Quantitative Examination of Upper and Lower Extremity Muscle Activation During Common Shoulder Rehabilitation Exercises Using the Bodyblade

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Abstract

Oliver, GD, Sola, M, Dougherty, C, and Huddleston, S. Quantitative examination of upper and lower extremity muscle activation during common shoulder rehabilitation exercises using the bodyblade. J Strength Cond Res 27(9): 2509–2517, 2013—The kinetic chain approach to shoulder rehabilitation has become a standard of care within sports medicine. Attempting to incorporate the kinetic chain method of proximal stability for distal mobility requires a stable base of not only the lower extremity but also the upper extremity. Therefore, it was the purpose of this study to quantify muscle activation of the upper and lower extremity during common shoulder rehabilitation exercises using the Bodyblade. An observational descriptive study design was used. Thirty healthy collegiate graduate students (age: 23.5 ± 1.34 years; height: 174.4 ± 11.0 cm; weight: 76.6 ± 16.9 kg), regardless of gender, consented to participate. The independent variables were the 2 observational categories of exercise and muscle. The dependent variable was considered muscle activation as presented as percent maximum voluntary isometric contraction. Results revealed moderate to moderately strong activation of both the musculature of the upper and lower extremity while performing the shoulder rehabilitation exercises. The findings of this study demonstrate that any of these exercises may be incorporated into a shoulder rehabilitation program. The muscle activations described in this study are beneficial in choosing appropriate exercises to perform during shoulder rehabilitation. Information from this study can be applied to the kinetic chain approach to shoulder rehabilitation where focus is on the movement pattern. The Bodyblade is a unique rehabilitation tool because a variety of kinetic chain movement pattern exercises allow for scapular control via muscle activation about the hip and shoulder.

Key Words kinetic chain, functional rehabilitation, eEMG

Introduction

The purpose of the shoulder, glenohumeral (GH) joint, is to position the hand for dynamic function. The GH joint is unique in its mobility while compromising its stability. For the shoulder to function efficiently, the GH and scapular musculature must provide both dynamic and static stability and mobility. In an attempt to adequately rehabilitate an injured shoulder, there must be an understanding of the involved structures and the mechanism of injury.

The shoulder comprises dynamic stabilizers that require proper coordination to maintain normal shoulder function (9,22). Muscular imbalance, weakness, or fatigue of these stabilizers can result in altered shoulder mechanics resulting in injury (25). Typically, a weak proximal link in the kinetic chain is the cause of injury. Therefore, the initial focus of the rehabilitation program should be the proximal support for distal mobility (9,18,22). The kinetic chain approach to shoulder rehabilitation is a twofold approach where scapular control is coordinated through trunk stabilization. It is known that muscle activation begins with the scapula stabilizers and proceeds to the rotator cuff when performing overhead activities (14). In addition, emphasis should be on scapular stability and control as a basis for rotator cuff activation (15). Strong anchor muscles, such as the rhomboids, trapezius, infraspinatus, and serratus anterior, provide a proximal base of support to stabilize the scapula (9,22,30). Scapular stability is accomplished through the efficient function of the scapular stabilizing muscles and a stable base of support from the trunk and pelvis (20).

Shoulder rehabilitation protocols use closed kinetic chain activities and proprioception as they progress to open kinetic chain activities. However, if the mechanism of the injury is overuse, often the culprit of the injury is not particularly
isolated to the shoulder and is often an association of a weak proximal link in the kinetic chain. With many clinicians aware of the kinetic chain model representing a proximal-to-distal sequencing of segments, shoulder rehabilitation has become more of total body rehabilitation vs. focusing solely on the shoulder (18). The kinetic chain model is often used to depict dynamic sport activity that has each body segment working interdependently of each other from a proximal-to-distal sequence (23). Thus, it incorporates the entire kinetic chain to effectively and efficiently perform dynamic activities (24). It has been reported that the normal movement patterns of the upper extremity require lower extremity and trunk muscle activation before upper extremity movement (7,32). In addition, for upper extremity movement to occur, there must be sequential muscle activation beginning with the legs and trunk (3,7,31). Thus, based on sequential muscle activation sequencing, shoulder rehabilitation should take a kinetic chain approach (18), and the lumbopelvic-hip musculature should be the initiator of all shoulder movement.

The use of an oscillatory device requires neuromuscular control, gross motor strength, and proprioceptive feedback (26). The Bodyblade, an oscillatory device, is an effective rehabilitative adjunct to strengthen dynamic and static shoulder stabilizers (4). It is postulated that the Bodyblade allows for increased neuromuscular control and muscular strength provided by the co-contraction of muscle groups targeted by the Bodyblade (1,26). Current surface electromyographic (sEMG) research on the Bodyblade suggests that the device is an effective way to train the scapular and spinal stabilizers, thus incorporating the kinetic chain (19,27). However, there has been no reported data describing the proximal musculature of the kinetic chain while

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*ABD = abduction; ER = external rotation; OH = overhead; PB = physioball.
†Wide base position is defined as shoulder width apart. All single leg exercises are performed on the dominant side and contralateral side. The hand holding the body blade determined the dominant side. Neutral range of motion is defined as the amount of motion needed to maintain oscillation at the given position. Full range of motion is defined as the maximum amount of motion that the subjects can move through while maintaining oscillations in the given plane of movement.
performing Bodyblade exercises. Therefore, it was the purpose of this study to quantitatively examine the muscle activations of the proximal and distal links of the kinetic chain while performing shoulder rehabilitation exercises using the Bodyblade.

METHODS

Experimental Approach to the Program

The goal of the experiment was to determine the muscle activations of selected torso and shoulder musculature while performing several common shoulder exercises while using the Bodyblade. The Bodyblade exercises included static overhead (OH), both static and dynamic physioball (PB), shoulder dump, ipsilateral and contralateral leg external rotation (ER), static abduction (ABD), ipsilateral/contralateral leg ABD, static flexion, and ipsilateral/contralateral leg flexion. The muscles examined were all dominate side gluteus maximus, lower trapezius, upper trapezius, infraspinatus, and anterior deltoid. The hand the subject chose to write with was determined as their dominant side. An observational descriptive study with 2 observational categories was implemented. Descriptive statistics were used to determine the muscle activations by examining normalized sEMG data as a percent of their maximum voluntary isometric contraction (%MVIC).

Subjects

Thirty healthy collegiate graduate students (age: 23.5 ± 1.34 years; height: 174.4 ± 11.0 cm; weight: 76.6 ± 16.9 kg), regardless of gender, consented to participate. Healthy was defined as having no history of any type of injury in the last 6 months and currently participating in physical activity for at least 30 minutes, 4 times a week. In addition, subjects were excluded if they reported a history of shoulder pain. All subjects signed written informed consent documents. Data collection sessions were conducted indoors at the University of Arkansas at Little Rock.

FIGURE 2. Dynamic physioball.

FIGURE 3. A) Shoulder dump starting position and B) shoulder dump ending position.
of Arkansas Health, Physical Education, and Recreation building. The University of Arkansas Institutional Review Board approved testing protocols used in this study; and before participation the approved procedures, risks, and benefits were explained to all the subjects. All the subjects consented, and the rights of the subjects were protected according to the guidelines of the University’s Institutional Review Board.

**Procedures**
The subjects reported for testing before engaging in any vigorous activity for that day. Location of the dominant side

![Figure 4. Static abduction.](image)

![Figure 5. Static flexion.](image)

![Figure 6.](image)

**Figure 6.** A) Gluteus maximus muscle activation presented as percent maximum voluntary isometric contraction (%MVIC) for single plane exercises. B) Gluteus maximus muscle activation displayed as %MVIC for dynamic exercises.
gluteus maximus, lower trapezius, upper trapezius, infraspinatus, and anterior deltoid were identified through palpation. Before testing, the identified locations for surface electrode placement were shaved, abraded, and cleaned using standard medical alcohol swabs. Subsequent to surface preparation, adhesive 3M Red-Dot bipolar, 6 cm Ag/AgCl diameter disk shaped, surface electrodes (3M, St. Paul, MN, USA) were attached over the muscle bellies and positioned parallel to muscle fibers using previously published standardized methods (2,8,32). The selected inter-electrode distance was 25 mm (10). Electromyographic data were collected via a Noraxon Myopac 1400L 8-channel amplifier (Noraxon USA, Inc., Scottsdale, AZ, USA). The signal was full wave rectified and root mean squared at 100 milliseconds. Surface EMG data were sampled at a rate of 1,000 Hz. The surface EMG data were notch filtered at frequencies of 59.5 and 60.5 Hz (21). An additional electrode was placed on the anterior superior iliac spine to serve as a ground lead for the examined muscles. After the application of surface electrodes, manual muscles testing (MMT) techniques by Kendal et al. (13) were used to determine steady state contraction. A certified athletic trainer, familiar with the techniques, performed all MMTs to ensure reliability throughout testing. Three MMTs, lasting 5 seconds, were performed for each muscle and the first and last seconds of each contraction were removed (21). The MMT provided baseline data in which all surface EMG data could be compared.

After electrode placement, the investigators instructed the subjects on the proper technique for each of the exercises. All the subjects used the Bodyblade C × T (Mad Dog

**Figure 7.** A) Lower trapezius muscle activation presented as percent maximum voluntary isometric contraction (%MVIC) for single plane exercises. B) Lower trapezius muscle activation displayed as %MVIC for dynamic exercises.

**Figure 8.** A) Upper trapezius muscle activation presented as percent maximum voluntary isometric contraction (%MVIC) for single plane exercises. B) Upper trapezius muscle activation displayed as %MVIC for dynamic exercises.
Athletics) because it was applicable for beginners, and the smaller size (0.57 kg, 101.6 cm) was easier to control. Before the subjects began the exercises, they were given time to warm up and become familiar with the Bodyblade. After the subjects were familiar with the exercise techniques, they were given a randomized order of exercises. The subjects performed 3 repetitions of each dynamic exercise, 5 seconds of each static exercise. During the trials, the subjects were instructed on proper posture through verbal cues and visual aids by a certified athletic trainer.

The exercises that the subjects performed were the following (Table 1):

**Overhead.** The subjects stood with feet shoulder width apart and arm positioned overhead at 180° of flexion, with the elbow in full extension. They then oscillated the Bodyblade in the sagittal plane while maintaining the overhead arm position (Figure 1).

**Physioball.** The subjects lay prone with their hips on a physioball with arm overhead in line with their body. They oscillated the Bodyblade in the sagittal plane while keeping their arm in line with their body (Figure 2).

**Dynamic Physioball.** The subjects lay prone with their hips on a physioball with the arm overhead in line with their body. They oscillated the Bodyblade in the sagittal plane while moving their arm through flexion and extension.

**Shoulder Dump.** The subjects stood in a narrow lunging position with feet wider than shoulder width and facing forward. They started with their shoulder in abduction.
and external rotation and then oscillated the Bodyblade while flexing and rotating the trunk, imitating an overhead throwing motion (Figures 3A, B).

**Ipsilateral/Contralateral Leg External Rotation.** The subjects stood on a single leg with their arm at their side and elbow flexed to 90°. They then oscillated the Bodyblade in the transverse plane while maximally externally rotating their arm, before returning their arm to a neutral position.

**Static Abduction.** The subjects stood with their feet shoulder width apart and their arm at 90° of abduction and elbow extended. They oscillated the Bodyblade in the frontal plane while maintaining 90° of abduction (Figure 4).

**Ipsilateral/Contralateral Leg ABD.** The subjects stood on a single leg with their arm at their side, with elbow extended. They oscillated the Bodyblade in the frontal plane while moving it through a full comfortable range of abduction, before returning to the starting position.

**Static Flexion.** The subjects stood with feet shoulder width apart, arm at 90° of flexion, and elbow extended. They oscillated the Bodyblade in the sagittal plane while maintaining 90° of flexion (Figure 5).

**Ipsilateral/Contralateral Leg Flexion.** The subjects stood on a single leg with their arm at 0° of flexion and elbow extended. They oscillated the Bodyblade in the sagittal while moving through a comfortable range of flexion before returning their arm to the starting position.

**Statistical Analyses**

Data from each muscle were normalized and expressed as a percent contribution of the MVIC. Statistical analyses were performed using IBM SPSS Statistics 19. Descriptive statistics were expressed by means and SDs.

**RESULTS**

The results of the descriptive analysis muscle activations normalized as a %MVIC are summarized in Figures 6–10. Data revealed moderate to moderately strong activation of both the musculature of the upper and lower extremity while performing the shoulder rehabilitation exercises.

Gluteus maximus muscle activity revealed moderate activity (≥20%MVIC) for all exercises tested, with moderately strong activity (≥40%MVIC) for external rotation and abduction using ipsilateral single leg support (Figure 6). Lower trapezius displayed moderate activity for all the exercises tested while exhibiting moderately strong activity for all abduction and dynamic exercises (Figure 7). The upper trapezius muscle activity was similar in that all exercises elicited moderate activity, whereas abduction and the dynamic exercises displayed moderately strong activation (Figure 8). The muscle activations of the infraspinatus revealed moderate activity in all single plane exercises while moderately strong activation in all dynamic exercises (Figure 9). The anterior deltoid, unlike the other muscles, did not have moderate activity in all exercises. External rotations did not elicit moderate deltoid activity as compared with all other exercises. In addition, ipsilateral abduction was the only exercise to achieve moderately strong activation (Figure 10).

In addition to examining the muscle activation of the lower and upper extremity while performing common shoulder rehabilitation exercises, we also were able to quantify some common force couples of the shoulder. Figure 11 displays the upper trapezius, lower trapezius, and infraspinatus muscle activations. The OH exercise elicited greater infraspinatus and upper trapezius activation, whereas the PB and dynamic PH displayed greater lower trapezius

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**Figure 11.** Muscle activation: A) infraspinatus, B) lower trapezius, C) upper trapezius as percent maximum voluntary isometric contraction (%MVIC) for dynamic exercises.
activity, while the shoulder dump revealed greater lower trapezius and infraspinatus muscle activation as compared with that of the upper trapezius.

**DISCUSSION**

This study aimed to identify muscle activations of the lower and upper extremity while performing different shoulder exercises using the Bodyblade. The musculature of the lumbo-pelvic-hip complex comprises the abdomen, proximal lower extremity, hips, pelvis, and spine. The lumbo-pelvic-hip complex functions to maintain lumbo-pelvic stability and function as the direct link in the transfer of forces from the lower extremity to the upper extremity (16). It is known that the musculature of the trunk becomes active during both upper and lower extremity movements and a preparatory action for spinal stability (11,12). Studies have shown that unilateral horizontal shoulder abduction is associated with high activation of the multifidus and longissimus on the contralateral side (28). In addition, both small amplitude and large amplitude motions of the upper extremity and performing the exercise unilaterally or bilaterally allow for trunk muscle activation (19). It is known that the key to injury reduction is an effective strength training program to allow the athlete to perform within safe parameters at maximum effort.

Kibler et al. (17) have reported that sEMG levels of 20–30% MVIC are considered to be effective for moderate muscle strengthening. In addition, Tucker et al. (29) have reported that muscle activation of 35–50% MVIC as moderately strong activity, and 50% MVIC as significantly high muscle activity. This study is in agreement with previous studies (19,28) examining the musculature of the shoulder, and in addition, we have introduced new data to the literature of gluteal muscle activation. As proposed by McMullen and Uhl (18), our findings demonstrate that one can obtain effective activation of the core musculature and the periscapular musculature in a single activation exercise. The results follow the concept that shoulder rehabilitation exercises can simultaneously address lumbo-pelvic-hip muscular dysfunction.

Efficient shoulder function uses the muscle activations that allow for scapular stability between the mobile GH joint and the stable pelvis. To achieve scapular stability, there must be force couples of the musculature that support the scapula (17). Previous research has isolated upper trapezius muscle imbalance in relation to the lower trapezius (6). Often, it is the over activation of the upper trapezius that alters scapular stability (6). This study was able to identify muscle activations of the upper trapezius, lower trapezius, and infraspinatus. It was revealed that the dynamic exercises were able to activate both the upper and lower trapezius and the infraspinatus. It has been reported that the upper trapezius has increased activation while the other stabilizing muscles have decreased activation in any type of scapular dyskinesis (5). Thus, when analyzing strengthening exercises, it is important to moderate upper trapezius activity while focusing on increasing lower trapezius, serratus anterior, and infraspinatus activity (5). We were able to conclude that the exercises demonstrated here are consistent with exercises that can result in co-activation of the periscapular and core musculature. In addition, these exercises result in a level of MVIC consistent with a level of muscle activation that has been shown to be effective at injury prevention in sport.

The muscle activations described in this study are beneficial in choosing appropriate exercises to perform during shoulder injury prevention and rehabilitation. Information from this study can be applied to the kinetic chain approach to shoulder strengthening and rehabilitation where focus is on the movement pattern. Movement patterns for a total kinetic chain approach focus on GH motion through scapular control and scapular control through hip stability. Therefore, applying these data to a proximal-to-distal kinetic chain approach to shoulder rehabilitation may have tremendous clinical relevance. The level of muscle activation indicates that these exercises may be adjunctive to a shoulder kinetic chain exercise program because they do not achieve a high level of MVIC but are consistent with activation levels that when performed over time can result in the development of endurance strength. Thus, these exercises can be promising as adjunctive exercises to a shoulder exercise program and to assist in the development of endurance strength in the overhead athlete.

**PRACTICAL APPLICATIONS**

The findings of this study demonstrate that any of these exercises may be incorporated into a total kinetic chain shoulder rehabilitation program activating the whole kinetic chain proximally and distally. In addition, these findings may be used as adjuncts to supplement a currently implemented shoulder rehabilitation program. Based on the results of this study, further research is warranted. Future research should focus on not only healthy populations but also on individuals with shoulder injury and or pain. An intervention study would allow for these exercises to be examined on both healthy and individuals with shoulder pain and or injury. After performing the exercises for a period of time, it would be interesting to examine the muscle activation after a shoulder rehabilitation program. In addition, it would be interesting to note the effect the rehabilitation program would have on the correction of static or dynamic scapular dyskinesia or the reduction in the presentation of these conditions in an overhead athlete population.

**REFERENCES**


