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Original Research

Electromyographic Characteristics of a Single Motion Shoulder Exercise: A Pilot Study Investigating a Novel Shoulder Exercise

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Background

Shoulder exercises focused on strengthening the rotator cuff and scapular stabilizing muscles as well as addressing scapular dyskinesis and motor control have been shown to improve rotator cuff function and decrease shoulder pain. A single motion shoulder exercise that effectively activates the rotator cuff and scapular stabilizing muscles, engages the scapulohumeral rhythm, and includes eccentric contractions may be more effective and easier for patients to consistently perform as compared to multiple standard shoulder exercises.

Purpose

To compare the electromyographic muscle activation of key shoulder complex muscles during a single motion exercise and individual exercises (standard exercises) typically included in shoulder rehabilitation protocols.

Study Design

Case-controlled, cohort study

Methods

Nineteen healthy men and women without shoulder pain or dysfunction were studied. Muscle activity of the rotator cuff and scapular stabilizing muscles (supraspinatus, infraspinatus, teres minor, trapezius [upper, middle and lower], serratus anterior, middle deltoid) was measured using surface EMG while subjects performed, in a standing position, several standard shoulder exercises typically included in shoulder rehabilitation protocols (resisted shoulder flexion, abduction in the scapular plane/scaption, external rotation, extension) and a single motion shoulder exercise consisting of a continuous movement creating the shape of "Figure of 8" in the transverse plane. The subjects used a weight between 5-15 pounds that produced muscle activation at 40-60% maximum voluntary isometric contraction (MVIC) for shoulder external rotation. That weight was then used for all of the exercises performed by the subject. The single highest EMG reading for each of the eight muscles studied, expressed as a percentage of MVIC, at any point during the second, third and fourth repetitions in a five repetition set was used to compare the single motion shoulder exercise and each exercise in the standard exercises set.

Results

Ten men and nine women between 18-65 years of age were tested. No significant

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difference (p=.05) between the exercises was noted for the supraspinatus, infraspinatus, teres minor, serratus anterior, middle deltoid or upper trapezius. There was a significant difference favoring the standard exercises in the middle and lower trapezius. (p= 0.0109 and 0.0002 respectively)

Conclusion

In this pilot study, muscle activation during the single motion, Figure of 8 pattern exercise was not significantly different from the standard shoulder exercises in six of eight key muscles that are usually included in shoulder rehabilitation protocols. The exceptions were the middle and lower trapezius which were activated to a significantly higher degree with the standard exercises. Further evaluation of the clinical effectiveness of the single motion shoulder exercise is needed.

Level of Evidence

Level 3b

INTRODUCTION

Shoulder exercises focused on strengthening the rotator cuff and scapular stabilizing muscles as part of a shoulder rehabilitation program have been shown to improve rotator cuff function and decrease pain.[1–3] However, there is little consensus on an ideal exercise program. Furthermore, addressing scapular dyskinesis and motor control have also been described as effective components of a shoulder rehabilitation program.[4–6] The standard shoulder exercise program typically consists of individual resistance exercises usually including external rotation, internal rotation, abduction/scaption, forward flexion, extension and in some instances, rowing, dips and modified push-ups.[7] Activation of muscles to 40-60% maximum voluntary isometric contraction (MVIC) is considered high activity and may be optimal for use during a rehabilitation program.[8,9] Strengthening of the scapular stabilizers has been shown to be helpful as well.[10,11] Eccentric contractions may also be important in the rehabilitation of shoulder impingement.[12] As shoulder rehabilitation protocols become more complex, compliance and possibly clinical outcomes may suffer.[13] A single motion shoulder exercise that effectively activates the rotator cuff and scapular stabilizing muscles, engages the scapulohumeral rhythm and includes eccentric contractions, offers the advantage of a simple movement pattern that may be more effective and will be easier for patients to remember and perform as part of a home exercise program. The single motion shoulder exercise evaluated in this study offers a novel shoulder rehabilitation option that could improve long-term exercise compliance and therefore, possibly improve long-term outcomes in the management of chronic shoulder pain

The standard shoulder exercises studied include resisted shoulder flexion, abduction in the scapular plane/scaption, external rotation and extension, all performed in the standing position. The single motion exercise used in this study was a continuous movement creating the shape of a "Figure of 8" in the transverse plane while in the standing position. Starting at the subject's side, the top circle of the 8 is in front of the subject and the bottom continues behind them. As subjects move the arm medially, they were instructed to move past the midline of their body in both the front and back portions of the movement. Shoulder abduction was kept below 45 degrees in all parts of the movement. The exercise takes approximately five seconds to complete one cycle. (Figure 1)

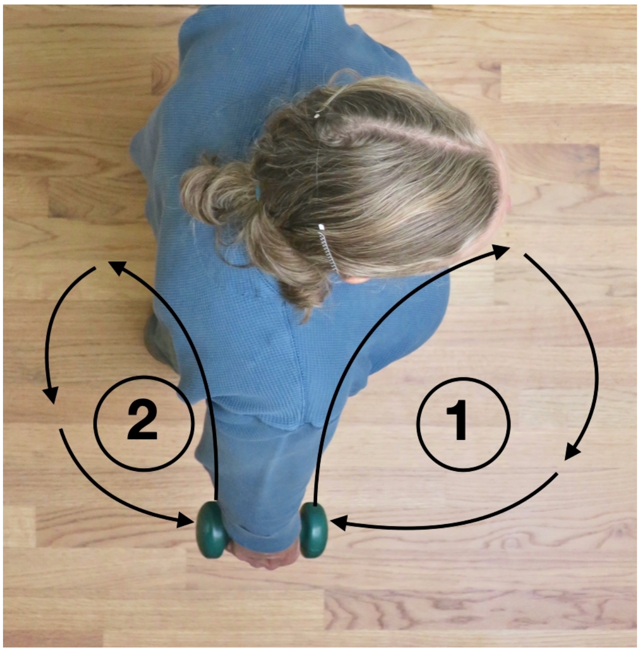

Figure 1. Single motion exercise using a figure of 8 movement pattern.

The purpose of this study was to compare the electromyographic muscle activation of key shoulder complex muscles during a single motion exercise and individual exercises (standard exercises) typically included in shoulder rehabilitation protocols. Investigation of the single motion exercise is a step toward creating a larger study measuring clinical outcomes when comparing the single motion shoulder exercise to standard shoulder rehabilitation exercises.

METHODS

The study protocol was approved by the San Jose State University Human Subjects Institutional Review Board.

SUBJECTS

Ten men and nine women between 18-65 years of age were tested. Primary exclusion criteria included: under the age of 18, previous shoulder surgery, shoulder pain at the time of the study, shoulder pain lasting more than three days in the prior month or participation in a shoulder rehabilitation program within the preceding three months.

STUDY PROTOCOL

The skin was vigorously cleaned with alcohol, and surface EMG sensors (Delsys Trigno Avanti™ Sensor, Delsys inc, Natick, MA) with interelectrode spacing of 10 mm were placed over eight different muscle bellies: 1) supraspinatus (SS), 2) infraspinatus (IS), 3) teres minor (TMi), 4) middle deltoid (MD), 5) upper trapezius (UT), 6) middle trapezius (MT), 7) lower trapezius (LT) and 8) serratus anterior (SA). Since surface EMG recordings were used in this study, it is presumed that for the theoretical basis of the study, each of the electrode locations was representative of each of the muscle functions in the subjects. Electrode placement was performed as described by Tsuruike.[14] Care was taken to ensure lead placement was standardized between subjects. All eight leads were monitored simultaneously during performance of the exercise protocols for each subject.

The muscle electrical activity from a MVIC of the muscles to be studied was then recorded. The positions used to discern MVIC's were standing for resisted external rotation (IS, TMi), scaption (SS), abduction to 90 degrees with the elbow fully flexed and the humerus internally rotated (MD), shoulder shrug (UT), and quadruped for abduction at 100°with full external rotation (MT). Use of these positions to measure MVIC has been validated previously.[15,16] Resisted scaption while standing was used to generate the MVIC for both the LT and SA as supported by the data from Boettcher, et al.[17] The mean EMG activity of the middle two seconds of each 5-second MVIC was calculated to determine the individual's MVIC. The subjects were then asked to select a weight between 5-15 pounds that they felt would offer a comfortable amount of resistance when externally rotating the arm at 90 degrees elbow flexion and 0 degrees shoulder abduction. EMG activity of the infraspinatus muscle was recorded during external rotation with the subject in a standing position using their chosen weight. The weight was then adjusted to produce muscle activation between 40-60% of the MVIC. Self-selection of weights was utilized to mimic what most patients do in a home setting. This weight was then used for all of the exercises in order to standardize the resistance load for a given subject. Since this is a case-controlled study, this method provided a consistent load for each patient.

The standard exercise protocol was performed in the standing position and consisted of four exercises: shoulder flexion, abduction in the scapular plane (scaption), extension to 60 degrees and external rotation to 90 degrees at 0 degrees abduction, performed in succession (grouped together). The single motion exercise was described previously and is shown in Figure 1. The subject was instructed to cross the midline with the movement both in front and back. They were also instructed to bring the weight up to 45 degrees in front and keep the weight low and next to the body with the behind the back portion of the movement. The subject was allowed to do several practice movements before data were collected.

All exercises were performed in the standing position. Five repetitions were made with all movement patterns in both the single motion and standard exercise protocols. Repetitions two through four were used for data analysis to reduce artifacts from starting and stopping the exercise patterns. To control for muscle fatigue as a possible confounding variable, there was a one-minute rest period between different exercises and the order of the exercises, single motion versus standard exercises grouped together, was alternated between subjects (standard exercise group first/single motion exercise second or single motion exercise first/standard exercise group second) and assigned on an alternating basis as the subjects enrolled in the study. The order of the exercises within the standard exercise group was kept the same for all subjects.

EMG activity was continuously recorded during the exercise cycles. Care was taken to ensure that all recordings were made with the same lead placement. In two cases, a lead came off during the exercises. The lead was replaced and the entire exercise protocol was repeated with the new placement position. The speed of the exercises was standardized by having the subject complete the movements paced to a metronome set at 60 beats per minute. The EMG electrodes were pre-amplified and routed through the EMG mainframe, which further amplified with bandwidth filtered (20–450 Hz) signals. The EMG activities were then collected with a sample rate of 1000 Hz; all data were recorded and stored in a computer for off-line analysis. All data were calculated in root-mean-square (RMS) values, normalized to MVIC of the corresponding muscles, and analyzed as a percentage of MVIC (% MVIC). The EMG value used for analysis of the single motion and standard exercises was the highest peak reading, as a percentage of MVIC, at any point during the second, third and fourth repetitions in the five repetition cycles. Two tailed, paired t-tests were performed, for each muscle studied, comparing the EMG value for the single motion shoulder exercise to an EMG value obtained during any of the standard shoulder exercises as they were performed in a group.

RESULTS

No significant difference was noted in the supraspinatus, infraspinatus, upper trapezius, serratus anterior, middle deltoid and teres minor between the single motion and standard shoulder exercises when comparing the maximum peak EMG values for each muscle group tested, expressed as a percentage of MVIC. A significant difference, favoring the standard exercises, was noted between the single motion and standard shoulder exercises in the middle and lower trapezius. The two tailed, paired t-test comparisons are presented in Table 1.

DISCUSSION

Simplified exercise programs have been shown to increase compliance with home exercise performance.[13] The potential clinical advantage of the single motion shoulder exercise may be that, due to its simplicity, it will be easier for patients to integrate into their regular exercise programs and may provide a new shoulder rehabilitation option to help maintain long term improvements in shoulder biomechanics and pain reduction. This pilot study demonstrates that the single motion exercise is not significantly different in activating rotator cuff and scapular stabilizing muscles, with the exception of the middle and lower trapezius, when compared to the standard exercises used in this study. With its similarity to standard shoulder exercises in activating key rotator cuff and scapular muscles established, as well as its simplicity and multiplanar movement pattern, a larger outcome study is indicated to evaluate whether these potential advantages of the single motion shoulder exercise translate to increased clinical effectiveness.

There are several limitations to this study. First, the value of using surface EMG electrodes for the measurement of shoulder muscles has been questioned.[18,19] However, the authors feel that any error introduced by using surface electrodes would be equal for each exercise trial since the data were case-controlled.

Second, it was a challenge in this study to compare a continuous motion, multiplanar exercise that took about five seconds to perform and six uniplanar exercises that took approximately two seconds each to perform. Applying standard MVIC uniplanar movements to a multiplanar single motion exercise has not been previously validated, but the authors feel this was the most standardized metric to use for comparison. The case-controlled design used in this study is also important in helping to mitigate potential errors produced by MVIC measurement technique as well as exercise performance variability and the subjects self-selecting the weight they used for the exercises. By comparing each subject to themselves, these possible confounding variables would affect both the single motion and standard shoulder exercises to the same degree.

Table 1. Results of two-tailed, paired t-tests comparing the peak EMG value, as a percentage of MVIC, for the single motion exercise and the highest peak EMG value, as a percentage MVIC, among any of the standard exercises.

Muscle	t-value	p-value
Supraspinatus	1.1100	0.2806
Infraspinatus	1.1000	0.2852
Upper Trapezius	0.1193	0.8657
Middle Trapezius	2.8369	0.0109
Lower Trapezius	4.5639	0.0002
Serratus Anterior	-1.0981	0.2867
Middle Deltoid	-0.6004	0.5557
Teres Minor	-1.8591	0.0794

N= 19

CONCLUSIONS

The results of this pilot study indicate that the Figure of 8 pattern, single motion shoulder exercise activates key muscle groups in the rotator cuff and shoulder girdle, similarly to the group of standard exercises consisting of resisted flexion, abduction (scaption), extension and external rotation to 90 degrees at 0 degrees abduction, when performed with the same weight. However, the middle and lower trapezius, were activated to a greater extent during the standard exercises than with the single exercise. These data suggest that the single motion exercise may have utility as part of a shoulder rehabilitation program and warrants additional evaluation for clinical effectiveness. In particular, further studies are needed to determine whether this novel shoulder exercise, because of its simplicity, offers any clinical advantage to produce improved, long term outcomes in managing rotator cuff pathology and decreasing the incidence of chronic shoulder pain when compared to groups of standard shoulder exercises.

CONFLICTS OF INTEREST

None

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