This is to certify that the
thesis entitled

BODYBLADE: EFFECTS OF RHYTHMIC STABILIZATIONS ON ROTATOR CUFF MUSCLES MEASURED BY EMG, AMONG FEMALES AGES 19-25

presented by

Kristen Rodriguez Sutton

has been accepted towards fulfillment
of the requirements for the

MS degree in Kinesiology

Major Professor's Signature

6/9/06

Date

BODYBLADE: EFFECTS OF RHYTHMIC STABILIZATIONS ON ROTATOR CUFF MUSCLES MEASURED BY EMG, AMONG FEMALES AGES 19-25.

By

Kristen Rodriguez Sutton

A THESIS

Submitted to
Michigan State University
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

Department of Kinesiology

2006

ABSTRACT

BODYBLADE: EFFECTS OF RHYTHMIC STABILIZATIONS ON ROTATOR CUFF MUSCLES MEASURED BY EMG, AMONG FEMALES AGES 19-25.

By

Kristen Rodriguez Sutton

Purpose: The purpose of this study was to examine the difference in the amount of muscle recruitment across six shoulder muscles comparing the four positions performing both static holds and rhythmic stabilizations using the Bodyblade™.

Methods: A total of 20 female subjects volunteered for this study. Using electromyography, all participants performed eight exercises using the Bodyblade™ (four static hold exercises, four rhythmic stabilization exercises) in four different shoulder positions.

Results: Results revealed a greater percent of maximal voluntary contraction while performing rhythmic stabilization compared to static hold activities using the Bodyblade™. Teres minor produced the greatest percent of muscle recruitment during the Bodyblade™ exercises in the shoulder shrug, front raise and IR/ER positions. The front raise Bodyblade™ exercise produced the greatest muscle recruitment across the six muscles.

Conclusion: Results of this study suggest that rhythmic stabilization provides greater rotator cuff muscle recruitment compared to a static hold with the Bodyblade™. This supports the use of the Bodyblade™ among sports medicine professionals as a proficient rehabilitation tool for the rotator cuff muscles.

DEDICATION

To Rod and Margaret Rodriguez

You have brains in your head,

You have feet in your shoes

You can lead you life any direction you chose

You're on your own now

And you know what you know

And you are the GUY

Who will decide where you go!

DR. SUEUSS

ACKNOWLEDGEMENTS

I would like to acknowledge the efforts of my thesis committee. Through all the trials and tribulations in the past two years, you stood by my side, giving me confidence, support and inspiration. Thank You for all your time and effort.

To Dr. Powell, thank you for help as an advisor for the past two years. All your efforts are greatly appreciated.

To Dr. Tracey Covassin, thank you for all your support. Thank you for the late evenings, early morning testing subjects and for all your tireless efforts to help make this happen. You have been a mentor, a teacher and most of all a friend.

To Dr. Larry Nassar, thank you for the inspiration to become a better athletic trainer, as well as a better person. Thank you for your guidance and willingness to help.

To Dr. Derek Scott, thank you for your time and knowledge. Your willingness to help was greatly appreciated.

To GM Pugh and Nathan Cline, thank you for sharing your experiences, for holding me to high standard and believing that I was capable of achieving them. Thank you for your guidance as mentors and as friends.

To the graduate athletic training class of 2006, thank you for being a second family. Julie, thank you for lending a shoulder to cry on or a ear to talk to. I could not have done it without you.

To my parents, thank you for always being there, for all your love and support throughout the past 23 years. And to Kenny, Charlie and Casey, thank you for your light heartedness and love. To Justin, thank you for always being a friend when times got tough.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Overview of Problem

As insight develops in the fields of exercise physiology and biomechanics, rehabilitation tools are greatly enhanced. Based on the theory of proprioception and neuromuscular facilitation, the Bodyblade™ was developed as a self executed rhythmic stabilization tool. This investigation attempted to identify which rotator cuff muscles were recruited while using the Bodyblade™ for static hold and rhythmic stabilization exercises. Differences between six muscles were observed in order to determine which had the greatest and which had the least amount of muscle recruitment across a total of eight exercises.

In 1994, Bruce Hymanson developed the Bodyblade™ to strengthen and rehabilitate the shoulder (www.bodyblade.com). Most clinicians believe it is obvious that the rotator cuff muscles are activated while performing these exercises. Yet, little research has been published on recruitment of muscle activity when using the Bodyblade™. Stone, Partin, Lueken, Timm, & Edward (1994) examined the Bodyblade™ for performance and strength enhancements while Schulte & Warner (2001) used a Cybex Electronic Digital Inclinometer 320 to measure gains in proprioceptive response. Although both of these studies showed an overall gain in proprioception and function, the question arises as to the amount of neuromuscular recruitment initiated by the rotator cuff muscles when performing rhythmic stabilizations using the Bodyblade™. By investigating the motor recruitment of the rotator cuff muscles and additional scapular stabilizers alternative exercise tools can be identified.

Over the past decade, Bodyblade™ has been a rehabilitation tool that allows athletes to work scapular stabilizing muscles through self induced rhythmic stabilization. The Bodyblade™ was incorporated into rehabilitation protocols to produce co-contractions of shoulder musculature. This creates approximation of the shoulder while enough force is produced to rhythmically move the tips of the blade. Although there is little research to support specific muscle innervations during rhythmic stabilization exercises using the Bodyblade™, there have been a number of studies discussing rhythmic stabilization as a component of proprioception (Leggin & Kelly, 2000). Theoretically, rhythmic stabilization exercises using the Bodyblade™ promote synergistic muscles to co-contract, improving proprioception of the rotator cuff muscles. Previous research on Bodyblade™ examined performance enhancement protocols in sports such as baseball and softball (Schulte & Warner, 2004). The athletes tested used the Bodyblade™ to mimic their throw through a full range of motion. Throwing acceleration was measured before and after completing the Bodyblade™ regiment. Results suggest that using Bodyblade™ increased speed in which the ball was thrown.

Significance of Problem

The Bodyblade™ is used both in the medical world and among strength and conditioning specialists. The Bodyblade™ is an integral part of many rehabilitation and maintenance protocols for athletes. By providing evidence of the effectiveness in activating the rotator cuff muscles using the Bodyblade™, more athletic trainers may be inclined to use it as an alternative to manual rhythmic stabilization exercises. Furthermore, it may allow athletes to facilitate strengthening and maintenance rehabilitation protocols at home more regularly.

Sports rehabilitation may not be the only atmosphere for the Bodyblade™. Rhythmic stabilization exercises have shown improvements in an industrial setting for adhesive capsulitis in middle-aged adults (Rizk, Christopher, Pinals, Higgins, & Frix, 1983). In this case a Bodyblade™ may help factory and construction workers maintain shoulder strength and stability after physical therapy is completed. Hintermeister, Lange, Schultheis, Bey, and Hawkins (1998) determined a "take home" program of Thera-band exercises for postoperative patients improved strength and proprioception. A similar protocol could be created for the Bodyblade™ which may produce parallel benefits for the patients.

The shoulder is an inherently unstable joint due to the anatomical relationship of the glenoid fossa and the humeral head, creating a lack of bony stability. This relationship reinforces the importance of surrounding muscular strength, the rotator cuff muscles. The glenohumeral joint relies on both static and dynamic stabilizers in order to function properly. Neuromuscular control is dependent on proprioceptors located in the joint capsule, as well as muscular strength. Many injuries are sustained when stress is placed on a shoulder with weak surrounding musculature. Likewise, after a traumatic injury has occurred to the shoulder, the rotator cuff muscles play an active role in protecting it from further injury. After surgery, it is vital for patients to maintain strength of the rotator cuff muscles in order to maintain stability.

A study by Kelly, Williams, Cordasco, Backus, Otis, Weiland, Craig, Wickiewicz, & Warren (2005) was conducted using symptomatic and asymptomatic adults with rotator cuff tears. Electromyography was used to measure rotator cuff activation during the performance of 10 functional tasks. Asymptomatic participants tended to have increased firing patterns of the muscles, while symptomatic participants continued to rely on "torn tendons and periscapular muscle substitution, resulting in compromise" (Kelly et al., 2005). Researchers suggested that the rotator cuff muscles aid in protecting the shoulder from major injury. Myer, Yan-ying-yu, McMahon, Rodosky, and Lephart (2004) demonstrated greater firing pattern in unstable an glenohumeral joint.

Statement of the Purpose

The purpose of this study was to determine the amount of muscle recruitment occurring across six shoulder muscles during static and dynamic actions of the Bodyblade™, measured by electromyography (EMG). The goal was to specifically describe which shoulder position was most effective in facilitating recruitment of the six shoulder muscles examined; anterior deltoid, serratus anterior, pectoralis major, supraspinatus, infraspinatus and teres minor. From these results, specific shoulder positions can be implemented in exercise and rehabilitation that result in high levels of muscle activation.

Need for Study

The current study will help develop suggestions for arm positions that may improve rotator cuff muscle rehabilitation protocols. Despite the popularity of the Bodyblade™, there is a limited amount of credible research published. Data collected may assist in validating techniques currently used by medical professionals by clarifying which muscles are recruited during specific exercises. In contrast to most studies incorporating the Bodyblade™, which use functionality and performance enhancement as a standard for improvement, this study will look at the EMG activity of shoulder muscles during Bodyblade™ exercises.

Research Questions

1. Is motor unit recruitment during rhythmic stabilization with the Bodyblade™ greater than recruitment during static contraction for active female college students across all four exercises?

2. Which of the six shoulder muscles has a greater percentage of reference contraction during each of the eight activities?
3. Which of the eight tests require the overall greatest amount of muscle recruitment of the six muscles being monitored?
4. Which of the eight tests require the overall least amount of muscle recruitment of any of the six muscles being monitored?

Definitions

The Bodyblade™ is a fiber glass blade containing a plastic handle in the center and two flexible plastic tips housing weighted pieces. Using inertia, the Bodyblade™ is oscillated using the shoulder muscles, as well as others, to create the desired motion. A variety of blade length and weights are available depending on desired results. The blades may also vary by pliability of the blade. The CXT was used in this study.

Electromyography (EMG)- uses a recording device that measures the electrical impulse of the muscle in order to detect contraction or motor unit recruitment. EMG may be performed with electrode contact on the surface of the skin or with fine needles placed into the muscle belly.

Polymeric- the process of muscular activity, which involves the eccentric loading of a muscle, followed by an immediate concentric unloading.

Proprioception- the position sense of awareness as to where the body is in space.

Proprioceptive neuromuscular facilitation- A variety of techniques used to perform rehabilitation using all three planes of motion in the body and the proprioceptive input from the involved joints and muscles.

Rhythmic stabilization- an isometric contraction of the agonist and antagonist muscles, producing co-contractions of synergistic muscles and aiding in stability.

Rotator cuff muscles- a musculotendonous structure about the capsule of the glenohumeral joint, including the 1) supraspinatus, 2) infraspinatus, 3) teres minor, and 4) subscapularis. A portion of the capsule is formed by the blending of the inserting fibers of these muscles which provide mobility and strength to the shoulder joint).

CHAPTER 2

REVIEW OF LITERATURE

Anatomy of the Shoulder

Due to the lack of bony stability, the shoulder relies on the surrounding musculature to maintain the strength and proprioception necessary to move. The lack of bony stability creates a larger amount of force placed on the shoulder musculature; therefore, the rotator cuff muscles must withstand the increased load. The rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis) play an active role in maintaining the stability of the glenohumeral joint. The rotator cuff sustains a number of different injuries including strains, tears, and avulsions. The glenohumeral joint is comprised of four muscles, three of them inserting on the greater tubercle of the humerus. The acronym used to remember their order of origin superior to inferior is SIT: supraspinatus, infraspinatus, and teres minor. The forth rotator cuff muscle is the subscapularis which inserts on the lesser tubercle of the humerus. The subscapularis is not directly palpable and holds little reliability when pinpointing for using fine wire needles and will not be utilized in this study. The infraspinatus, supraspinatus, and teres minor will be tested via fine wire EMG.

Supraspinatus

The supraspinatus originates on the middle two thirds of the supraspinous fossa and inserts on the superior aspect of the greater tubercle. To test this muscle for a reference contraction, the subject should stand with both shoulders abducted to 90 degrees, horizontally adducted 30 degrees, and internally rotated so the subject's thumbs face the floor. The tester resists maximal shoulder abduction at the forearm (Konin, Wiksten, Isear, & Brader, 2002).

Infraspinatus

The infraspinatus originates along the medial two thirds of the infraspinous fossa of the scapula and inserts in the middle facet of the greater tubercle of the humerus and the shoulder joint capsule (Kendall, McCreary, & Provance, 1993). In order to perform a manual muscle test, the subject must be in a seated position with the shoulder at the side and the elbow flexed to 90 degrees. The subject then resists external rotation while manual pressure is applied at the forearm. This muscle is critical in the stabilization of the humeral head in the glenoid fossa. The muscle's predominate action is external rotation.

Teres Minor

The teres minor originates on the upper two-third of the dorsal surface of the scapula's lateral boarder (Kendall, McCreary, & Provance, 1993). It inserts slightly more inferior on the greater tubercle than the infraspinatus muscle. By remembering SIT, the insertions move superior to inferior.

Subscapularis

The subscapularis is a challenge to palpate, making it difficult to insert an EMG wire. The subscapularis originates on the upper two-thirds of the dorsal surface of the scapula and inserts on the lesser tubercle of the humerus. It is the primary internal rotator of the shoulder. Kendall, McCreary, and Provance (1993) describe the main action as medial rotation providing stabilization of the humeral head in the glenoid fossa.

Bodyblade™

The Bodyblade™ is a fiberglass blade consisting of a handle in the center and two flexible, weighted plastic tips on each end. The Bodyblade™ uses rhythmic stabilization by oscillating the tips of the blade throughout a range of different shoulder positions.

Rhythmic stabilization incorporates the use of both agonist and antagonist muscles co-contracting while extraneous perturbations, or forces, are exercised on the body part. This technique combines proprioception and neuromuscular stimulation to strengthen and re-educate the glenohumeral joint. Rizk et al. (1983) showed rhythmic stabilization, to be an effective method of rehabilitation for adhesive capsulitis (frozen shoulder). By the improvements seen in shoulder motion, this study suggests that rhythmic stabilization is effective for proprioception and range of motion improvements, not necessarily strength gains. Although frozen shoulder is an extreme shoulder pathology and rhythmic stabilization is only one facet of proprioceptive training, it illustrates that there is increased rotator cuff activity during proprioceptive exercises.

Stone, Partin, Lueken, Timm, and Edward (1994) discussed the importance of sports specific proprioceptive training. Rehabilitation suggestions were made comparing open kinetic chain athletes consisting of volleyball players, basketball players, and weight lifters, to closed chain athletes consisting of gymnasts, swimmers, canoeists, rowers, and kayakers. According to Stone et al. (1994), it was most beneficial for an athlete to begin rhythmic stabilization through a range of motion as soon as pain and strength permitted as well as progress into upper body weight bearing proprioceptive exercises. This investigation reinforces the importance of rhythmic stabilization as a rehabilitation technique for the upper extremity.

Static verses Rhythmic Stabilization using the Bodyblade™

Proprioception is defined as the awareness and understanding of the shoulders position in space and how it adjusts to external forces placed upon it. A key component in rehabilitation of the shoulder is proprioception. The rhythmic stabilization technique targets an increase in proprioception. Due to the lack of structural stability, it is important for the shoulder to regain a sense of position and kinesthesia. Exercises provided by oscillatory devices, such as the Bodyblade™, are termed "co-activation exercises." This concept entails reciprocal recruitment of the agonist and antagonist muscles in a synergistic fashion. The synergistic contraction helps maintain joint stability by co-contracting against potentially harmful external forces. This leads to the idea that there is more muscle activation with rhythmic stabilization when compared to static hold exercises.

Strength may be measured by a reference contraction or through sport specific functional testing. Armstrong (2002) examined the functionality of 17 male college baseball players. No direct improvement was shown in strength, yet through functional testing, throwing velocity improved following Bodyblade™ training

Myers et al. (2004) described the need for proprioceptive rehabilitation, incorporating neuromuscular stimulation in patients with anterior shoulder instabilities. A comparison was made between patients with and without anterior shoulder instabilities during upper extremity perturbations in an externally rotated position. The research demonstrated both weakness and latent reactions of the musculature surrounding the shoulder.

Signorile, Lister, Rossi, Ma, Stoutenburg, Adams, and Tobkin (2005) used EMG to measure the amount of motor unit firing of the scapular stabilizers during Bodyblade™, Thera-band, and cuff weight exercises. EMG recordings were collected for the upper trapezius, lower trapezius, and serratus anterior. Only two shoulder positions were examined, shoulder flexion and shoulder abduction. It was concluded that the upper trapezius had significantly greater motor unit recruitment while performing the Bodyblade™ exercises when compared to the Thera-band and the cuff weight. The greatest percentage of reference contraction for the lower trapezius was recorded during Bodyblade™ while the shoulder was in an abducted position. During flexion and abduction, both the Bodyblade™ and Thera-band exercises produced an overall greater percentage of contraction when compared to cuff weight exercises. Signorile et al. (2005) was one of the first studies published to use EMG in measuring muscular activity of the shoulder muscles with the use of the Bodyblade™. Although, Bodyblade™ exercises are based on proprioception, not strength, this leads to the idea that the use of the Bodyblade™ will cause greater recruitment among rotator cuff muscles during rhythmic stabilization than with a static hold.

Specific Shoulder Positions

The four positions used in the current study are commonly included in the rehabilitation protocol suggested by Bodyblade™. The four different positions examined during both the Bodyblade™ and static hold exercises were:

Shoulder Shrug (SS): neutral shoulder adduction, elbow fully extended

Lateral Raise (LR): shoulder in 90 degrees of abduction, elbow fully extended, forearm pronated

Front Raise (FR): shoulder in 90 degrees of forward flexion, forearm pronated

Internal/External Rotation (IRER): neutral shoulder adduction, 90 degrees of elbow flexion, forearm in neutral

These four positions are also common in shoulder rehabilitation protocols using Thera-bands and cuff weights. Using similar positions, Hintermeister et al. (1998) studied seven exercises: external rotation, internal rotation, forward punch, shoulder shrug, and seated row with a narrow, middle, and wide grip. Increased motor recruitment of the supraspinatus, subscapularis, anterior deltoid, infraspinatus, pectoralis major, latissimus dorsi, serratus anterior, and trapezius was demonstrated during elastic band exercises.

Townsend, Jobe, Pink, & Perry (1991) incorporated similar positions in their study which utilized baseball athletes participating in a shoulder strengthening maintenance program. The positions that were examined included arm elevated in the coronal plane, arm elevated in the sagittal plane, press-ups, and shoulder internal and external rotation. Each of the exercises demonstrated increased recruitment of the rotator cuff muscles. Force couples were examined of the supraspinatus and anterior deltoid; these muscles aid in stabilizing the humeral head in the glenoid fossa. The results indicated that the exercises performed in the scapular plane above 90 degrees produced the highest percentage of reference contraction.

Wise et al. (2004) discussed the percentage of reference contraction recruited during AROM of the shoulder in forward flexion. Results found the greatest percentage of muscle contraction in the supraspinatus followed by anterior deltoid, infraspinatus, and pectoralis major, respectively.

Muscle Recruitment during Activity Variations

An examination by Hinestermeister et al. (1998) focused on muscle recruitment during Thera-band activities. For example, it was recognized that the subscapularis was used predominantly during internal rotation when compared to the infraspinatus. The infraspinatus produced the greatest percentage of muscle contraction during external rotation. The Thera-band activity in the shoulder shrug position, similar to neutral shoulder adduction, incorporated the greatest number of muscles used simultaneously, five of the seven. A number of rehabilitation exercises using elastic resistance were discussed, each of which using fine wire EMG. The findings proved for each exercise focus on a different set of muscles. Therefore, it is demonstrated that muscles produce an increased contraction depending on the position of the arm and the external forces created through movement of the Bodyblade™ during rhythmic stabilization.

Motor Unit Recruitment using Electromyography

EMG has been used to measure the relative activation of motor units in different shoulder muscles by examining the electrical potential in the muscle. An increase in the rate of motor unit activation signifies an increase in force development.

When discussing various proprioceptive techniques it is important to include the effects of motor unit reflexes. An increase in the reflex motor unit contraction may indicate an increase in the rate of force development. Also, an increase in neutral adaptations may result in an improvement in co-contractions between agonist and antagonists muscles during large motor movements. Muscular strength can be improved by increasing the number of motor units activated or by increasing the firing rate of the active motor units (Friedhelm & Culcea, 2004). Systematically, the muscle will increase the number of motor units recruited, in size order, smallest units first followed by the larger units. The additional number of recruited motor units aids in a more rapid initiation of muscle contraction.

Electromyography

Many researchers have studied the Bodyblade™ measuring improvements in performance using methods such as acceleration, velocity, and strength (Schulte et al., 2001). To date, no studies have examined the activation of rotator cuff muscles during rhythmic stabilization using the Bodyblade™. Signorile et al. (2005) recently observed EMG analysis of the scapular stabilizers which compared Bodyblade™, Thera-band, and cuff weight activities. Each muscle was tested and recorded as a percentage of reference contraction. The reference contraction assisted in normalizing the data so the muscles were able to be cross examined.

Noise Interference

The major problem with using fine needle EMG during Bodyblade™ activities was input impedance (Rogoff et al., 1961). The use of "quiet files" assisted in establishing a baseline measurement. This helped make a greater distinction between time of activity and baseline recordings. A "quiet file" is an EMG recording done while the subject is sitting at an inactive state. The "quiet file" provided a reason for performing a static hold as a control condition and for establishing a baseline. This aided in determining an increase in percentage of muscle contraction during Bodyblade™ activities.

Rhythmic Stabilization using the Bodyblade™

Although few studies have measured Bodyblade™ exercises as a direct cause of rotator cuff muscle activation, it was measured indirectly through a number of studies. Most studies used Bodyblade™ exercises to examine the functional improvements of an activity following a rehabilitative protocol rather than the neuromuscular aspect of use. Rhythmic stabilization using the Bodyblade™ showed improvement in areas such as throwing acceleration (Schulte, 2001.) Bodyblade™ exercises are one of many forms of rhythmic stabilization techniques. Leggins and Kelley, (2000) discussed this technique as a form of rehabilitation tool. The rehabilitation programs in post surgical rotator cuff patients were investigated. The rehabilitation program included Bodyblade™ exercises as a proprioceptive activity. Similarly, rhythmic stabilization demonstrated proficient gross improvements in shoulder rehabilitation in patients with adhesive capsulitis (Rizk et al., 1983). By using EMG to detect the difference in muscle firing patterns between static hold and rhythmic stabilization, new strengthening protocols may be developed.

CHAPTER 3

METHODS

The purpose of this study was to determine the amount of muscle recruitment occurring across six shoulder muscles during static and dynamic actions of the Bodyblade™, measured by electromyography (EMG). The goal was to specifically describe which shoulder position was most effective in facilitating recruitment of the six shoulder muscles examined; anterior deltoid (AD), serratus anterior (SA), pectoralis major (PM), supraspinatus (SS), infraspinatus (IS), and teres minor (TM).

Research design

A randomized, counterbalanced, within-subject experimental design was used to compare the effects of static hold and rhythmic stabilization on four different shoulder positions.

Shoulder Shrug (SS): neutral shoulder adduction, elbow fully extended

Lateral Raise (LR): shoulder in 90 degrees of abduction, elbow fully extended, forearm pronated

Front Raise (FR): shoulder in 90 degrees of forward flexion, forearm pronated

Internal/External Rotation (IRER): neutral shoulder adduction, 90 degrees of elbow flexion, forearm in neutral

The within-subjects design helped control for subjects' variability, such as individual differences in flexibility and strength. The counterbalancing technique helped control for practice affects that result from repeated Bodyblade™ testing.

The dependent variable for this study was the EMG data regarding muscle recruitment for six shoulder muscles. The data points included intramuscular fine wire needles placed in the muscle belly of three muscles; infraspinatus, supraspinatus, and teres minor. Surface electrodes were placed on the serratus anterior, anterior deltoid and pectoralis major.

The independent variables for this study were the static hold exercises verses rhythmic stabilization exercise using the Bodyblade™, the four different shoulder positions tested, and the six shoulder muscles examined.

Little research has validated the use of Bodyblade™ as a proficient tool for rotator cuff rehabilitation and strengthening. It is unknown as to which muscles are actually firing during specific Bodyblade™ exercises and which of these exercises most effectively facilitate activation of the rotator cuff muscles and scapular stabilizers. This protocol studied the effects of static hold verses rhythmic stabilization using electromyographical analysis of muscle recruitment.

Participants

Twenty healthy females between the ages of 18 and 26 were used for this study. Participants were accepted if they were recreationally active, defined as participating in some form of physical activity a minimum of two days a week and not playing a high level sport (collegiate or professional level). Participants were recruited on a volunteer basis from a Midwestern Division I university. Consent forms and a health history questionnaire were completed and signed by all participants prior to data collection. Females with a previous history of shoulder surgery or cervical spine pathologies were excluded from the study. Individuals with major wrist, elbow, hand, or shoulder problems (i.e. chronic pain, previous diagnosis of shoulder pathology, impingement, sprains, moderate strains) during the past six months were also excluded. All participants self reported right arm dominance. Participants were restricted from upper body maximal lifting activities for at least four days prior to testing. A waiver of informed consent was required to be signed prior to the beginning of the study in order to participate.

Instrumentation

Bodyblade™

A CXT Bodyblade™ was used during this study. It was 40 inches long and had an approximate weight of 1.25 lbs. It is recommended for "increasing muscular endurance, balance, and coordination" (www.bodyblade.com). This Bodyblade™ is commonly used to strengthen shoulders during rehabilitation and functional exercises.

Electromyography

An eight-channel FM transmitter attached to the Myopac system (Run Technologies, Mission Viejo, CA) was used to detect the EMG activity of the serratus anterior, anterior deltoid, pectoralis major, infraspinatus, supraspinatus, and teres minor. The Myopac system is equipped with eight channels, each with two leads. Each of the leads has an alligator clip that attaches to the surface electrodes (AMBU, Blue Sensor electrodes, Glen Burnie, Maryland). In order to use the fine wires, each channel required individual adapter. The adapters consisted of a small rectangle with two male connectors for the alligator clips to attach and two coils to attach the fine wires. The adapters were placed on the skin using Mastisol and tape.

Once all electrode placements were verified through manual muscle tests, the subjects began their randomized trials.

EMG data were measured by a raw voltage (volt * second) using Datapac 2K2 (Run Technologies, Mission Viejo, CA). EMG raw scores (volt* seconds) were then divided by an average reference contraction to produce a percentage of the reference contraction, similar to the procedure for measuring maximal voluntary contraction (MVC) described by Hintermeister et al. (1998). Reference contractions were obtained through a control isometric contraction. Each subject performed a reference contraction for each muscle pre-exercise and post-exercise. Each contraction lasted five seconds with at least three to five seconds of rest between the contractions. For each muscle, reference contractions were performed with a joint configuration that maximized EMG activity under isometric conditions and within a normal range of motion. The positions selected for reference contraction performance isolated each respective muscle, based on muscle strength testing positions (Kendall, McCreary, & Provance, 1993). The reference contraction value represents the average taken from pre-exercise and post-exercise manual muscle tests for each muscle. The reference contraction was used as a baseline for EMG data collection during the specified activities.

During an EMG reading, the signals from the leads inserted or attached to the muscle were passed to a battery operated Myopac eight-channel FM transmitter (RUN Technologies, Mission Viejo, CA). The signal was amplified by a gain of 1000 V with a single-ended amplifier with impedance greater than ten MOmega. Waveform processing was filtered with a notch Butterworth filter (60.0 Hz) and common mode rejection ratio of 130 dB at direct current with a minimum of 85 dB across the entire frequency of 10-500 Hz. A Datapac receiving unit with a sixth order filter (gain 2, total gain 2000) further amplified the signal. The analog signal was converted to a digital signal by an analog-to-digital converter card (Run Technologies, Mission Viejo, CA) and was stored in the Datapac Software, version 3.00. The raw digital signal (reference contraction and trials) was sampled at a rate of 960 Hz and smoothed using a root mean square algorithm over a 50-ms moving window.

Data Collection Procedures

Testing involved two sessions, the first lasted only 15 to 20 minutes and the second involved a 60-minute time period. The first session tested the proficiency of rhythmic stabilization with the Bodyblade™. Participants were considered proficient when they are able to flex the tips of the Bodyblade™ with minimal movement of the shoulder. During the second testing session, participants were placed in a "quiet room" in order to reduce extraneous noise and verify proficiency of the Bodyblade™ exercises. They were then familiarized with the manual muscle tests used to calculate reference contractions for each individual muscle. Participants remained seated on a medical table while the right side of the body was prepared for electrode placement. Over the areas of surface electrode placement, the participants were shaved, abraded, and cleansed with 70% isopropyl alcohol pads. The participants were then cleansed with alcohol pads over the posterior aspect of the right shoulder where the fine wires were to be inserted. All muscles with superficial orientation were assessed with surface electrodes (pectoralis major, anterior deltoid, and serratus anterior). Surface electrode placement was determined by finding the mid-point between the origin and insertion of the designated muscle. Serratus anterior was generally placed at the level of the seventh and eighth rib. After proper preparation, two forty-millimeter-diameter self-adhesive silver/silver-chloride bipolar surface electrodes (AMBU, Glen Burnie, Maryland) were placed parallel to the underlying muscle fibers. Each pair of surface electrodes had a two cm separation from the center of each electrode (Basmajian et al, 1989). Correct position of the electrode was confirmed by real-time visual inspection of the EMG signal on an oscilloscope during manual muscle testing that isolated activation in the designated muscle (Basmajian et al., 1989). Then, under sterile conditions, the fine wire needles were inserted by a sports medicine physician into the infraspinatus, supraspinatus, and teres minor. All participants were given the option to use Flori-Methane spray and stretch (Gebauer Company, Clevland, OH) for an analgesic effect prior to insertion of the fine wire needles. The fine wire electrodes consisted of a 0.002 x 8" nickel alloy wire insulated with nylon (Chalgren Enterprise, Inc. Gilroy, CA). This type of fine wire was chosen according to published recommendations (Kelly et al., 1997). Fine wires were inserted intramuscularly into the respective muscle via a disposable paired fine wire EMG needle electrode 1.5-in (3.81-cm), 27-gauge needle (Chalgren Enterprise, Inc. Gilroy, CA) (Geiringer et. al, 1998). Two single-wire electrodes were inserted into each muscle at an interelectrode distance of one cm (Kelly et al., 1997). A forty millimeter-diameter self-adhesive silver/silver-chloride bipolar surface electrode (AMBU, Blue Sensor electrodes, Glen Burnie, Maryland) was placed just inferior to the participant's olecranon process to serve as the dispersion electrode. Prior to Bodyblade™ exercise, each participant was assigned a random order in which to perform the exercises. During the one-minute rest, the investigator told the participant the exercise they were to execute during the next 30-second exercise session. All participants used the right arm for all exercises.

Four different positions were examined twice, once holding the Bodyblade™ in a static state and once using it during rhythmic stabilization exercises. The positions performed as a static hold acted as the control for the exercises executed with rhythmic stabilization. All eight exercises were completed in a randomly assigned order. The positions examined included: shoulder shrug, lateral raise, front raise, and internal/external rotation.

No two subjects were given the same order of exercises. Each exercise was executed for 30 seconds with one minute rest between each test. During the 30 second exercise only three five-second intervals were analyzed; 5-10 seconds, 15-20 seconds, and 25-30 seconds. After completion of all exercises, the participant performed the same manual muscle tests in the same order to calculate an average reference contraction. Investigators then removed the electrodes and cleansed the affected area. The fine wires and electrode pads were removed from the participant and data were saved. Each participant was provided with a copy of the results of the study in order to better inform them of the purpose and significance of the study. If participants indicated an interest in the results of the study, they were provided with a copy of the abstract.

Statistical Analysis

Means and standard deviations were calculated for descriptive purposes. For clarification, the results section is limited to values based on percentage of reference contraction. Raw data that was measured in volt * seconds is available in the appendices. Reference contractions were measured as described in Muscles Testing Function (Kendall, McCreary, & Provance, 1993) for the anterior deltoid (AD), pectoralis major (PM), serratus anterior (SA), supraspinatus (SS), infraspinatus (IS), and teres minor (TM). Reference contractions were recorded prior to and again following testing exercises. The scores were combined and averaged to attain the number used as the divisor to determine percentage of reference contraction.

Subjects with an increased percentage of reference contraction, when comparing static and rhythmic stabilization exercises, indicated a greater amount of activity for that specific muscle in a single position. This helped normalize data across muscles to examine relative improvements from the control to experimental activities.

A 2 treatment (experimental, control) X 8 exercises repeated measures analysis of variance (ANOVA) was conducted to analyze the effectiveness of each exercise. All eight EMG test scores were analyzed individually using a repeated measure ANOVA. Another 2 treatment (experimental, control) X 6 muscle (AD, PM, SA, SS, IS, TM) repeated measures ANOVA was conducted to determine the amount of muscle involved across the group. The level of significance was set at $p = .05$ and all analyses were conducted using SPSS version 11.1 for Windows (SPSS Inc., Chicago, IL).

CHAPTER 4

RESULTS

The purpose of this study was to determine the amount of muscle recruitment occurring across six shoulder muscles during static and dynamic actions of the Bodyblade™, measured by electromyography (EMG). For clarification, the results section is limited to values based on percentage of reference contraction. Raw data is measured in volt * seconds is available in the appendix.

Static hold stabilization (SH) was used in order to compare the amount of muscle activity used while performing rhythmic stabilization (RS) exercise with the Bodyblade™. The four positions performed in this study were:

Shoulder Shrug (SS): neutral shoulder adduction, elbow fully extended

Lateral Raise (LR): shoulder in 90 degrees of abduction, elbow fully extended, forearm pronated

Front Raise (FR): shoulder in 90 degrees of forward flexion, forearm pronated

Internal/External Rotation (IRER): neutral shoulder adduction, 90 degrees of elbow flexion, forearm in neutral.

Subject Demographics

A total of 20 females (age = 21.15 ± 1.76 years, height = 64.85 ± 2.64 inches, weight = 143.35 ± 21.35 lbs, arm length = 67.45 ± 3.07 cm) volunteered to participate in the study (Table 1). Due to the within-subject experimental design, all subjects were considered part of both the experimental and the control groups.

Table 1: Subject Demographic Information

Demographics	N	Mean	SD
Age (years)	20	21.15	1.76
Weight (lbs)	20	143.35	21.35
Height (in)	20	64.85	2.64
Arm length (cm)	20	67.45	3.07

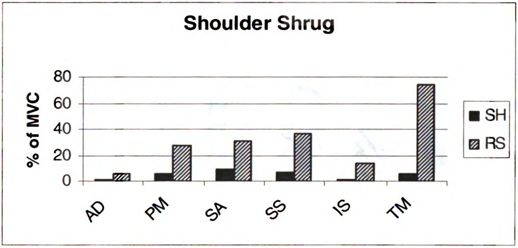
Static Stabilization verses Rhythmic Stabilization

An individual repeated measure ANOVA was performed on each of the eight exercises across the six muscles. All eight exercises revealed significant differences across all six muscles (See Appendices, Table 22- 31).

Shoulder Shrug

Results reveals significant differences during rhythmic stabilization activities for shoulder shrug position between the six muscles ($F_{(5,19)}$ = 5.32, P = 0.00). During the shoulder shrug position, the teres minor (TM) displayed the greatest percentage of muscle contraction (74.23%) in comparison to the other five muscles tested (See Figure 1).

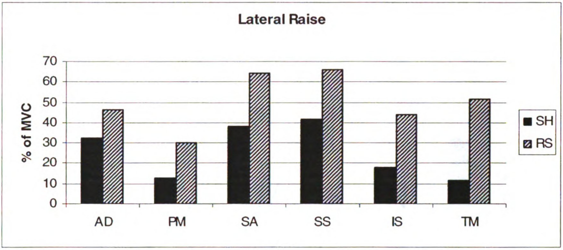
Figure 1: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Shoulder Shrug Position



Lateral Raise

During both the static hold and rhythmic stabilization activities in the lateral raise position, there was a greater percentage of muscle recruitment from the supraspinatus (SH = 41.45%, RS = 66.13%) and serratus anterior (SH = 37.97%, RS = 64.17%) compared to the anterior deltoid (SH = 32.66%, RS = 46.41%), teres minor (SH = 11.41%, RS = 51.32%), infraspinatus (SH = 17.83%, RS = 44.02%), and pectoralis major (SH = 12.51%, RS = 30.18%) muscles (See Figure 2). The lowest percentage of muscle contraction during the lateral raise was static hold using the Bodyblade™ for the pectoralis major.

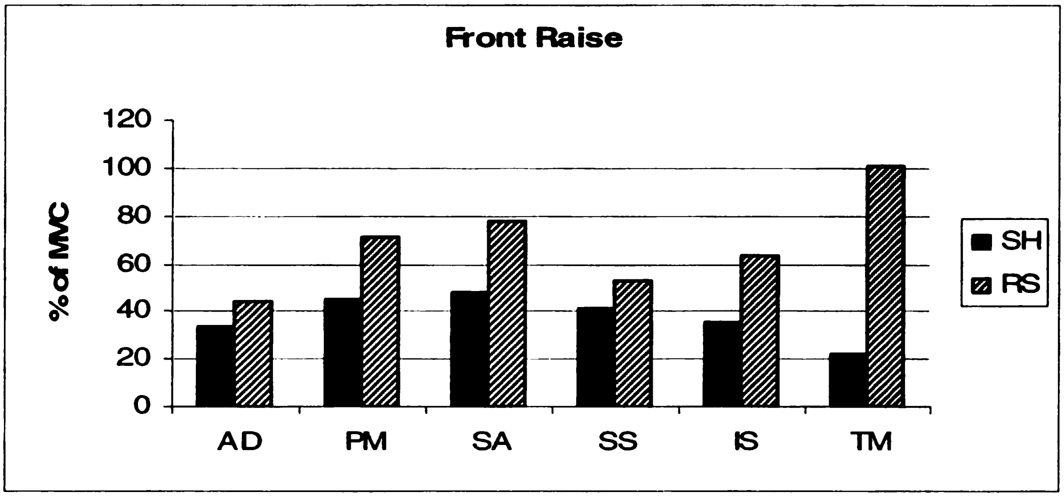
Figure 2: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Lateral Raise Position



Front Raise

During the front raise activity, the greatest percentage of muscle recruitment was seen during the rhythmic stabilization activity in the teres minor (101.21%) and serratus anterior (78.09%) (See Figure 3, See Appendix Table, 9). Values greater than 100% exist due to the methods used to establish the percentage of reference contraction. As stated in chapter three, raw scores were divided by an average of two maximal contractions to produce the percentage of reference contraction. Teres minor revealed the lowest percentage of muscle recruitment during the static hold activity (22.41%). Pair-wise comparisons revealed that the teres minor displayed the greatest change in the percentage of muscle contraction when comparing between the static hold and rhythmic stabilization activities.

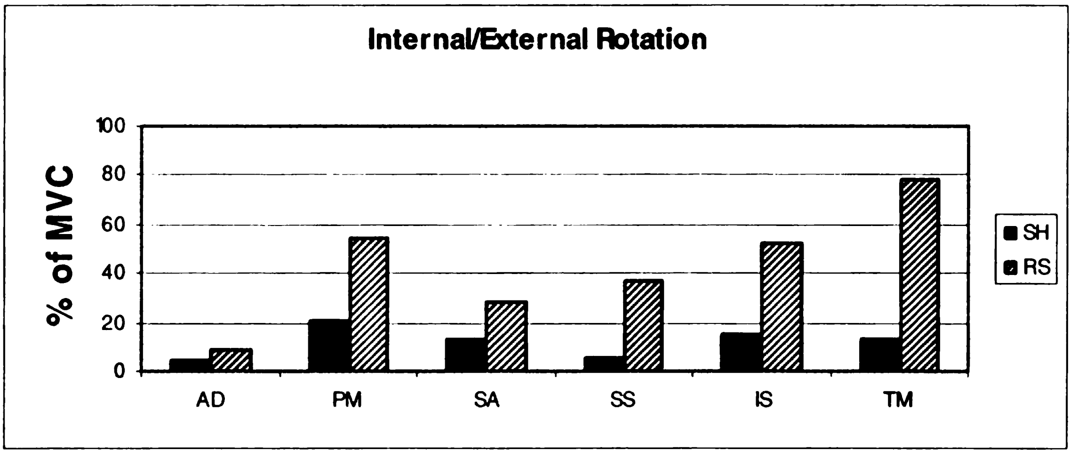
Figure 1: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Front Raise Position



Internal/External Rotation

The teres minor (78.65%) produced the greatest percentage of muscle recruitment when compared to anterior deltoid (AD), pectoralis major (PM), serratus anterior (SA), supraspinatus (SS), and infraspinatus (IS) during the internal/external rotation rhythmic stabilization exercises. The AD (4.54%) displayed the lowest percentage of muscle contraction during the static hold position (See Figure 4, See Appendices Table 24).

Figure 4: Comparison of Means between Static Hold Exercises and Rhythmic Stabilization Exercises in Internal/External Position



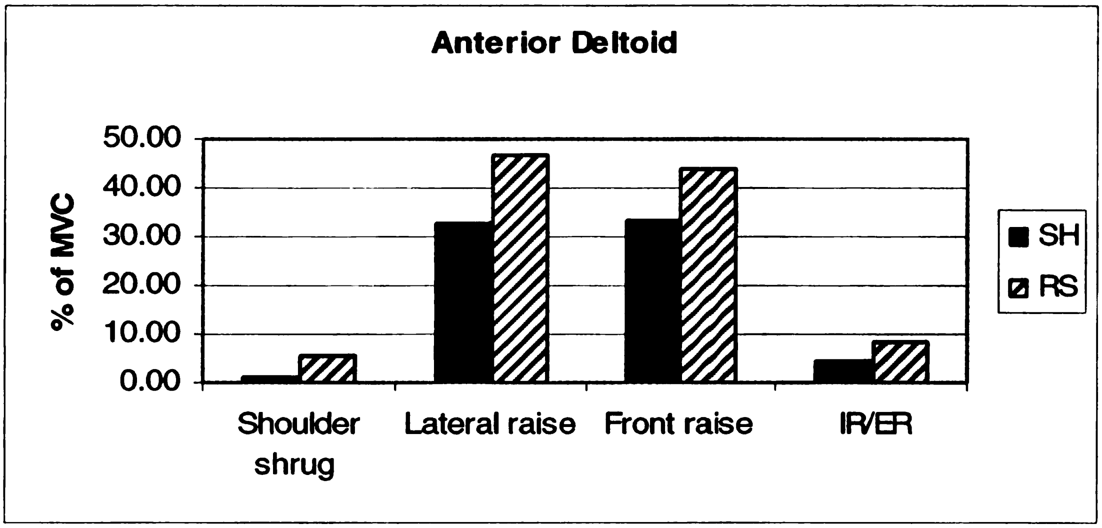
Rotator Cuff and Accessory Shoulder Musculature

An individual repeated measure ANOVA was performed on each of the six muscles across the eight exercises. Each of the six muscles revealed significant differences across all eight exercises (See Appendices Tables 31-38).

Anterior Deltoid

The anterior deltoid displayed the greatest percentage of reference contraction when individuals performed the lateral raise (46.41%) and front raise (43.69%) using Rhythmic Stabilization activities with the Bodyblade™ (See Figure 5). Static hold shoulder shrug position (1.09%) exhibited the lowest percentage of reference contraction.

Figure 52: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Anterior Deltoid

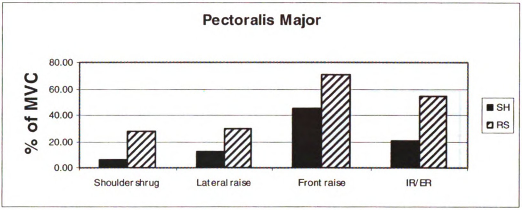


SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

Pectoralis Major

The greatest percentage of reference contraction for the pectoralis major occurred when performing IR/ER (54.54%) and FR (70.89%) during the rhythmic stabilization activity (See Figure 6). The lowest percentage of reference contraction occurred during the SS static hold position (6.08%).

Figure 63: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Pectoralis Major

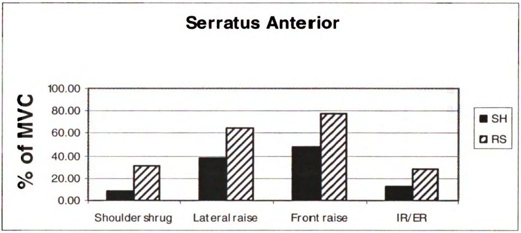


SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

Serratus Anterior

The greatest percentage of reference contraction for the SA was demonstrated during the front raise rhythmic stabilization activity (78.09%) (See Figure 7). The second most efficient exercise in recruiting the serratus anterior muscle was shown in the lateral raise during the rhythmic stabilization activity (64.17%). The lowest percentage of reference contraction was recorded during the static hold shoulder shrug activity (9.09%).

Figure 74: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Serratus Anterior

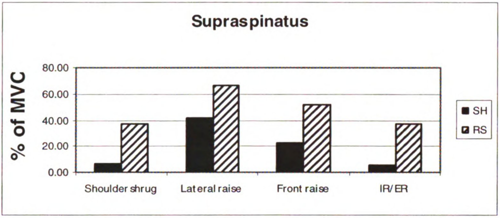


SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

Supraspinatus

The supraspinatus displayed the greatest percentage of reference contraction when individuals performed the lateral raise during the rhythmic stabilization activity (66.13%) (See Figure 8). Static hold in both the IR/ER (5.46%) and shoulder shrug (6.97%) positions exhibited the lowest percentage of reference contraction.

Figure 85: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Supraspinatus

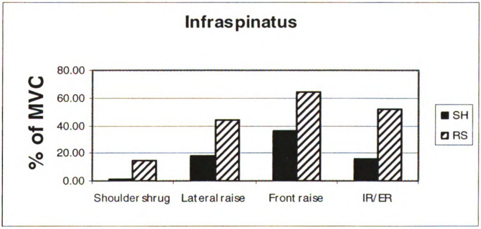


SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

Infraspinatus

The front raise (63.71%) and IR/ER (52.83%) rhythmic stabilization activities produced the greatest percentage of muscle recruitment while the shoulder shrug static hold position (1.47%) produced the lowest percentage of muscle recruitment for the infraspinatus (See Figure 9).

Figure 96: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Infraspinatus

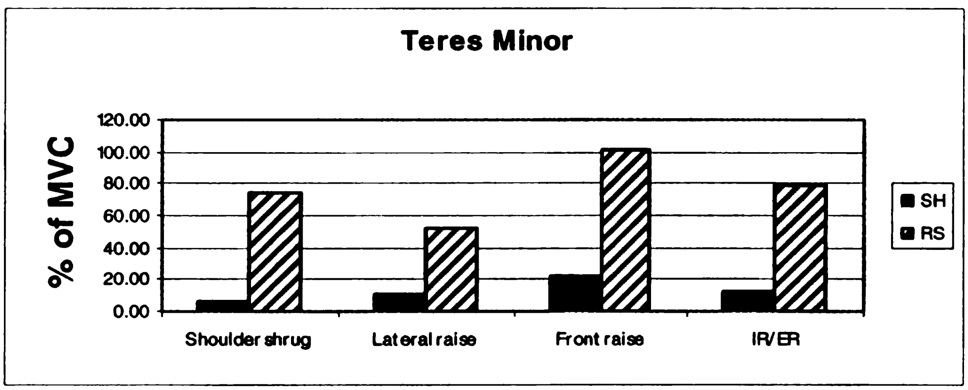


SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

Teres Minor

The two activities that incorporated the greatest percentage of reference contraction for the teres minor were IR/ER (78.65%) and FR (101.21%) during rhythmic stabilization activities (See Figure 10). The lowest percentage of reference contraction was observed in the shoulder shrug static hold position (6.28%).

Figure 7: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Teres Minor



SS-Shoulder Shrug, LR-Lateral Raise, FR-Front Raise, IR/ER-Internal External Rotation

CHAPTER 5

DISCUSSION

The purpose of this study was to determine the amount of muscle recruitment occurring across six shoulder muscles during static and dynamic actions of the Bodyblade™, measured by electromyography (EMG).

Results demonstrated four significant findings from this study. The four positions revealed a greater percentage of reference contraction while performing rhythmic stabilization compared to static hold activities using the Bodyblade™. Teres minor produced the greatest percentage of muscle recruitment when compared to anterior deltoid, pectoralis major, serratus anterior, supraspinatus, and infraspinatus during the rhythmic stabilization activity in the shoulder shrug, front raise, and IR/ER positions. The front raise rhythmic stabilization exercise produced the greatest overall muscle recruitment across the six muscles. The shoulder shrug static hold exercise produced the lowest overall recruitment of muscle activity.

Analysis of Static verses Rhythmic Stabilization Exercises

In all four positions, rhythmic stabilization with the Bodyblade™ produced a greater percentage of reference contraction when compared to static hold. Leggin and Kelly (2000) suggested rhythmic stabilization exercises should be incorporated during rehabilitation following rotator cuff surgery. They concluded that rhythmic stabilization enhances "strength, dynamic control, proprioception, and endurance training." Similarly, the results of their study suggest integrating rhythmic stabilization exercises during shoulder rehabilitation to strengthen the rotator cuff muscles. In contrast to the current study, Schulte et al. (2001) used the Bodyblade™ to examine proprioceptive response to exercise. Results demonstrated improvement in proprioception when incorporating the rhythmic stabilization compared to a control condition. Although there is no direct correlation between the two studies, there was an overall improvement with rhythmic stabilization compared to static hold using the Bodyblade™.

The findings of the present study determined using the Bodyblade™ for rhythmic stabilization in the front raise position produced the greatest percentage of reference contraction. The pectoralis major, serratus anterior, and teres minor produced the greatest amount of activity during this exercise. Hintermeister et al. (1998) observed the greatest percentage of MVC of the supraspinatus, anterior deltoid, and serratus anterior when examining the effects of elastic-band resistance on a forward punch activity. The serratus anterior, upper trapezius and lower trapezius produced the greatest percentage of MVC during rhythmic stabilization exercises in shoulder flexion when compared to the exercises performed with the Thera-band and cuff weights (Signorile et al., 2000). The study suggested that front raise Bodyblade™ exercises should be incorporated in the clinical settings to increase strength of both the rotator cuff muscles and surrounding scapular stabilizers. By placing the shoulder in forward flexion, it cannot depend predominantly on ligamentous and bony support and must rely on the rotator cuff muscles and scapular stabilizing muscles to resist the oscillations of the Bodyblade™. The serratus anterior is predominantly used for protraction and helping to stabilize the scapula, whereas, the teres minor is utilized to maintain posterior capsular stability.

A comparison between the four static activities revealed the shoulder shrug position elicited the lowest amount of muscle contraction. Similar to the study by Hintermeister et al. (1998) on elastic resistance, the

Bodyblade™ shoulder shrug activity exhibited the lowest percentage of reference contraction. A possible explanation may be due to positioning the shoulder in a gravity dependent position. In the same way, assuming capsular stability and intact surrounding ligaments, the humeral head is comfortably held in the glenoid fossa with minimal stress placed on adjoining musculature. In addition, Stone et al. (1994) described the benefits of incorporating proprioceptive exercises, similar to the rhythmic stabilization using the Bodyblade™.

Analysis of the Six Muscles across the Eight Exercises

Teres minor demonstrated the greatest percentage of reference contraction with rhythmic stabilization activities, while the anterior deltoid elicited the lowest percentage of reference contraction while using the Bodyblade™ for rhythmic stabilization. The serratus anterior displayed the greatest percentage of reference contraction and the teres minor revealed the lowest percentage of reference contraction during static hold activities. The increased use of the teres minor while performing rhythmic stabilization exercises may be attributed to the need for glenohumeral stability. The teres minor acts predominately as an external rotator and a posterior glenohumeral stabilizer, which is necessary to perform oscillations of the Bodyblade™. Likewise, this may account for the increased use of the supraspinatus as a humeral head depressor. The supraspinatus aids in maintaining humeral head stability in the glenoid fossa.

The use of the serratus anterior as a shoulder depressor and a scapular protractor may explain the increased activity while holding a Bodyblade™ in a static position. The current study exhibited a greater percentage of muscle contraction for the serratus anterior, pectoralis major and anterior deltoid. This may be due to the extended length of time the subject held the Bodyblade™, resulting in recruitment of the scapular stabilizers in place of the rotator cuff muscles.

Utilization and Clinical Incorporation of the Bodyblade™

The present study provided a foundation for positions used during shoulder rhythmic stabilization using the Bodyblade™ in rehabilitation protocols. Until now, the Bodyblade™ has been predominantly used as a tool for proprioceptive training. Demonstrating an increase in percentage of reference contraction suggests implementing the Bodyblade™ for strengthening programs in the clinical setting. When treating impingement pathologies, clinicians may strengthen the teres minor to aid in depression of the humeral head and increase the subacromial space. In addition, using the Bodyblade™ for rhythmic stabilization in a front raise or IR/ER position may be most beneficial when working with patients lacking control of external rotation. In contrast, if the supraspinatus requires more strengthening, the lateral raise position may be more appropriate.

To obtain the greatest percentage of muscle recruitment when rehabilitating the shoulder complex, it is recommended that sports medicine practitioners primarily focus on front raise and lateral raise exercises. Although shoulder shrug and IR/ER rotation exercises do produce muscle contraction, it is suggested that they are used on patients in the preliminary stages of rehabilitation.

Limitations

Only recreational athletes from one Division I university participated in this study. Recruiting recreational and NCAA athletes from multiple institutions across the country would provide a more diverse sample. Variables such as education level, hydration status, and hours of sleep were not controlled in this study.

Another limitation was fitness levels of the participants causing them to become fatigued by the final exercise. The exercises were randomized and participants were allowed to rest between sessions which minimized fatigue.

Only female recreational athletes were included in this study; therefore, the results can only be generalized to the female population. Future research needs to examine male athletes using the Bodyblade™.

These limitations should be addressed and controlled in future studies examining differences in the amount of muscle recruitment in the shoulder when comparing the use of the Bodyblade™ in static and rhythmic stabilization positions.

Future Research Considerations

Future research should examine different positions incorporating the Bodyblade™. These positions should include comparisons between overhead and underarm or prone and supine in order for clinicians to develop a progression for return to play criteria. Although strength is an important aspect of rehabilitation, proprioception must also be considered when observing the effects of rhythmic stabilization exercises on the rotator cuff and scapular stabilizing muscles.

Future research should examine the effects of co-activation patterns in order to determine different muscle activation patterns using agonist and antagonist muscle between scapular stabilizers and rotator cuff muscles.

Other areas of future interest should include the effects of Bodyblade™ size in comparison to subject's height to arm ratio. Understanding these two factors will assist clinicians in developing more efficient rehabilitation programs and prescribing the most effective Bodyblade™.

The current study should be expanded to include post surgical patients, males, and athletes from a variety of sports. This may help generalize the findings of the current study to a larger population.

Conclusion

This study examined the percentage of reference muscle contraction during eight different exercises across six different shoulder muscles. More specifically, this study observed differences in the amount of muscle recruitment of six muscles in the shoulder comparing the use of the Bodyblade™ during four static and four rhythmic stabilization activities. This was one of the first studies to demonstrate the effects of rhythmic stabilization using Bodyblade™ on the rotator cuff muscles in terms of motor unit recruitment.

At the present time the four positions revealed a greater percentage of reference contraction while performing rhythmic stabilization exercises compared to static hold activities. In addition, the teres minor produced the greatest percentage of muscle recruitment when compared to anterior deltoid, pectoralis major, serratus anterior, supraspinatus, and infraspinatus during the Bodyblade™ activity in the shoulder shrug, front raise, and IR/ER positions. The overall greatest muscle recruitment was produced during the front raise rhythmic stabilization exercise using the Bodyblade™. In the future, studies may be conducted to help broaden the subject population, as well as help develop more effective rehabilitation protocols.

BIBLIOGRAPHY

Bodyblade.(2004, October 12). Retrieved November 12, 2005, from http://www.bodyblade.com.

Brindle, T., Nyland, J., Shapiro, R., Caborn, D., & Stine, R. (1999). Shoulder proprioception: latent muscle reaction times. *Medicine and Science in Sports and Exercise, 31*(10), 1394-8.

Condor, B., Newest ways to sweat it. (2002). *Chicago Tribune, 13*, 11. (Unreliable source)

David, G., Margarey, M. E., Jones, M. A., Dvir, Z., Turker, K. S. & Sharpe, M. (2000). EMG and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint. *Clinical Biomechanics, 15*(2), 95-102.

Decker, M., Tokish, J., Ellis, H., Torry, M. & Hawkins, R.(2003). Subscapularis Muscle activity during selected rehabilitation exercises. *The American Journal of Sports Medicine*, 31(1), 126-134.

Delagi E. R., Perotto, A., Lazzetti, J. & Morrison, D. (1975). Anatomic guide for the Electromyographer. Springfield, Charles C. Thomas, 67-111.

Dockery, M. L., LaStayo, P.C. & Wright, T.W.(1998). Electromyography of the Shoulder: an analysis of passive modes of exercise. *Orthopedic,* 21(11), 1181-1184.

Hintermeister, R., Lange, G., Schultheis, J., Bey, M. & Hawkins, R.(1998).Electromyographic activity and applied load during shoulder rehabilitation exercises using elastic resistance. *The American Journal of Sports medicine,* 26:210-220.

Igneizl, R. J., Gizmo expo. (2002). *San Diego Union Tribune. Currents: arts. lifestyles.TV*, Monday, July 15, 2003, 1. (Unreliable source)

Kang, W. J., Cheng, C. K., Lai, J. S., Shiu, J. R. & Kuo, T.S. (1996). A comparative analysis of various EMG pattern recognition methods. *Medical engineering & physics, 18*(5), 390-5.

Kelly, B. T., Williams, R. J., Cordasco, F. A., Backus, S.I., Otis J.C., Weiland D. W., Craig, E.V., Wickiewicz, T. L., & Warren R. F. (1994). Differential patterns of muscle activation in patients with symptomatic and asymptomatic rotator cuff tear. *Journal of Shoulder and Elbow Surgery*, 14(2), 165-167.

Kendall, F.P., McCreary, E.K. & Provance, P.G.. (Fourth Edition). (1993). *Muscles Testing and Function.* Philidelphia, PA: Lipppincott Williams Wilkins.

Konin, Wiksten, Isear & Brader.(2002) Special Tests for Orthopedic Examination. :Thomson Learning.

Leggin, B. & Kelley, M. (2000). Rehabilitation of the shoulder following rotator cuff surgery. *The University of Pennsylvania Orthopaedic Journal, 13*, 10-17.

McCann, P. D., Wootten, M. E., Kadaba, M. P. & Bigliani, L. U. (1993). A kinematic and electromyographic study of shoulder rehabilitation exercises. *Clinical Orthopedics, 288*, 179-88.

Meskers, C. G., de Groot, J. H., Arwert, H. J., Rozendaal, L. A. &Rozing, P. M. (2004). Reliability of force direction dependent EMG parameters of shoulder muscles for clinical measurements. *Clinical Biomechanics, 19*(9), 913-20.

Myer, J.B., Yan-ying-yu, Hwang, J., McMahon, P. J., Rodosky, M.D., Lephart S.M. (2004). Reflexive shoulder activation alterations in the shoulder with anterior glenohumeral instability. *The American Journal of sports medicine,* 32(4), 1013-1021.

Powers, S. K., Howley, E. T. (2001). Exercise Physiology: Theory and application to fitness and performance: forth edition. New York, NY. McGraw-Hill Higher Education.

Reinoid, M. M., Wikk, K. E., Fleisig, G. S., Zheng, N., Barrentine, S. W., Chmielewski, T., Cody, R. C., Jameson, G. G., & Andrews, J. R. (2004). Electromyographic analysis of the rotator cuff and deltoid musculature during common shoulder external rotation exercises. *The Journal of Orthopedic and Sports Physical Therapy, 34*(7), 385-94.

Rizk, T. E., Christopher, R. P., Pinals, R. S., Higgins, A. C. & Frix,R. (1983). Adhesive Capsulitis (Frozen shoulder): A new approach to its management. *Physical Medicine and Rehabilitation*, 64, 29-33.

Sadhukhan, A. K., Goswami, A., Kumar, A., & Gupta, S. (1994). Effects of sampling frequency on EMG power spectral characteristics. *Electromyography and Clinical Neurophysiology*, 34(3), 159-163.

Schulte, R. & Warner, C. (2004) Oscillatory devices accelerate proprioceptive training. *Biomechanics, 805*, 85-91.

Signorile, J.F., Lister, J. L., Rossi, G.D, Ma, F., Stoutenburg, M., Adams, J. B., & Tobkin, S. (2005). Electromyographical analysis of scapular stabilizers using Bodyblade, cuff weights and Thera-band resistance. Medicine & Science in Sports & Exercise, 37(5), S147.

Stone, J. A., Partin, N. B., Lueken, J. S., Timm, K. E., & Edward, J. (1994). Upper extremity proprioceptive training. *Journal of Athletic Training*, 29(1), 15-18.

Townsend,H., Jobe, F.W., Pink, M., & Perry, J. (1991). Electromyographic analysis of the glenohumeral muscles during baseball rehabilitation programs. The *American journal of Sports Medicine*, 19:264-272.

APPENDICES

APPENDIX A

UCRIHS Study Approval Form

MICHIGAN STATE
U N I V E R S I T Y

Initial IRB Application Approval

January 16, 2006

To: John POWELL
105 IM Sports Circle
MSU

Re: **IRB # 05-951** Category: EXPEDITED 2-4
Approval Date: **January 12, 2006**
Expiration Date: **January 11, 2007**

Title: BODYBLADE: EFFECTS OF RHYTHMIC STABILIZATION ON ROTATOR CUFF MUSCLES MEASURED BY EMG AMONG FEMALES 18-30.

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **your project has been approved.**

The committee has found that your research project is appropriate in design, protects the rights and welfare of human subjects, and meets the requirements of MSU's Federal Wide Assurance and the Federal Guidelines (45 CFR 46 and 21 CFR Part 50). The protection of human subjects in research is a partnership between the IRB and the investigators. We look forward to working with you as we both fulfill our responsibilities.

Renewals: IRB approval is valid until the expiration date listed above. If you are continuing your project, you must submit an ***Application for Renewal*** application at least one month before expiration. If the project is completed, please submit an ***Application for Permanent Closure***.

Revisions: The IRB must review any changes in the project, prior to initiation of the change. Please submit an ***Application for Revision*** to have your changes reviewed. If changes are made at the time of renewal, please include an ***Application for Revision*** with the renewal application.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects, notify the IRB office promptly. Forms are available to report these issues.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

Gerald S. Schatz, J.D.
BIRB Chair

c: Kristen Sutton
3059 Biber St S8
East Lansing, MI 48823

OFFICE OF REGULATORY AFFAIRS

BIOMEDICAL & HEALTH NSTITUTIONAL REVIEW BOARD (BIRB)

:OMMUNITY RESEARCH NSTITUTIONAL REVIEW BOARD (CRIRB)

SOCIAL SCIENCE/ :HAVIORAL / EDUCATION INSTITUTIONAL REVIEW BOARD (SIRB)

202 Olds Hall
East Lansing, Michigan
48824-1046
517-355-2180
Fax: 517-432-4503

w.humanresearch.msu.edu
RB & BIRB: IRB@msu.edu
CRIRB: crirb@msu.edu

MICHIGAN STATE
UNIVERSITY

Revision Application Approval

January 24, 2006

To: John POWELL
105 IM Sports Circle
MSU

Re: **IRB # 05-951** Category: EXPEDITED 2-4
Revision Approval Date: January 24, 2006
Project Expiration Date: January 11, 2007

Title: BODYBLADE: EFFECTS OF RHYTHMIC STABILIZATION ON ROTATOR CUFF MUSCLES MEASURED BY EMG AMONG FEMALES 18-30.

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **the revision has been approved.**

This letter notes approval for the addition of two tasks to the protocol to improve quality of data and a revised consent form.

The review by the committee has found that your revision is consistent with the continued protection of the rights and welfare of human subjects, and meets the requirements of MSU's Federal Wide Assurance and the Federal Guidelines (45 CFR 46 and 21 CFR Part 50). The protection of human subjects in research is a partnership between the IRB and the investigators. We look forward to working with you as we both fulfill our responsibilities.

Renewals: IRB approval is valid until the expiration date listed above. If you are continuing your project, you must submit an ***Application for Renewal*** application at least one month before expiration. If the project is completed, please submit an ***Application for Permanent Closure***.

Revisions: The IRB must review any changes in the project, prior to initiation of the change. Please submit an ***Application for Revision*** to have your changes reviewed. If changes are made at the time of renewal, please include an ***Application for Revision*** with the renewal application.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects, notify the IRB office promptly. Forms are available to report these issues.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

Good luck in your research. If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

Sincerely,

Peter Vasilenko III, Ph.D.
BIRB Vice Chair

c: Kristen Sutton
3059 Biber St S8
East Lansing, MI 48823

OFFICE OF REGULATORY AFFAIRS

BIOMEDICAL & HEALTH INSTITUTIONAL REVIEW BOARD (BIRB)

COMMUNITY RESEARCH INSTITUTIONAL REVIEW BOARD (CRIRB)

SOCIAL SCIENCE/ BEHAVIORAL / EDUCATION INSTITUTIONAL REVIEW BOARD (SIRB)

202 Olds Hall
East Lansing, Michigan
48824-1046
517-355-2180
Fax: 517-432-4503

www.humanresearch.msu.edu
SIRB & BIRB: IRB@msu.edu
CRIRB: crirb@msu.edu

APPENDIX B

Human Subjects Consent Form

Body blade: Effects of Rhythmic Stabilizations on Rotator Cuff Muscles Measured by EMG, Among Females Ages 18-30

Informed Consent

For questions regarding this study,
Please contact:
Dr. John Powell
Department of Kinesiology
Michigan State University
Phone: (517) 432-5018
E-mail: powellj4@msu.edu or

Kristen R. Sutton
Graduate Assistant
Michigan State University
Email: suttonk4@msu.edu
Phone: (517) 333-3768
Work: (517) 353-1655

For questions regarding your rights
as a research participant, please contact:
Peter Vasilenko, Ph.D.
Committee on Research Involving Humans
Michigan State University
202 Olds Hall
East Lansing, MI 48824
ucrihs@msu.edu
Phone: (517) 355-2180
Fax: (517) 432-4503

The purpose of this study is to observe the activation of the rotator cuff muscles using a combination of surface and intramuscular electromyography while using the Bodyblade in three different shoulder positions during static holds and rhythmic stabilization. The Body blade is a rehabilitation tool used for shoulder strengthening. Once the ends begin to move, inertia wants to keep them in motion and it's up to you to resist the blade while moving through a predertemined range of motion. Your participation in this study will consist of one 15 minute session and a second 60 minute session. The first session will be used as a practice session to allow you to become proficient at the Bodyblade. During the second session, you will be asked to return for testing. At that time, a physician will place two fine needle electrodes into each of your teres minor, infraspinatus and supraspinatus. A certified athletic trainer will then place 6 surface electrodes on the pectoralis major, serratus anterior, and anterior deltoid. You will then be asked undergo 6 separate tasks, each lasting approximately 30 seconds. The 6 tasks will be performed using a Bodyblade at three different shoulder positions using both a static hold and rhythmic stabilization. The three different shoulder positions will include: arm by your side moving the blade up and down, mimicking shoulder elevation/depression, the shoulder by your side with the elbow bent to 90 degrees, mimicking internal/external rotation and arm at shoulder height moving the blade perpendicular to your arm.

It is impossible for the risk of injury to be completely eliminated during physical activity. Due to the nature of the test the minor potential for misplacement of the needle may cause damage to neural or vascular sites, possible infection at insertion site, and pain from the needle placement. Measures will be taken during the test to ensure your safety during and after the needle insertion. A resident physician specializing in EMG will insert and remove the needles. A certified athletic trainer will be on hand during all testing sessions. Proper precautions will be made before and after the needle placement to help prevent infection. There will be an easily accessible phone in order to dial for emergency medical services. This study will contribute to understanding the benefits of the Bodyblade. You will receive training and education about the use of the Bodyblade.

All data will be stored in a computer which will have a password and login/user name that must be entered before the data can be accessed. All subjects can be identified by the researchers but will be aggregated in all publications, writings, and journals. Your identity and recorded information will remain confidential. Your privacy will be protected to the maximum extent allowable by law.

Participation in this study is completely voluntary. There will be no monetary compensation provided in exchange for participation. In order to participate in this study, we need your written consent in the spaces provided below. You may also discontinue participation at any time without penalty. Your

This consent form was approved by the Biomedical and Health Institutional Review Board (BIRB) at Michigan State University. Approved 1/12/06 – valid though 1/11/07. This version supersedes all previous versions. IRB # 05-951 participation in this research project will not involve any additional costs to you or your health care insurer.

If you are injured as a result of your participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for your research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. Financial compensation for lost wages, disability, pain or discomfort is not available. This does not mean that you are giving up any legal rights you may have. You may contact Dr. John Powell with any questions.

Any questions concerning participation in this study should be directed to Kristen R. Sutton (517) 333-3768 or Dr. John Powell (517) 432-5018. If you have any additional questions concerning your rights as a volunteer or are dissatisfied at any time with any aspect of this study you may contact-anonymously, if you wish- Peter Vasilenko, PhD, Michigan State University's Chair of the Committee on Research Involving Human Subjects by phone: (517) 355-2180, fax: (517) 432-4503, e-mail: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

Your signature below indicates your voluntary agreement to participate in this study.

I, ______________________________ have read and agree to participate in this study as
(Please Print Your Name)

described above.

______________________________   _____/_____/_____
(Please Sign Your Name)   *(Date)*

This consent form was approved by the Biomedical and Health Institutional Review Board (BIRB) at Michigan State University. Approved 1/12/06 – valid though 1/11/07. This version supersedes all previous versions. IRB # 05-951

APPENDIX C

Health History Questionnaire

Name:____________________
Date:____________________
Subject ID:________________

Study Questionnaire

Sex: ________ Age: ________

Weight:__________ Height:_______ Right arm length:__________

How many times, on average, do you work out per week? _________

Do you currently participate in collegiate or professional sports? Yes ☐ No ☐

Medical History

Have you ever had surgery on your shoulder? Yes ☐ No ☐

If so, right or left shoulder? _______________

Have you incurred shoulder problems, i.e. chronic shoulder pain, previously diagnosed shoulder pathology (impingements, sprains, moderate to severe strains, dislocations, etc.) in the past 6 months? Yes ☐ No ☐

If so, please describe the injury:

____

____

Have you ever been diagnosed with shoulder multi- directional instabilities?
Yes ☐ No ☐

If so, right or left shoulder? _______________

Have you been diagnosed with a major wrist, hand or elbow problem in the past 6 months? Yes ☐ No ☐

If so, please describe the injury:

____

____

Do you have a history of cervical spine injuries? Yes ☐ No ☐

If so, please describe the injury:

____

____

APPENDIX D

Descriptive Statistics

Descriptive Statistics: Raw Data(Volt*seconds)

Table 2: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Anterior Deltoid

Exercise	N	Mean (V*sec)	Std. Deviation
Shoulder shrug static hold	20	0.038	0.021
Shoulder shrug rhythmic stabilization	20	0.202	0.152
Lateral raise static hold	20	1.170	0.557
Lateral raise rhythmic stabilization	20	1.633	0.814
Front raise static hold	20	1.145	0.399
Front raise rhythmic stabilization	20	1.435	0.614
IR/ER static hold	20	0.121	0.098
IR/ER rhythmic stabilization	20	0.292	0.205

Table 3: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Pectoralis Major

Exercise	N	Mean (V*sec)	Std. Deviation
Shoulder shrug static hold	20	0.057	0.014
Shoulder shrug rhythmic stabilization	20	0.252	0.108
Lateral raise static hold	20	0.115	0.049
Lateral raise rhythmic stabilization	20	0.252	0.137
Front raise rhythmic stabilization	20	0.406	0.249
Front rhythmic stabilization	20	0.620	0.334
IR/ER static hold	20	0.198	0.067
IR/ER rhythmic stabilization	20	0.463	0.176

Table 4: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Serratus Anterior

Exercise	N	Mean (V*sec)	Standard Dev
Shoulder shrug static hold	20	0.070	0.074
Shoulder shrug rhythmic stabilization	20	0.228	0.213
Lateral raise static hold	20	0.483	0.376
Lateral raise shrug rhythmic stabilization	20	0.343	0.204
Front raise static hold	20	0.287	0.238
Front raise shrug rhythmic stabilization	20	0.563	0.383
IR/ER static hold	20	0.099	0.099
IR/ER shrug rhythmic stabilization	20	0.229	0.264

Table 5: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Supraspinatus

Exercise	N	Mean (V*sec)	Standard Dev
Shoulder shrug static hold	20	0.382	0.669
Shoulder shrug rhythmic stabilization	20	1.430	0.910
Lateral raise static hold	20	2.500	1.836
Lateral raise rhythmic stabilization	20	3.240	1.826
Front raise static hold	20	1.193	0.789
Front raise rhythmic stabilization	20	2.261	1.179
IR/ER static hold	20	0.221	0.218
IR/ER rhythmic stabilization	20	1.275	1.072

Table 6: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Infraspinatus

Exercise	N	Mean (V*sec)	Standard Dev
Shoulder shrug static hold	20	0.117	0.141
Shoulder shrug rhythmic stabilization	20	1.226	0.831
Lateral raise static hold	20	1.535	0.975
Lateral raise rhythmic stabilization	20	3.818	1.778
Front raise static hold	20	2.860	1.172
Front raise rhythmic stabilization	20	5.269	2.235
IR/ER static hold	20	1.327	0.653
IR/ER rhythmic stabilization	20	4.467	2.113

Table 7: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Teres Minor

Exercise	N	Mean (V*sec)	Standard Dev
Shoulder shrug static hold	20	0.160	0.249
Shoulder shrug rhythmic stabilization	20	1.114	1.384
Lateral raise static hold	20	0.303	0.520
Lateral raise rhythmic stabilization	20	1.011	1.090
Front raise static hold	20	0.442	0.537
Front raise rhythmic stabilization	20	1.713	1.539
IR/ER static hold	20	0.507	0.836
IR/ER rhythmic stabilization	20	1.782	1.839

Table 8: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Shoulder Shrug Position

Muscle		N	Mean (V*sec)	Std. Deviation
AD	Static Hold	20	0.038	0.021
	Rhythmic Stabilization	20	0.202	0.152
PM	Static Hold	20	0.057	0.014
	Rhythmic Stabilization	20	0.252	0.108
SA	Static Hold	20	0.070	0.074
	Rhythmic Stabilization	20	0.228	0.213
SS	Static Hold	20	0.382	0.669
	Rhythmic Stabilization	20	1.430	0.910
IS	Static Hold	20	0.117	0.141
	Rhythmic Stabilization	20	1.226	0.831
TM	Static Hold	20	0.160	0.249
	Rhythmic Stabilization	20	1.114	1.384

Table 9: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise Lateral Raise Position

Muscles		N	Mean (V*sec)	Std. Deviation
AD	Static Hold	20	1.170	0.557
	Rhythmic Stabilization	20	1.633	0.814
PM	Static Hold	20	0.115	0.049
	Rhythmic Stabilization	20	0.252	0.137
SA	Static Hold	20	0.483	0.376
	Rhythmic Stabilization	20	0.343	0.204
SS	Static Hold	20	2.500	1.836
	Rhythmic Stabilization	20	3.240	1.826
IS	Static Hold	20	1.535	0.975
	Rhythmic Stabilization	20	3.818	1.778
TM	Static Hold	20	0.303	0.520
	Rhythmic Stabilization	20	1.011	1.090

Table 10: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise Front Raise Position

Muscles		N	Mean (V*sec)	Std. Deviation
AD	Static Hold	20	1.145	0.399
	Rhythmic Stabilization	20	1.435	0.614
PM	Static Hold	20	0.406	0.249
	Rhythmic Stabilization	20	0.620	0.334
SA	Static Hold	20	0.287	0.238
	Rhythmic Stabilization	20	0.563	0.383
SS	Static Hold	20	1.193	0.789
	Rhythmic Stabilization	20	2.261	1.179
IS	Static Hold	20	2.860	1.172
	Rhythmic Stabilization	20	5.269	2.235
TM	Static Hold	20	0.442	0.537
	Rhythmic Stabilization	20	1.713	1.539

Table 11: Comparison of Means between Static Hold Exercise and Rythmic Stabilization Exercise IR/ER Position

Muscles		N	Mean (V*sec)	Std. Deviation
AD	Static Hold	20	0.121	0.098
	Rhythmic Stabilization	20	0.292	0.205
PM	Static Hold	20	0.198	0.067
	Rhythmic Stabilization	20	0.463	0.176
SA	Static Hold	20	0.099	0.099
	Rhythmic Stabilization	20	0.229	0.264
SS	Static Hold	20	0.221	0.218
	Rhythmic Stabilization	20	1.275	1.072
IS	Static Hold	20	1.327	0.653
	Rhythmic Stabilization	20	4.467	2.113
TM	Static Hold	20	0.507	0.836
	Rhythmic Stabilization	20	1.782	1.839

Descriptive Statistics (% of MVC)

Table 12: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Shoulder Shrug Position

Shoulder Shrug

Muscles	SH	Std Dev	RS	Std Dev
Anterior deltoid	1.09	0.59	5.48	4.53
Pectoralis major	6.08	2.65	27.35	15.68
Serratus anterior	9.09	4.26	30.89	18.16
Supraspinatus	6.97	7.20	37.11	41.10
Infraspinatus	1.47	1.99	14.22	8.57
Teres minor	6.28	4.43	74.23	114.71

Table 13: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Lateral Raise Position

Lateral Raise

Muscles	SH	Std Dev	RS	Std Dev
Anterior deltoid	32.66	13.96	46.41	24.74
Pectoralis major	12.51	7.57	30.18	26.15
Serratus anterior	37.97	18.42	64.17	32.59
Supraspinatus	41.45	13.58	66.13	38.55
Infraspinatus	17.83	10.84	44.01	22.53
Teres minor	11.41	10.07	51.32	48.93

Table 14: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in Front Raise Position

Front Raise

Muscle	SH	Std Dev	RS	Std Dev
Anterior deltoid	33.32	14.32	43.69	28.12
Pectoralis major	44.98	31.63	70.89	56.07
Serratus anterior	47.95	20.65	78.09	41.23
Supraspinatus	41.45	10.24	52.32	38.54
Infraspinatus	35.81	19.83	63.71	35.71
Teres minor	22.41	25.21	101.21	139.27

Table 15: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise in IR/ER Position

Internal/External Rotation				
Muscle	SH	Std Dev	RS	Std Dev
Anterior deltoid	4.54	5.98	8.52	7.39
Pectoralis major	20.70	8.67	54.54	37.51
Serratus anterior	12.52	5.64	28.49	14.98
Supraspinatus	5.46	6.57	36.89	57.39
Infraspinatus	15.45	6.19	51.83	25.28
Teres minor	13.10	9.59	78.65	112.75

Table 16: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Anterior Deltoid

		SH		RS
Exercises	Mean (% MVC)	Std Deviation	Mean (% MVC)	Std Deviation
Shoulder Shrug	1.09	0.59	5.48	4.53
Lateral Raise	32.66	13.96	46.41	24.74
Front Raise	33.32	14.32	43.69	28.12
Internal/External Rotation	4.54	5.98	8.52	7.39

Table 17: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Pectoralis Major

		SH		RS
Exercises	Mean (% MVC)	Std Deviation	Mean (% MVC)	Std Deviation
Shoulder Shrug	6.08	2.65	27.35	15.68
Lateral Raise	12.51	7.57	30.18	26.15
Front Raise	44.98	31.63	70.89	56.07
Internal/External Rotation	20.70	8.67	54.54	37.51

Table 18: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Serratus Anterior

	SH		RS	
Exercises	Mean (% MVC)	Std Dev	Mean (% MVC)	Std Dev
Shoulder Shrug	9.09	4.26	30.89	18.16
Lateral Raise	37.97	18.42	64.17	32.59
Front Raise	47.95	20.65	78.09	41.23
Internal/External Rotation	12.52	5.64	28.49	14.98

Table 19: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Supraspinatus

	SH		RS	
Exercises	Mean	Std Dev	Mean	Std Dev
Shoulder Shrug	6.97	7.20	37.11	41.10
Lateral Raise	41.45	13.58	66.13	38.55
Front Raise	41.45	10.24	52.32	38.54
Internal/External Rotation	5.46	6.57	36.89	57.39

Table 20: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Infraspinatus

	SH		RS	
Exercises	Mean	Std Dev	Mean	Std Dev
Shoulder Shrug	1.47	1.99	14.22	8.57
Lateral Raise	17.83	10.84	44.01	22.53
Front Raise	35.81	19.83	63.71	35.71
Internal/External Rotation	15.45	6.19	51.83	25.28

Table 21: Comparison of Means between Static Hold Exercise and Rhythmic Stabilization Exercise by the Teres Minor

	SH		RS	
Exercises	Mean	Std Dev	Mean	Std Dev
Shoulder Shrug	6.28	4.43	74.23	114.71
Lateral Raise	11.41	10.07	51.32	48.93
Front Raise	22.41	25.21	101.21	139.27
Internal/External Rotation	13.10	9.59	78.65	112.75

Pair wise Comparisons

Table 22: Pair wise Comparison for Shoulder Shrug with Static Hold

Muscles		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	-4.99	0.000	-6.21	-3.78
AD	SA	-8.00	0.000	-10.06	-5.94
AD	SS	-5.88	0.002	-9.21	-2.55
AD	IS	-0.38	0.406	-1.31	0.55
AD	TM	-5.19	0.000	-7.11	-3.27
PM	SA	-3.01	0.003	-4.87	-1.14
PM	SS	-0.89	0.630	-4.68	2.90
PM	IS	4.62	0.000	2.90	6.34
PM	TM	-0.20	0.874	-2.75	2.35
SA	SS	2.12	0.269	-1.77	6.01
SA	IS	7.62	0.000	5.25	9.99
SA	TM	2.81	0.058	-0.11	5.73
SS	IS	5.50	0.005	1.92	9.09
SS	TM	0.69	0.724	-3.34	4.72
IS	TM	-4.81	0.000	-6.93	-2.70

Table 23: Pair wise Comparison for Shoulder shrug with Rhythmic Stabilization

Muscles		Mean Diff	Sig.	95% CI Lower Bound	95% CI Upper Bound
AD	PM	-21.870	0.000	-28.91	-14.83
AD	SA	-25.406	0.000	-34.27	-16.54
AD	SS	-31.632	0.003	-50.95	-12.31
AD	IS	-8.733	0.000	-12.34	-5.13
AD	TM	-68.746	0.015	-122.53	-14.96
PM	SA	-3.536	0.379	-11.76	4.68
PM	SS	-9.762	0.240	-26.61	7.08
PM	IS	13.137	0.000	6.75	19.52
PM	TM	-46.876	0.071	-98.21	4.45
SA	SS	-6.225	0.345	-19.68	7.23
SA	IS	16.674	0.001	8.32	25.03
SA	TM	-43.340	0.089	-93.86	7.19
SS	IS	22.899	0.018	4.31	41.49
SS	TM	-37.114	0.073	-78.05	3.82
IS	TM	-60.013	0.029	-113.04	-6.98

Table 24: Pair wise Comparison for Lateral Raise with Static Hold

Muscles		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	20.15	0.000	14.67	25.64
AD	SA	-5.31	0.151	-12.74	2.12
AD	SS	-8.79	0.085	-18.93	1.35
AD	IS	14.83	0.000	7.74	21.92
AD	TM	21.25	0.000	14.04	28.46
PM	SA	-25.46	0.000	-32.94	-17.97
PM	SS	-28.94	0.000	-36.91	-20.97
PM	IS	-5.32	0.028	-10.00	-0.63
PM	TM	1.10	0.635	-3.68	5.88
SA	SS	-3.48	0.558	-15.69	8.72
SA	IS	20.14	0.000	12.28	28.00
SA	TM	26.56	0.000	17.82	35.30
SS	IS	23.62	0.000	15.23	32.02
SS	TM	30.04	0.000	22.10	37.99
IS	TM	6.42	0.026	0.86	11.98

Table 25: Pair wise Comparison for Lateral Raise with Rhythmic Stabilization

Muscles		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	16.231	0.004	5.76	26.70
AD	SA	-17.760	0.019	-32.20	-3.33
AD	SS	-19.719	0.043	-38.76	-0.68
AD	IS	2.408	0.691	-10.07	14.88
AD	TM	-4.901	0.617	-25.09	15.29
PM	SA	-33.992	0.000	-44.86	-23.12
PM	SS	-35.951	0.000	-50.42	-21.48
PM	IS	-13.823	0.013	-24.41	-3.23
PM	TM	-21.133	0.025	-39.30	-2.96
SA	SS	-1.959	0.763	-15.37	11.45
SA	IS	20.168	0.012	4.90	35.44
SA	TM	12.859	0.267	-10.68	36.40
SS	IS	22.128	0.027	2.82	41.44
SS	TM	14.818	0.248	-11.23	40.86
IS	TM	-7.309	0.468	-27.97	13.35

Table 26: Pair wise Comparison for Front Raise with Static Hold

Muscle		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	-11.66	0.073	-24.50	1.18
AD	SA	-14.63	0.003	-23.73	-5.53
AD	SS	10.88	0.011	2.79	18.97
AD	IS	-2.49	0.604	-12.40	7.41
AD	TM	10.91	0.050	0.00	21.81
PM	SA	-2.97	0.675	-17.58	11.64
PM	SS	22.54	0.014	5.20	39.88
PM	IS	9.17	0.242	-6.72	25.05
PM	TM	22.57	0.006	7.22	37.92
SA	SS	25.51	0.000	15.71	35.31
SA	IS	12.14	0.025	1.68	22.59
SA	TM	25.54	0.001	12.35	38.73
SS	IS	-13.37	0.003	-21.61	-5.14
SS	TM	0.03	0.996	-12.40	12.46
IS	TM	13.40	0.047	0.22	26.58

Table 27: Pair wise Comparison for Front Raise with Rhythmic Stabilization

Muscles		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	-27.20	0.008	-46.50	-7.90
AD	SA	-34.41	0.002	-53.92	-14.89
AD	SS	-8.64	0.329	-26.70	9.43
AD	IS	-20.02	0.009	-34.35	-5.69
AD	TM	-57.53	0.047	-114.12	-0.94
PM	SA	-7.20	0.495	-28.87	14.46
PM	SS	18.56	0.049	0.12	37.00
PM	IS	7.18	0.479	-13.64	28.00
PM	TM	-30.33	0.266	-85.66	25.01
SA	SS	25.77	0.001	11.72	39.81
SA	IS	14.38	0.103	-3.19	31.95
SA	TM	-23.12	0.434	-83.65	37.41
SS	IS	-11.38	0.181	-28.53	5.7
SS	TM	-48.89	0.108	-109.48	11.70
IS	TM	-37.50	0.213	-98.43	23.42

Table 28: Pair wise Comparison for IR/ER with Static Hold

Muscles		Mean Diff	Sig.	95% CI Lower Bound	Upper Bound
AD	PM	-16.16	0.000	-20.79	-11.52
AD	SA	-7.98	0.000	-10.95	-5.01
AD	SS	-0.92	0.646	-5.08	3.23
AD	IS	-10.91	0.000	-13.51	-8.31
AD	TM	-8.56	0.001	-13.04	-4.08
PM	SA	8.18	0.001	4.02	12.34
PM	SS	15.23	0.000	10.67	19.79
PM	IS	5.25	0.033	0.46	10.04
PM	TM	7.60	0.008	2.21	12.99
SA	SS	7.05	0.000	3.55	10.55
SA	IS	-2.93	0.109	-6.58	0.72
SA	TM	-0.58	0.765	-4.59	3.43
SS	IS	-9.98	0.000	-14.20	-5.76
SS	TM	-7.64	0.015	-13.61	-1.66
IS	TM	2.35	0.346	-2.73	7.43

Table 29: Pair wise Comparison for IR/ER with Rhythmic Stabilization Exercise

Muscles		Mean Diff	Sig.	95% Confidence Interval for Difference Lower Bound	Upper Bound
AD	PM	-46.02	0.000	-62.06	-29.99
AD	SA	-19.97	0.000	-28.01	-11.93
AD	SS	-28.37	0.039	-55.22	-1.52
AD	IS	-43.31	0.000	-54.57	-32.04
AD	TM	-70.13	0.009	-120.91	-19.36
PM	SA	26.05	0.003	9.89	42.21
PM	SS	17.66	0.164	-7.87	43.18
PM	IS	2.71	0.650	-9.61	15.04
PM	TM	-24.11	0.258	-67.41	19.19
SA	SS	-8.39	0.459	-31.63	14.85
SA	IS	-23.34	0.000	-33.22	-13.45
SA	TM	-50.16	0.058	-102.30	1.98
SS	IS	-14.94	0.183	-37.59	7.71
SS	TM	-41.77	0.121	-95.65	12.12
IS	TM	-26.82	0.273	-76.55	22.91

Table 30: Repeated Measures ANOVA for Delayed Comparing Four different Positions during Static Hold and Rhythmic Stabilization across Six Muscles

Exercises	SS	df	MS	F	P
SSSH	1020.46	5.00	204.09	12.02	0.000
SSBB	57009.49	5.00	11401.90	5.32	0.000
LRSH	17744.84	5.00	3548.97	25.73	0.000
LRBB	18072.38	5.00	3614.48	5.33	0.000
FRSH	11708.99	5.00	2341.80	6.67	0.000
FRBB	41360.08	5.00	8272.02	2.63	0.028
IRERSH	3746.63	5.00	749.33	17.26	0.000
IRERBB	58379.93	5.00	11675.99	4.82	0.001

Table 31: Repeated Measures ANOVA for Delayed Eight Exercises Comparing Six Muscles across Eight Exercises

Muscles	SS	df	MS	F	P
AD	50093.95	7.00	7156.28	50.61	0.000
PM	67544.94	7.00	9649.28	19.33	0.000
SA	80283.97	7.00	11469.14	49.20	0.000
SS	62385.35	7.00	8912.19	13.37	0.000
IS	65273.55	7.00	9324.79	42.84	0.000
TM	186844.58	7.00	26692.08	5.92	0.000