinatus (IS) (Cram et al., 1998). Before attaching the electrodes, the skin was shaved, abraded with fine sandpaper, and cleaned with alcohol. The maximal voluntary isometric contraction (MVIC) of each muscle was measured following procedures from a previous study (Kendall et al., 2005), to enable normalization of the EMG amplitude. The mean value of two trials for each muscle activity was taken as the MVIC.

3. Procedure

Participants performed two diagonal exercises (D1F-E and D2F-E) with and without distal movement in a standing position. To perform D1F-E, the participant started with the right arm down by the right side and brought it up towards the left ear, moving through the glenohumeral actions of flexion, adduction, and external rotation. After

elevating arm as high as possible for each individual, participant descend their arm from maximally flexed, adducted, externally rotated to the position to started position through the glenohumeral actions of extension, abduction, and internal rotation. The pattern of D2F-E was performed with the participant beginning with the arm on the left side of the waist and bringing the arm up above the right side of the head, which includes glenohumeral movements of flexion, abduction, and external rotation. After elevating arm as high as possible for each individual, participant descend their arm from maximally flexed, abducted, externally rotated to the position to started position through the glenohumeral actions of extension, adduction, and internal rotation (Adler et al., 2008). For the diagonal exercise with distal movement condition in D1F-E, the participant flexed his wrist and finger at shoulder elevation, and extended his wrist and finger at shoulder depression. For the diagonal exercise with distal movement condition in D2F-E, the participant extended his wrist and finger at shoulder elevation, and flexed his wrist and finger at shoulder depression.

As a cuff load, 10% of the subject's weight was adjusted at forearm during the diagonal exercise. Each subject conducted exercises within a 6 s time frame, as indicated with a metronome; 3 second for elevation and 3 second for depression. Subjects were given a 3 min practice period to acclimatize to the movement and the speed required, and a 5 min period of rest was given between exercises. All raw sEMG data were root mean squared and smoothed with a 125 ms moving window. The sEMG values of the three trials were averaged and normalized. Normalization of EMG signals is performed by dividing the EMG signals during diagonal exercises by a reference EMG value obtained from MVIC, and represented as %MVIC as actual muscle activity.

4. Statistical analysis

The SPSS statistical software (version 18.0; SPSS, Chicago, IL, USA) was used to evaluate differences in

Table 1. The average and standard deviation(SD) of muscle activity values(%MVIC) during exercise conditions

Muscles	Exercises	Muscle activity(%MVIC, Mean±SD)		Mean difference(95% CI)	
		With distal movement	Without distal movement	Exercises	Distal movement
Upper trapezius(UT)	D1F-E	28.67±15.37	25.89±15.40	-1.06	2.43*
	D2F-E	29.38±10.68	27.30±9.77	(-7.31~5.20)	(1.07~3.79)
Lower trapezius(LT)	D1F-E	11.94±5.18	11.36±5.29	-21.59*	-0.92
	D2F-E	32.02±14.47	34.45±14.06	(-27.49~ -15.68)	(-2.30~0.46)
Serratus anterior(SA)	D1F-E	42.38±21.56	39.39±20.86	-3.47	2.54*
	D2F-E	45.39±22.62	43.31±21.67	(-8.61~1.68)	(1.05~4.02)
Anterior deltoid(AD)	D1F-E	30.97±11.81	27.05±10.25	-11.33*	2.81*
	D2F-E	41.19±14.39	39.49±14.80	(-17.72~ -4.95)	(1.28~4.34)
Infraspinatus(IS)	D1F-E	35.54±12.69	32.06±11.93	3.43	2.83*
				(-2.12~8.97)	(1.58~4.08)

*Significant difference between conditions.

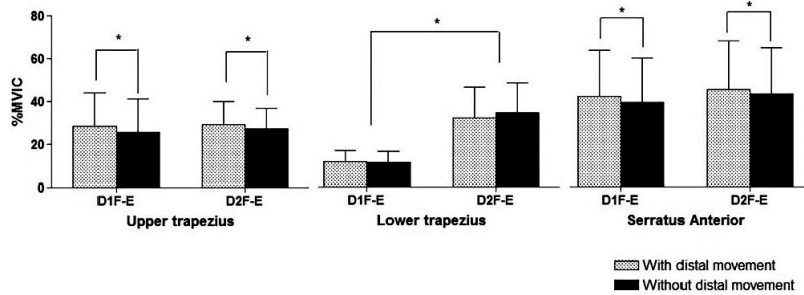


Fig. 1. The normalized EMG data of the upper and lower trapezius, and serratus anterior

the %MVIC of each muscle. Two-way repeated measures analysis of variance (ANOVA) was performed to evaluate differences in %MVIC values; one factor was the exercises (D1F-E vs. D2F-E) and the other factor was the presence of resistance. For pairwise multiple comparison, the Bonferroni correction was performed to identify differences. p -value<0.05 was considered to indicate statistical significance.

III. Results

The average muscle activity values (%MVIC) of the

lower trapezius and anterior deltoid differed significantly according to the exercise conditions: higher with D2F-E than with D1F-E (Table 1; $F_{1,16}=14.16$, $\eta^2=0.47$, observed power=0.942 for the anterior deltoid, $F_{1,16}=60.01$, $\eta^2=0.79$, observed power=1.000 for the lower trapezius; $p<0.05$) (Figure 1 & 2).

A distal movement effect was observed with all measured muscle except the lower trapezius (Figure 1 & 2). The mean muscle activity values within distal movement condition were significantly greater than which exercise without distal movement conditions (Table 1; $F_{1,16}=14.26$, $\eta^2=0.47$, observed power=0.94 for upper trapezius, $F_{1,16}=15.21$, $\eta^2=0.49$, observed power=0.96 for anterior deltoid,

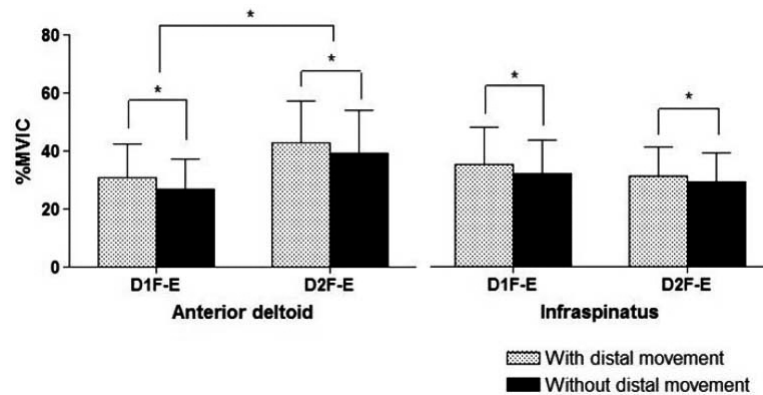


Fig. 2. The normalized EMG data of the anterior deltoid and infraspinatus

$F_{1,16}=13.06$, $\eta^2=0.45$, observed power=0.92 for serratus anterior, $F_{1,16}=23.14$, $\eta^2=0.59$, observed power=.995 for inferior spinatus; $p<0.05$).

IV. Discussion

We expected that exercises with distal movement condition might increase the overall muscular activation around the upper extremity, and the results showed that there was significant effect on muscle activity except for that of the lower trapezius. Similar results have been reported previously. Alenabi et al. (2014) investigated the effect of distal exercise on shoulder and scapular muscle activity during immobile shoulder condition. They reported that elbow, wrist, and finger movements could be considered as tool for strengthening proximal musculature especially for shoulder injured patient with post-operation. Precisely, distal movement condition in our study was not generated wrist and finger movement during whole phase of exercise, but was induced in initial phase of exercise. After exercise had performed, the distal joints were closed to be fixated rather than moving condition. Although investigated movements were different, Yoo et al (2010) suggested that immobile wrist condition generated by the orthosis elevate the scapular muscle activity during

assembly work.

This significant effect of distal movement on the muscle activities could be explained as compensate movements of proximal joints and recruitment of motor unit mechanism. Forman et al (1999) investigated the low low-threshold motor-units in trapezius during voluntary concentric and eccentric shoulder movement, and mouse work which induced wrist and finger movements. And they reported similar recruitment patterns were existed in the trapezius muscle in both of mouse work and arm and shoulder movements. This manifest distal movement could activate the specific portion of proximal musculature. In our study, wrist and finger motion is occurred at initial phase of exercise, this could recruit the low low-threshold motor-units of proximal musculature, and could elevate the overall muscle activations during exercise. Other possible explanation is the compensate movement of proximal joint. When the wrist and finger joint is in immobile condition, increases in compensative shoulder and scapular movement were required for generating accurate shoulder movement (Yoo et al., 2010).

When comparing D1F-E and D2F-E exercises, the LT and the AD showed significant differences; both muscles showed higher muscle activity values with D2F-E than D1F-E. Both D1F-E and D2F-E have components of shoulder flexion, which is the main action of the AD, but

the D2F-E showed a significantly higher muscle activity for AD than did D1F-E. We suggest the cause of this result may be that the height of the shoulder elevation was different in each pattern of exercise. Although we could not measure the kinematic data for D1F-E, the component of horizontal shoulder adduction could restrict the flexion movement by the tightened posterior glenohumeral capsule and passive tension of the lengthened latissimus dorsi and rotator cuff musculatures (Schenkman et al., 1987; Forbush et al., 2013). For the LT, this result is natural because the D1F-E exercise induces scapular internal rotation and abduction, which generates an eccentric phase of the LT for elevation phase. In a previous study that compared the D1F-E and D2F-E with sEMG, the results also showed a significantly higher value for the LT in D2F-E than in D1F-E (Witt et al., 2011).

There are some limitations to the present research. First, we could not investigate the kinematic data throughout the diagonal pattern of exercises, thus the accuracy of the shoulder elevation and depression could not be measured. Secondly the mean differences in a factor of distal movement condition were as 2~3% of MVIC, which is too low to affirm the exercise effect. Considering the present study is performed in subject with healthy participant, however, this low effect size with significant differences could be increased when future study is performed in subject with neuromuscular disorder or orthopedic problems.

V. Conclusion

The %MVICs values of all conditions were >20% except for the LT muscle activity; these values suggest that diagonal pattern of upper extremity exercises is moderate to facilitate muscular activation (DiGiovine et al., 1992). Both the D1F-E and D2F-E exercise pattern were effective for activating the shoulder and scapulothoracic muscles.

The present study simply suggests that the D2F-E exercise pattern is more effective for activating LT and AD muscles than D1F-E. We identified a positive effect of distal movement on muscular activation during the diagonal exercises. Although the effect was not clearly observed as mean differences, exercise with distal movement condition significantly activate the UT, SA, AD, and IS, compared with exercise without distal movement condition.

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