Muscle Activity Comparison of Four Common Shoulder Exercises in Stable and Unstable Shoulders

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ABSTRACT

Introduction: The purpose of this study was to determine if electromyographic (EMG) activity of six shoulder muscles was significantly different between subjects presenting with multidirectional instability (MDI), generalized joint laxity (GL), anterior instability (AI), and normal shoulders (N) while performing four common shoulder exercises.

Subjects: 39 volunteer subjects (age = 21.3 ± 3.3 yr, height = 172 ± 9.6 cm, weight = 73 ± 19.4 kg) were classified as having either multi-directional instability, anterior instability, generalized laxity, or a healthy stable shoulder based on one orthopedic surgeon's evaluation. All subjects had the study explained to them and signed an institutional approved informed consent.

Methods: Indwelling electrodes were used to study supraspinatus (Sup), infraspinatus (INF), and teres major (TM) amplitude, onset, and duration of activity, while surface electrodes were used for the serratus anterior (SA), middle deltoid (MD), and upper trapezius (UT) muscles. The four exercises studied were scaption (SCA), prone horizontal abduction (PHA), prone external rotation (PER), and a kneeling push up plus (PU).

Results: Repeated measures ANOVAs with one within factor and one between factor were used to determine differences in EMG amplitude, onset and duration. Overall, the musculature in unstable shoulders was activated in the same manner as the musculature in stable shoulders. A trend was identified that the GL group exerted greater infraspinatus activity throughout all the exercises. Specifically, the infraspinatus was activated significantly more during PHA and push up plus.

The onset of activation and duration of muscular activity was not significantly different between the four groups for all exercises. The serratus anterior was found to be most active and on the longest during the push up plus exercise. The infraspinatus was most active and activated the longest for PER. During PHA the infraspinatus and supraspinatus were activated for the longest duration and to the highest amplitude. The supraspinatus was active throughout scaption and displayed the highest average amplitude.

Conclusions: Scaption, PER, PHA, and push up plus appear to activate their target muscles in an unstable population as effectively as in a stable population. These are effective exercises for inclusion in an instability rehabilitation program. Individuals with generalized joint laxity appear to activate shoulder musculature more to dynamically stabilize the glenohumeral joint to compensate for compromised ligamentous stability. Caution should be taken when loading unstable shoulders in terminal ranges of motion during an exercise.

INTRODUCTION

Shoulder instability is a common medical condition often treated with a conservative strengthening program of the glenohumeral and scapulothoracic musculature. Research on effectiveness and efficiency of shoulder strengthening exercises in unstable shoulders is limited. The objective was to evaluate shoulder muscle electromyo-graphical activity while individuals performed four shoulder strengthening exercises to determine differences between individuals with unstable shoulders and stable shoulder conditions.

METHODS

Subjects

39 volunteer subjects (11 males, 28 females, age = 21.3 ± 3.3 yr, height = 172 ± 9.6 cm, mass = 73 ± 19.4 kg) were recruited from the central Kentucky region.

Criteria for Participation

Subjects classified into the GL group met 3 of the 5 Carter & Wilkinson[1] criteria for generalized laxity. Subjects were classified as AI with positive apprehension/relocation tests and a history of recurrent anterior dislocation or subluxations. MDI subjects displayed a history of subluxations, positive load and shift , apprehension / relocation tests, and a sulcus sign. Subjects were excluded from this study if they had any neurological disorders present or previous shoulder surgery.

Procedures

Informed consent was obtained from all subjects before testing. Each exercise was performed using 25% of maximal load the subject could lift. A PowerTrack II™ Commander hand held dynamometer (Jtech Medical Ind., Salt Lake City, UT) was used to measure maximal force produced in the mid range of PHA, PER, and scaption. No additional resistance was used for push-up plus.

Bipolar surface electrodes (Medicotest, Olstykke, Denmark) were placed on the UT, MD, and SA using a standard protocol for electrode placement.[2] Indwelling electrodes were inserted in the SUP, INF, and TM using a double needle stick method. Following electrode placement, maximum voluntary isometric contractions (MVICs) were measured for each muscle. MVICs were collected for two trials of five seconds. The Myopac System (Run Technologies, Laguna Hills, CA) was used to collect (EMG) data. A Myopac transmitter belt unit transmitted all raw EMG data at 1000Hz via a fiber optic cable to its receiver unit. This device has a CMRR of 90 dB. The gain for the surface electrodes was set at 2000 microvolts (mv) for surface and 1000 mv for indwelling electrodes. All data were recorded, stored, and analyzed using Datapac software (Run Technologies, Laguna Hills, CA) on a PC computer.

Four exercises were investigated: PHA (Figure 1), PER (Figure 2), SCA (Figure 3), and PU (Figure 4).For motion analysis a photocell light sensor system was used. Photocells were placed in 30° increments for each subject and exercise individually, utilizing a Dualer™ inclinometer (JTech Medical Ind., Heber City, Utah). Subjects performed exercises holding a flash light approximately 4 inches away from a Velcro covered wall with the sensors. Several practice trials for each exercise were performed by each subject and recorded by the investigators to assure the photocells were tripped by the light beam. PHA and PER required 4 sensors (0° -90°), SCA 5 sensors (0° -120°), and PU 2 sensors (top and bottom of exercise).

The test consisted of three consecutive trials per condition. A rest period of three minutes was given between conditions. Order of exercises was randomized. Each exercise was performed at approximately 50º/sec controlled using a metronome except for the push up plus, which was performed at a self selected pace.

Statistical Analysis

A muscle was considered to be on when the EMG activity exceeded 10% of the MVIC[3] for 25 ms and did not fall below the 10% mark for more than 100 ms. Twenty-four 2-factor repeated measures ANOVAs were performed with 1 between factor (groups, 4 level) and 1 within factor (arc, 2-8 level) for amplitude analyses. Multiple chi square analyses were performed on each muscle separately to determine onset differences between groups. Four 2-factor repeated measures ANOVA analyses with 1 within factor (muscle, 6 level) and 1 between factor (group, 4 level) were performed for duration analyses. Alpha level set at p<.05 for all analyses.

RESULTS

• Amplitude analyses:
  - The GL group displayed a significantly higher EMG amplitude for the infraspinatus during PHA starting at 30° of the concentric and ending at 30° of the eccentric phase ($F_{4,40}$=2.6, p=.047), (Figure 5) when compared to the AI and N groups.
  - A significant interaction was found for infraspinatus activation of the GL group over the N group during the eccentric phase of push up plus ($F_{3,36}$ = 4.5, p =.009).

•Onset analyses:
  - No relevant differences were found for EMG onset activation between groups for all muscles.

•Duration analyses:
  - No significant differences were found for EMG duration activity between groups for all muscles, (p< .05). Duration differences for muscles per exercise are:
    - PHA: INF, SUP > MD > UT , SA , TM
    - PER: INF > SUP, SA > TM , MD , UT
    - SCA: SUP > INF, SA > UT , MD > TM
    - PU: SA > INF, SUP > MD , UT > TM

Figure 1: PHA

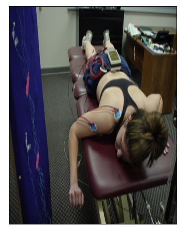

Figure 2: PER

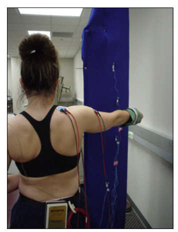

Figure 3: SCA

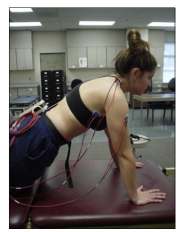

Figure 4: PU

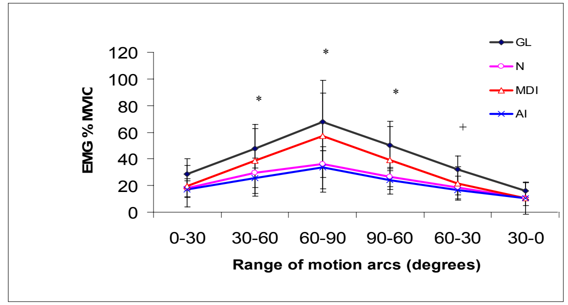

Figure 5: EMG amplitude for Infraspinatus during PHA; * = GL sig. greater than AI and N, + = GL sig. greater than AI, N, MDI (p< .05).

DISCUSSION/ CONCLUSION

•Our findings provide evidence that the primary musculature being exercised in a stable shoulder is the same musculature being worked in an unstable shoulder. In stable and unstable shoulders the musculature is activated to the same degree, at the same time, and over the same time period. Hence, the core exercises that have been previously identified in a healthy stable glenohumeral and scapulothoracic shoulders are just as effective in rehabilitation of unstable shoulders.

•In unstable shoulders the demand on the infraspinatus is most likely increased due to the decreased stability provided by the static stabilizers in demanding positions. This may explain the increased infraspinatus activity in the GL group during PHA.

•In PU, a closed chain exercise, infraspinatus activity has been identified to be increased in healthy shoulders[4] as well to decrease the posterior shear force of the axial load. Therefore, we can consider the increased infraspinatus activity in the GL group as a heightened typical response for an unstable shoulder.

•It was noticed that throughout the exercises the peak muscle activation occurred during the terminal ranges of the exercise for all muscles. Nine subjects were not able to complete the terminal 30° of motion in PHA and/or PER due to pain / discomfort/ instability.

•Clinical implications

  - Exercises previously documented to optimally activate glenohumeral and scapulo-thoracic musculature in stable shoulders is sufficient in targeting the same muscles during rehabilitation of unstable shoulders.
  - We do not recommend loading individuals with unstable shoulders in the terminal ranges of an exercise. Perhaps closed chain exercises may be of benefit as they activate the rotator cuff musculature to a great degree but do not place the ligamentous structures at the same risk as open chain exercises.

REFERENCES

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