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ELECTROMYOGRAPHIC ANALYSIS OF THE DELTOID MUSCLE DURING VARIOUS SHOULDER EXERCISES

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ELECTROMYOGRAPHIC ANALYSIS OF THE DELTOID MUSCLE DURING VARIOUS SHOULDER EXERCISES

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We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree Master of Science, Clinical Exercise Physiology.

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ABSTRACT

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The purpose of this study was to determine which exercise activates the deltoid muscle to the greatest degree using electromyographic (EMG) analysis. Sixteen experienced male lifters completed five repetitions of the following exercises using 70% of 1 RM, body weight, or a rope for resistance: dumbbell (DB) shoulder press, DB front raise, bent arm lateral raise, seated rear lateral raise, cable diagonal raise, push-ups, battling ropes, barbell upright row, 45 degree incline row, and dips. Surface EMG was recorded and represented as a percentage of the maximal voluntary contraction. A one-way ANOVA with repeated measures was used to test for differences in EMG between exercises. Anterior deltoid analysis showed a significant difference in muscle activation between the DB shoulder press and the other nine exercises. Middle deltoid analysis showed no significant difference between the 45 degree incline row and bent arm lateral raise while all other exercises elicited significantly lower muscle activation. Posterior deltoid analysis showed no significant difference between the seated rear lateral raise and 45 degree incline row while all other exercises elicited significantly lower muscle activation. Based on the musculature of the deltoid and the findings of this study, a variety of exercises are needed to effectively train the deltoid. Further research investigating shoulder exercises not tested in this study is still needed.

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INTRODUCTION

The Centers for Disease Control and Prevention (CDC) (2006) analyzed data from the National Health Interview Survey and estimated that nearly 20% of adults aged 18-65 years participate in some form of resistance training two or more times per week. These statistics reveal that there are still 80% of adults in America that do not participate in any form of regular resistance training. The American College of Sports Medicine (ACSM) (2013) recommends that in addition to aerobic exercise, individuals should perform resistance training 2-3 days per week. When performed on a regular basis, resistance training leads to higher levels of muscular strength, which is important when it comes to performing activities of daily living. Other benefits of resistance training include improvements in body composition, blood glucose levels, lipid values, resting blood pressure, bone mineral density, as well as the reduced risk of metabolic syndrome, cardiovascular disease, and all-cause mortality (ACSM, 2013).

One area of the body that is essential to train is the shoulders. Broad muscular shoulders are desired from an aesthetic point of view, but are also vital from a functional point of view. Individuals are often required to lift objects over their head as well as push and pull things. These movements require structurally sound and strong shoulder muscles. Weak shoulders lead to altered biomechanics and decreased performance, increasing an individual's chance of injury (Voight &Thomson, 2000). Since shoulder pain affects up to 67% of the population at some point in their lifetime, an emphasis on shoulder conditioning is essential to avoid common shoulder pathologies (Kolber, Beekhuizen, Cheng, & Hellman, 2008).

In order to train the shoulder muscles effectively, it is essential to understand the anatomical make-up of the shoulder. The shoulder is a ball and socket joint joining the humerus bone of the upper arm with the scapula (Evans, 2007). This type of joint allows for six main movements to occur at the shoulder: flexion, extension, adduction, abduction, internal rotation, and external rotation (Evans, 2007). The major muscles of the shoulder are the deltoid and the rotator cuff muscle group. The deltoid consists of three separate heads: anterior, middle, and posterior (Evans, 2007). The anterior deltoid attaches to the clavicle and raises the arm forward. The lateral deltoid attaches to the acromion process of the scapula and lifts the arm outward to the side (Evans, 2007). The posterior deltoid attaches to the scapula and moves the arm backward (Evans, 2007). The rotator cuff muscles consist of the supraspinatus, infraspinatus, teres minor and subscapularis (Evans, 2007). These muscles maintain stability by compressing the humeral head into the concave glenoid fossa of the scapula during upper extremity motion and are also responsible for internal and external rotation of the upper arm (Reinold et al., 2004).

Because the shoulder is such a complex joint, choosing the best exercise for the shoulder becomes difficult. One way to determine the level of muscle activation associated with a particular exercise is through the use of electromyography (EMG) (Jakobsen et al., 2012). Specifically, EMG amplitude is reflective of motor unit recruitment, firing rate, and synchronization in the muscle (De Luca, 2002). There has been a growing interest in the effect of exercise technique and variation on muscle activity in several exercises for development of the upper body. Previous studies have compared dumbbell (DB) vs. barbell (BB) exercises, seated vs. standing, as well as the effect of elbow range of motion and inclination of the torso (Barnett, Kippers, & Turner, 1995; Kohler, Flanagan, & Whiting, 2010; Paoli, Marcolin, & Petrone, 2010; Saeterbakken & Fimland, 2013). Kohler et al. (2010) compared DB vs. BB presses and reported similar EMG activity in the anterior and middle deltoid, despite the fact that the dumbbell load was only ~ 86% of the barbell load. Saeterbakken and Fimland (2013) reported that when comparing DB vs. BB shoulder presses while standing and seated, the exercise with the greatest stability requirement (standing and dumbbells) demonstrated the highest neuromuscular activity of the deltoid muscles. Paoli et al. (2010) investigated the effects of elbow range of motion on the EMG activity of the shoulder and rotator cuff muscles during the seated military press. The results showed that the highest EMG activity was obtained by performing the exercise with a complete range of motion. Barnett et al. (1995) looked at variations in torso inclination and hand spacing on EMG activity of five muscles acting on the shoulder joint. Anterior deltoid activity tended to increase as trunk inclination increased. The results of the previously mentioned studies were taken into consideration when planning the methods of this study.

The purpose of this study was to determine which exercise activates the deltoid muscle to the greatest degree during various shoulder exercises using EMG. The shoulder exercises chosen for this study are commonly performed by athletes, recreational lifters, and are commonly prescribed by personal trainers. By determining the most effective exercise(s), it may be possible to minimize the amount of time needed for resistance training, which could result in improved exercise adherence.

METHODS

Subjects

Sixteen male volunteers were recruited for this study. The subjects were apparently-healthy college students between the ages of 18-30 years. Subject had no history of shoulder injury and also had previous weight training experience. Descriptive characteristics of the subjects are presented in Table 1.

Table 1. Descriptive characteristics of the subjects (N=16).

	Mean ± SD	Range
Age (yrs)	22.3 ± 1.2	20.0 – 24.0
Height (in)	71.5 ± 3.4	64.5 – 77.0
Weight (lbs)	190.0 ± 29.7	140.0 – 240.0

The University of Wisconsin – La Crosse Institutional Review Board for the Protection of Human Subjects approved this study prior to testing. Each subject was informed of the purpose, procedures, potential risks, benefits, and confidentiality of the study and provided written informed consent before participating.

Exercises

Ten different exercises were performed during this study to determine which exercise(s) most effectively activates the deltoid muscles. Participants were required to attend one practice session and three testing sessions. During the practice session, subjects practiced each of the shoulder exercises to ensure safe and uniform technique. The exercises evaluated in this study as well as an explanation of each exercise are as follows:

Anterior Deltoid Maximal Voluntary Contraction (MVC): The subject was seated on an upright bench facing a squat rack with the bar at a height that put the elbow joint at 90 degrees. The subject then attempted to push the immovable bar overhead creating a maximal voluntary isometric contraction.

Middle Deltoid MVC: Seated in a shoulder press machine, the subject bent their elbows to 90 degrees. Without changing the bend in their elbows, the subject raised their arms upward until they were parallel to the floor and firm against the machine's handles. The subject then pushed through their elbows against an immovable weight creating a maximal voluntary isometric contraction.

Posterior Deltoid MVC: The subject was seated at the end of a bench, in-between a squat rack with safety catch bars. While bending over and resting their torso on their thighs, the subject maintained a flat horizontal back position and raised their arms to their sides until their elbows were at shoulder height. The arms were perpendicular to the torso while pushing against the immovable safety bars to create a maximal voluntary isometric contraction.

1. Dumbbell Shoulder Press: The subject was seated in an upright position with their back flat against the pad of the seat and their feet flat on the floor. The subject held a dumbbell in each hand, with their hands positioned at the side of their shoulders. The subject then pressed the dumbbells upward until their arms were extended overhead and lowered back to the sides of their shoulders to finish the movement.

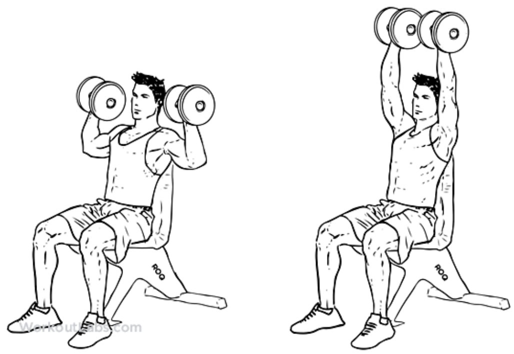

Figure 1. Dumbbell Shoulder Press

2. Dumbbell Front Raise: The subject grasped dumbbells in each hand with arms straight, but not locked at the elbow. The subject then raised the dumbbells forward and upward until their arms were parallel with the ground. To finish the exercise the dumbbells were lowered back to the starting position.

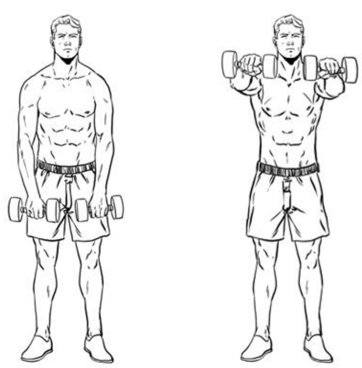

Figure 2. Dumbbell Front Raise

3. Bent Arm Lateral Raise: Grasping a pair of dumbbells, the subject bent their elbows to 90 degrees. Without changing the bend in their elbows, the subject raised their arms upward until they were parallel to the floor. Lastly, the subject lowered their arms back to their sides to finish the movement.

Figure 3. Bent Arm Lateral Raise

4. Barbell Upright Row: The subject was standing and grasped a barbell for this exercise. Keeping the barbell close to the body and elbows above the forearms, the subject lifted the barbell straight up. After reaching the top of the movement the subject lowered the barbell back to the starting position.

Figure 4. Barbell Upright Row

5. Seated Rear Lateral Raise: The subject was seated at the edge of a bench with their feet on the floor. While bending over and resting their torso on their thighs, the subject grasped dumbbells with arms extended under legs. While maintaining a flat horizontal back position, the subject raised their arms to their sides until their elbows were at shoulder height. The arms were perpendicular to the torso, with a fixed elbow position (10° to 30° angle) throughout exercise. The subject then lowered the dumbbells to the starting position.

Figure 5. Seated Rear Lateral Raise

6. Cable Diagonal Raise: The subject used a cable machine and D-handle attachment for this exercise. The subject stood with their feet shoulder width apart and far enough away from the pulley to ensure tension. While standing up straight, the subject slowly raised the handle upward to shoulder height, keeping their arm straight. While maintaining a straight arm, the subject lowered the handle back to the starting position.

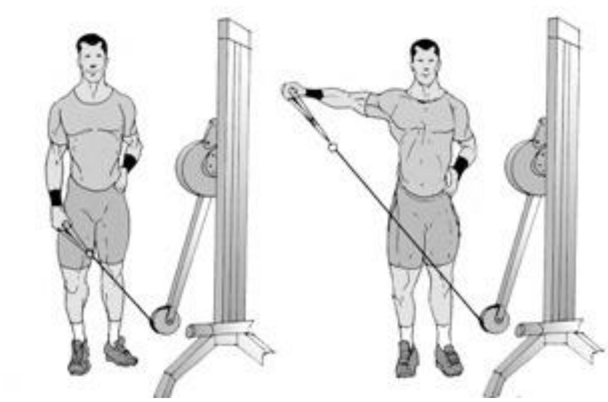

Figure 6. Cable Diagonal Raise

7. Push-ups: The subject started by lying prone on the floor with hands flat on the ground directly underneath their shoulders. Keeping their body straight, the subject rose up off the floor by extending their arms. A 2-inch foam sponge was placed underneath the subject's chest to standardize the test. Keeping their back flat and parallel to the floor, the subject lowered their body by bending their arms until the sponge was touched. Once the sponge was touched, the subject returned to the starting position body by extending their arms.

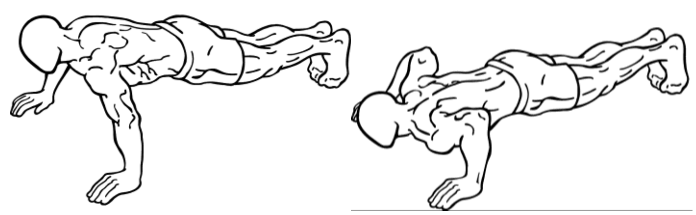

Figure 7. Push-ups

8. Battling Ropes: The subject started by planting their feet in a shoulder width squat stance ensuring a solid base. Next, the subject gripped each end of the rope firmly in each hand. The subject then alternated swinging their arms up and down creating a wavelike motion with the rope.

Figure 8. Battling Ropes

9. 45 Degree Incline Row: Lying prone on an incline bench (45 degrees), the subject let their arms hang straight while holding dumbbells. To initiate the exercise, the subject lifted their arms as high as possible by squeezing their shoulder blades together. Throughout the movement the upper arm remained perpendicular to the body and the forearms pointed toward the floor. The subject lowered the dumbbells back to the starting position after achieving the top of the movement.

Figure 9. 45 Degree Incline Row

10. Dips: The subject mounted the dip machine by grasping the parallel bars and using their arms to support their body weight. Shoulders were above their hands and arms were extended, but elbows not locked. The subject lowered their body by bending their arms until a 90 degree angle was made at the elbow. Once a 90 degree angle was achieved the subject pushed up again until arms were extended. Throughout the exercise the subject kept their body in a straight line, chest up, and elbows pointed straight back.

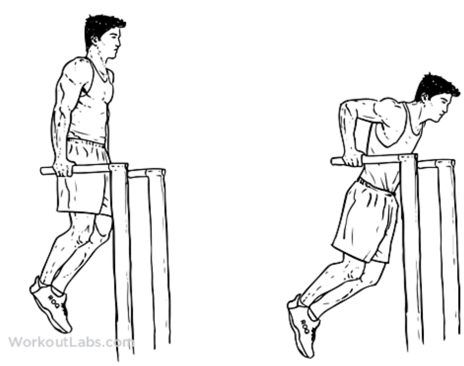

Figure 10. Dips

Testing

Subjects participated in three testing days, with a minimum of 3 days rest between each testing session. Participants were asked to not engage in any resistance training for 48 hours prior to each test day. On the first testing day, one-repetition maximum (1 RM) values were assessed for each of the following exercises: DB shoulder press, DB front raise, bent arm lateral raise, BB upright row, seated rear lateral raise, cable diagonal raise, and 45 degree incline row. A 1 RM was not established for push-ups, battling ropes, or dips because they use body weight or a rope as resistance. When establishing a 1 RM, each subject completed a 3 minute warm-up on an upper body arm ergometer at a self-selected pace. Next, the weight was incrementally increased until their 1 RM was achieved for each exercise.

On the remaining two test days, subjects had EMG electrodes placed on the deltoid muscle according to SENIAM recommendations to record muscle activation (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Each site was shaved, abraded, and scrubbed with alcohol to reduce skin resistance (De Luca, 2002). EMG electrodes were placed parallel to the muscle fiber direction of each portion of the deltoid muscle (Hermens et al., 2000). The anterior deltoid electrode was placed one finger width distal and anterior to the acromion (Figure 11. A). The middle deltoid electrode was placed at a point corresponding to the greatest bulge between the acromion of the scapula and the lateral epicondyle of the elbow (Figure 11. B). The posterior deltoid electrode was placed two fingerbreaths behind the angle of the acromion (Figure 11. C). The signal of each electrode was checked after application to ensure signal quality (Konrad, 2005).

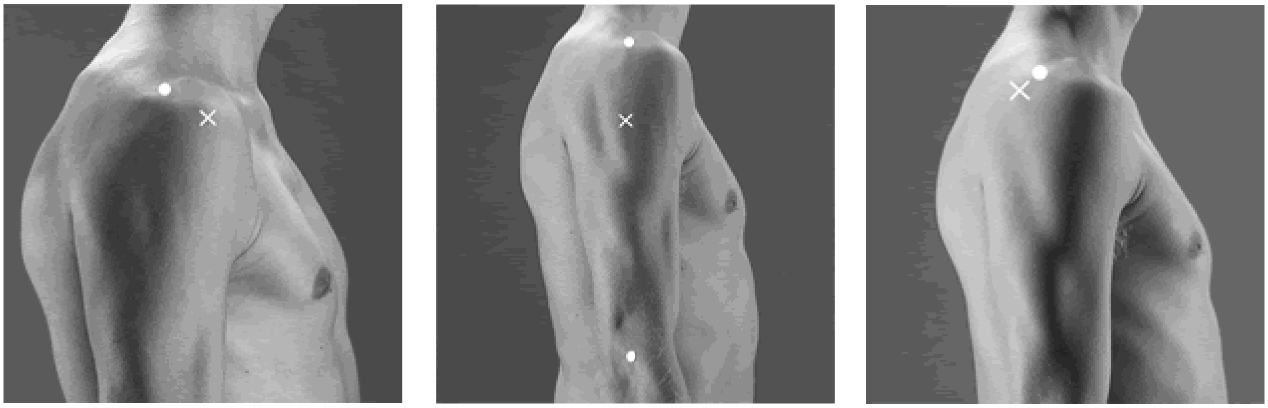

Figure 11. Electrode Placement
A. Anterior Deltoid B. Middle Deltoid C. Posterior Deltoid

After electrode placement, subjects performed a self-paced 3 minute warm-up on an upper body arm ergometer. Following warm-up, the subjects performed three maximal voluntary contractions (MVC) held for 10 seconds each and five of the exercises in a randomly assigned order. Subjects performed five repetitions of each exercise using 70% of 1 RM for resistance. This percent of intensity is recommended by the American College of Sports Medicine (2013) for novice to intermediate exercisers to improve strength. For exercises without an established 1 RM (push-ups, battling ropes, and dips) the subject's body weight or a weighted rope was used as resistance. Using a metronome, each exercise was performed at a pace of 1.5 seconds for the concentric and 1.5 seconds for eccentric phase of the lift. Three minutes of rest was given between exercises to ensure full recovery (ACSM, 2013).

Electromyographic Analysis

The raw EMG signals from the deltoid muscles were digitized at 2000 Hz and stored on a personal computer. Muscle activation of the second, third and fourth repetition were used for analysis of all exercises. The EMG signal was preamplified using a differential amplifier (Delsys Trigno Wireless Systems, Boston, MA; bandwidth 20-450 Hz). All signal processing was performed using custom programs written with MATLab programming software (Version R2012b, MathWorks,Natick, MA). The EMG signals were digitally bandpass filtered (fourth-order Butterworth) at 20-500Hz. The EMG amplitude (microvolts root mean square [uVrms]) values were calculated for each trial and represented as a percentage of the maximal EMG recorded during the MVC trial for that day.

Statistical Analysis

A one-way ANOVA with repeated measures was used to compare the normalized EMG for each of the deltoid muscles (%MVC). When there was a significant F ratio, Fisher's LSD was used for differences between the means. Alpha was set at 0.05 to achieve statistical significance. The data was analyzed using the IBM Statistical Package for the Social Sciences software (version 19.0; SPSS Inc., Chicago IL).

RESULTS

Subjects completed 10 different shoulder exercises in the current study. Average 1 RM values for seven of those exercises are presented in Table 2. One repetition values were not defined for dips, push-ups, or battling ropes because body weight or ropes were used as resistance for those exercises. EMG data was collected for the concentric and eccentric phase of each lift during each repetition of a five repetition set. Muscle activity of the complete movement (concentric and eccentric action) of the second, third, and fourth repetition was averaged to yield a value for each exercise. Average EMG for the anterior, medial, and posterior deltoid are presented in Tables 3-5 and Figures 12-14, respectively.

Table 2. One-repetition maximum (1 RM) values for each exercise (lbs).

	Mean ± SD	Range
DB Shoulder Press	69.5 ± 15.5	40.0 – 100
DB Front Raise	29.1 ± 6.8	15.0 – 40
Bent Arm Lateral Raise	33.6 ± 8.8	15.0 – 50
45 Degree Incline Row	39.8 ± 10.5	17.5 – 60
BB Upright Row	117.2 ± 23.9	75.0 – 160
Cable Diagonal Raise	39.2 ± 11.6	20.0 – 70
Seated Rear Lateral Raise	25.3 ± 6.9	12.5 – 40

Analysis of the anterior deltoid found that the DB shoulder press elicited the greatest muscle activation. All of the other exercises elicited significantly lower muscle activation values when compared to the DB shoulder press.

Table 3. Average EMG (%MVC) for the anterior deltoid.

Exercise	Average EMG
DB Shoulder Press	74 ± 15.9
DB Front Raise	57 ± 11.9*
Battling Ropes	49 ± 16.0*
Push-ups	48 ± 14.5*
Cable Diagonal Raise	46 ± 19.0*
Dips	41 ± 15.5*
BB Upright Row	33 ± 15.2*
Bent Arm Lateral Raise	32 ± 18.5*
45 Degree Incline Row	6 ± 4.0*
Seated Rear Lateral Raise	5 ± 4.1*

*Significantly different than DB shoulder press (< .05).
Values represent mean ± SD.

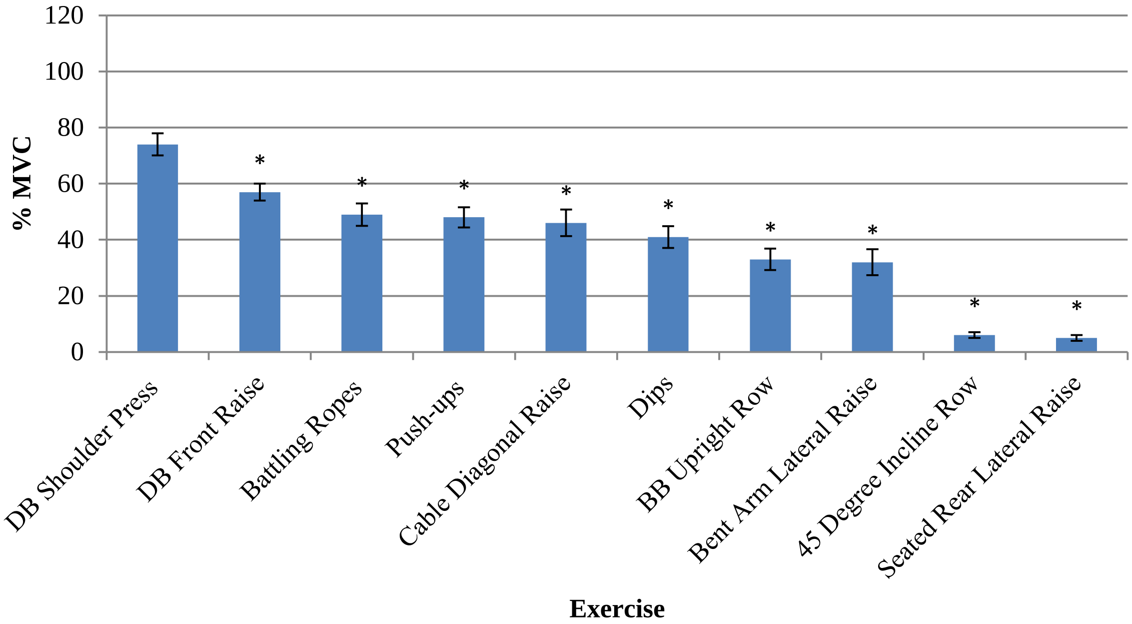

Figure 12. Muscle activation of the anterior deltoid for the ten different exercises. Error bars represent standard error.

Analysis for the medial deltoid found that there was no significant difference when comparing the 45 degree incline row to the bent arm lateral raise. All of the other exercises elicited significantly lower muscle activation values when compared to the 45 degree incline row.

Table 4. Average EMG (%MVC) for the middle deltoid.

Exercise	Average EMG
45 Degree Incline Row	84 ± 14.5
Bent Arm Lateral Raise	77 ± 16.1
Cable Diagonal Raise	74 ± 15.1*
BB Upright Row	73 ± 13.3*
Seated Rear Lateral Raise	70 ± 14.6*
DB Shoulder Press	62 ± 18.6*
Battling Ropes	37 ± 19.3*
DB Front Raise	36 ± 15.5*
Push-ups	13 ± 11.5*
Dips	7 ± 3.5*

*Significantly different than 45 degree incline row (< .05).
Values represent mean ± SD.

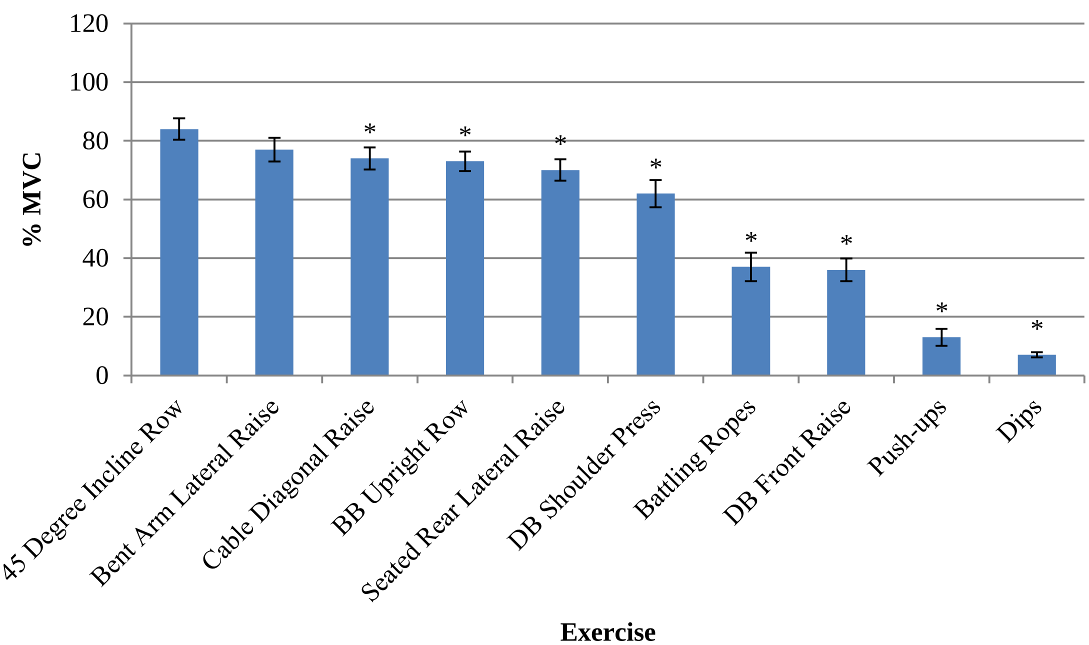

Figure 13. Muscle activation of the middle deltoid for the ten different exercises. Error bars represent standard error.

Analysis of the posterior deltoid found that there was no significant difference in muscle activation when comparing the seated rear lateral raise to the 45 degree incline row. All of the other exercises elicited significantly lower muscle activation values than those two exercises.

Table 5. Average EMG (%MVC) for the posterior deltoid.

Exercise	Average EMG
Seated Rear Lateral Raise	73 ± 9.9
45 Degree Incline Row	69 ± 14.0
Battling Ropes	38 ± 22.0*
Cable Diagonal Raise	35 ± 17.0*
Bent Arm Lateral Raise	33 ± 14.4*
BB Upright Row	31 ± 11.5*
Dips	26 ± 53.4*
DB Shoulder Press	10 ± 5.4*
DB Front Raise	9 ± 5.8*
Push-ups	6 ± 5.7 *

*Significantly different than seated rear lateral raise (< .05).
Values represent mean ± SD.

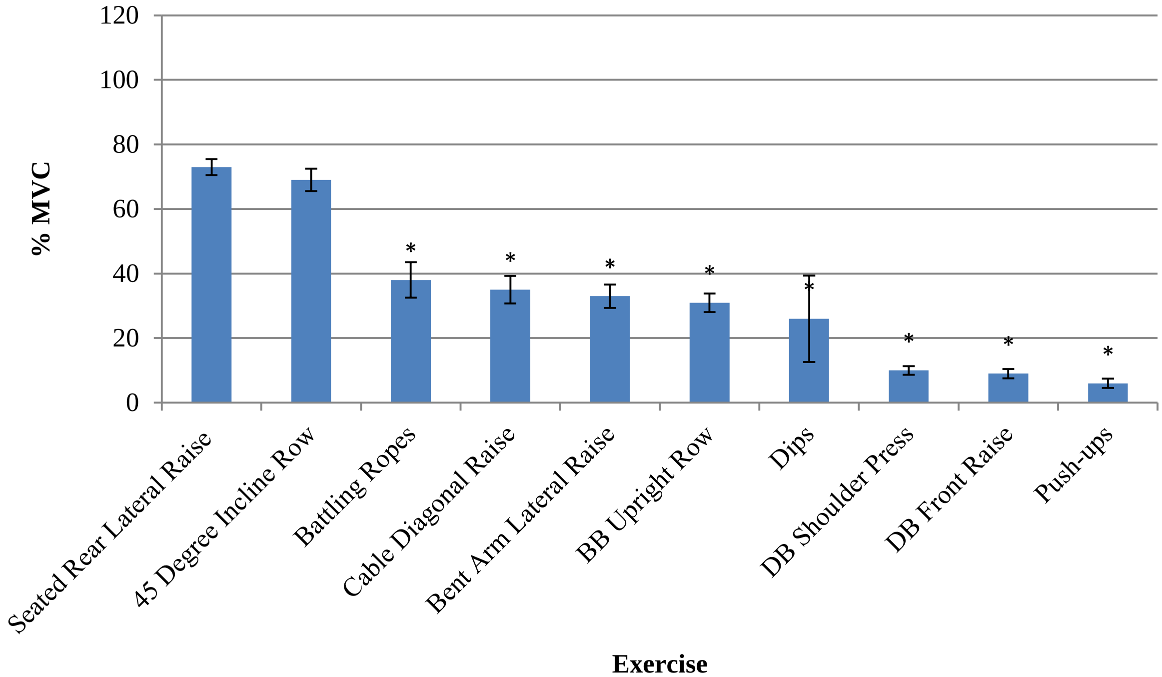

Figure 14. Muscle activation of the posterior deltoid for the ten different exercises. Error bars represent standard error.

DISCUSSION

The purpose of this study was to determine which commonly used shoulder exercises activate the deltoid muscle to the greatest degree using EMG. Because the deltoid muscle is composed of three different heads (anterior, middle, and posterior), EMG electrodes were placed on each section. This study compared ten different exercises that are generally used to strengthen the deltoid.

Previous studies which have studied muscle activation of the shoulder musculature using EMG have compared DB versus BB exercises, standing vs. seated, as well as the effect of range of motion, hand position, and torso inclination (Barnett et al., 1995; Kohler et al., 2010; Paoli et al., 2010; Saeterbakken & Fimland, 2013). All of the previous studies used some type of shoulder press to conduct their research. The current study analyzed the deltoid activation during nine commonly used shoulder exercises, in addition to the activation during the DB shoulder press.

This study found that activation of the anterior deltoid was greatest during the DB shoulder press in comparison to all the other exercises. Paoli et al. (2010) found that the highest EMG activity was obtained by performing the DB shoulder press with a complete range of motion, which was used in this study. This study did not compare barbell vs. dumbbell shoulder presses. However, both Kohler et al. (2010) and Saeterbakken and Fimland (2013) found that dumbbell shoulder presses were superior to barbell shoulder press. All of the other exercises activated the anterior deltoid to a lesser degree, with the 45 degree incline row and seated rear lateral raise providing virtually no activation of the anterior deltoid. This would be expected considering these exercises are often used to target the posterior portion of the deltoid when training.

Results for the middle deltoid activation indicated that there was no significant difference in muscle activation between the 45 degree incline row and the bent arm lateral raise. It was therefore concluded that these shoulder exercises could be used interchangeably to train the middle deltoid. When looking at other exercises, there was a steady drop off in muscle activation for the various exercises. Push-ups and dips elicited almost no activation of the middle deltoid in comparison to the 45 degree incline row, making them poor exercises when trying to target the middle deltoid.

Lastly, the posterior deltoid activation showed no significant difference in muscle activation between the seated rear lateral raise and 45 degree incline row. These exercises can also be used interchangeably to train the posterior deltoid. When looking at the other exercises, there was an overall significant decrease in posterior deltoid activation. DB shoulder press, DB front raise, and push-ups elicited the least amount of posterior deltoid activation. These results are consistent considering the high degree of anterior deltoid activation during these same exercises.

The results of this study indicate that it is impossible to select a single best shoulder exercise, since the shoulder is a complex joint and one exercise cannot maximally activate all three heads of the deltoid at once. For example, the seated rear lateral raise activated the posterior deltoid to the highest degree, but was lowest for anterior deltoid activation. The practical application for the results of this study is that athletes and personal trainers need to use a variety of exercises to train the deltoid muscle effectively. Further research investigating the muscle activation of shoulder exercises not tested in this study or different variations of the chosen exercises is still needed.

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APPENDIX A

PRE-EXERCISE HEALTH SCREENING QUESTIONNAIRE

ELECTROMYOGRAPHIC ANALYSIS OF THE DELTOID MUSCLE DURING VARIOUS SHOULDER EXERCISES

Pre-Exercise Health Screening Questionnaire

Name: ____

Age___________ Gender______________

Height___________ Weight__________

- **Have you done strenuous exercise within the past 24 hours (circle one)?** Yes No
- **Are you experiencing, or have previously experienced shoulder pain which is made worse with exercise?** Yes No

If yes, please explain____
____

Subject #

Day #1 Exercises

1. MVC
2. .
3. .
4. .
5. .

Day #2 Exercises

1. MVC
2. .
3. .
4. .
5.

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT

ELECTROMYOGRAPHIC ANALYSIS OF THE DELTOID MUSCLE DURING VARIOUS SHOULDER EXERCISES

I, ___________________________, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse.

• *Purpose and Procedure*

- The purpose of this study is to compare muscle activity of the shoulder muscle using electromyography (EMG) during different shoulder exercises.
- The exercises to be tested will be the dumbbell shoulder press, dumbbell front raise, bent arm lateral raise, barbell upright row, seated rear lateral raise, cable diagonal raise, push-ups, battling ropes, 45 degree incline row, and dips.

- My participation in this study will require me to complete four sessions, each lasting approximately 1 hour.
    - During the first session (practice session) I will perform all of the 10 different exercises to become accustomed to them.
    - During the second session, I will perform all 10 exercises to establish my 1 repetition maximum (1 RM) for each lift.
    - During the first testing session I will perform 5 of the exercises at random, using 70% of 1 RM.
    - During the second testing session I will perform the remaining 5 exercises, again at random and using 70% of 1 RM.
    - During the two testing sessions, I will have adhesive electrodes placed on my anterior, middle, and posterior deltoid in order to record and measure muscle activity.
- Testing will take place in the weight room located in Mitchell Hall on the University of Wisconsin-La Crosse campus.
- This study will be conducted by research assistants under the supervision and direction of Dr. John Porcari, a professor in the Department of Exercise and Sport Science.

• *Potential Risks*

- Muscle fatigue and muscle soreness are possible risk factors associated with participating in this study.
- Skin irritation from placement of the EMG electrodes is possible.
- During all testing sessions there will be individuals present who are trained in CPR and Advanced Cardiac Life Support if complications were to occur.
- The risk of serious or life-threatening complications, for healthy individuals, like me, is near zero.

• ***Potential Benefits***

- I, athletes, coaches, and trainers, may benefit from this study by gaining knowledge about which shoulder exercises elicit the most activation.

• ***Rights* & *Confidentiality***

- My participation in this study is voluntary.
- I can withdraw from the study at any time, for any reason, without penalty.
- The research findings of this study may be published or presented using group data.
- All information will be kept confidential and my data will not be linked with personally identifiable information.

I have read the information provided on this consent form. I have been informed of the purpose of the test, the procedures, and expectations of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that have concerned me and received clear answers to ensure my full understanding of all aspects of the study.

If I have any other questions that arise I may feel free to contact the principal investigator: Samantha Sweeney (715) 495-2530, or her study advisor, Dr. John Porcari, 141 Mitchell Hall, (608) 785-8684. Questions regarding the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Intuitional Review Board for the Protection of Human Subjects at (608) 785-8124

Participant: ____ Date: ____________

Investigator: ____ Date: ____________

APPENDIX C

REVIEW OF LITERATURE

REVIEW OF LITERATURE

According to the American College of Sports Medicine (2013) resistance training should be performed a minimum of 2-3 times per week. Even though the health benefits that coincide with resistance training are immense, 80% of Americans fail to meet ACSM recommendations (CDC, 2006). By determining which exercises are the most efficient, time spent resistance training could be reduced while potentially getting the same benefits. Electromyographic (EMG) analysis can be used to determine activation of desired muscles or muscle groups (De Luca, 2006). This review of literature will discuss how EMG can help to determine which shoulder exercises are the most effective at activating the deltoid muscle.

Basics of Electromyography

Use of electromyography to study muscle function has been known since the mid-1900s as a method to investigate muscle function (Paoli, Marcolin, & Petrone, 2010). EMG deals with the detection, analysis, and use of the electrical signal that arises from contracting skeletal muscles (De Luca, 2006). Muscle fibers are innervated in groups called motor units by the central nervous system (De Luca, 2006). The electrical signal that is detectable by an electrode emanates from the activation of these motor units resulting in a motor unit action potential (MUAP) (De Luca, 2006). The MUAP makes up the value of the EMG signal. Recruitment and firing frequency are two control mechanisms of contraction and force output that are reflected in the EMG signal (Konrad, 2005). Because human skin has a filter effect, the EMG signal does not present original recruitment and firing characteristics (Konrad, 2005). The EMG signal can be influenced by several outside factors changing its shape and characteristics.

The EMG Signal

The observed EMG signal is a product of the instrumentation used to acquire the signal as well as the electrical current that is generated by the motor unit. Two main concerns when detecting and recording EMG signal are the signal-to-noise ratio and any distortion (De Luca, 2002). Noise is defined as any electrical signals that are not part of the wanted EMG signal (De Luca, 2002). Minimal distortion means that any contribution of frequency in the EMG signal should not be altered (De Luca, 2002). In order to achieve the highest signal-to-noise ratio and minimal distortion an amplifier is used. Any noise signal that originates far away from the detection site will be removed and any relatively local EMG signals will be amplified (De Luca, 2002). Normalization of the EMG signal allows researchers to compare different activities for the same muscle, different muscles, activities on different days, and different subjects for the same or different tasks (Konrad, 2005).

EMG Electrodes

There are two main types of electrodes used for EMG: surface and indwelling. Surface EMG electrodes are placed on the surface of the skin and detect activity from beneath the electrodes (De Luca, 2006). Indwelling EMG electrodes are directly inserted into the muscle belly (De Luca, 2006). Both types of electrodes have advantages and disadvantages.

There are two types of indwelling electrodes: needle and fine wire. Both kinds of indwelling electrodes have an advantage over surface electrodes when it comes to collecting data on deep muscles. Needle electrodes have two main advantages. Needle electrodes are able to detect individual MUAPs during relatively low force contractions, and can be conveniently reposition within the muscle after insertion (De Luca, 2006). Wire electrodes are extremely fine, easily implanted, easily removed, and are generally less painful than needle electrodes (De Luca, 2006). When inserting wire electrodes some use the phrase "poke and hope" to describe the limitation of not being able to reposition the electrode once inserted (De Luca, 2006). Another limitation of the wire technique is the tendency the electrode has to migrate, especially during the first few contractions of the muscle (De Luca, 2006). To ensure safety when using indwelling electrodes sterilization procedures must be followed (De Luca, 2006).

Surface electrode use is limited to larger superficial muscles and can often pick up interface (crosstalk) from surrounding muscles (De Luca, 2006). This form of EMG is convenient, minimally invasive, and easy to apply. Surface EMG typically uses 3 electrodes per muscle: 2 active electrodes and 1 reference electrode (De Luca, 2002). The patented design of the Delsys surface electrode has a fixed parallel bar design, contour shape, and convenient adhesive skin interfaces that allow for consistent recording (www.delsys.com/educational-resources). The reference electrode is necessary for reducing and eliminating interference noise and should be placed as far away as possible on a bony prominence (De Luca, 2002).

Surface Electrode Placement

Proper EMG sensor location is critical for detecting quality surface EMG signals. It is important to also know the anatomical location, origin, insertion, and function of the muscle being studied. Delsys EMG Sensors have an arrow on top that should be aligned along the length of the muscle so that the parallel bar detection sites transects the muscle fibers (www.delsys.com/educational-resources). This design has the ability to monitor the maximum number of muscles fibers in a given location (www.delsys.com/educational-resources). To avoid crosstalk from adjacent muscles, the preferred electrode location is between the innervation zone and the tendinous insertion (www.delsys.com/educational-resources). A significant advantage of surface EMG sensors is that they require no skin preparation or adhesion for basic function. For this reason, it is possible to use a sensor as a probe. Once the general location for the sensor is determined, contractions of the muscle can be performed to ensure that a quality signal is being detected prior to applying adhesive.

Once the final EMG location is decided upon simple steps are required to prep the skin and to assure optimal signal detection. First shave any excessive hair from skin at the detection site (Konrad, 2005). The skin and silver detection bars of the EMG sensors should first be wiped with isopropyl alcohol to remove any surface residues (delsys.com). Once the skin is dry abrade the skin with a fine sand paper to remove any dead skin to further improve the impedance (De Luca, 2006). When using the Delsys system apply interface to the sensor, remove the adhesive backing from the interface, and apply the sensor to the skin at the prepared site (www.delsys.com/educational-resources).

Muscles of the Glenohumeral Joint

The shoulder is a ball and socket joint located between the humerus bone of the upper arm and the scapula (Evans, 2007). The deltoid muscle of the shoulder consists of three separate sections, capable of moving the arm in different directions. Six main movements occur at the shoulder: flexion, extension, abduction, internal rotation, and external rotation (Evans, 2007). From a broad tendon above the shoulder joint, the deltoid's three heads merge into a single tendon that attaches to the humerus bone of the upper arm (Evans, 2007). The anterior deltoid attaches to the clavicle and raises the arm forward (Evans, 2007). The middle deltoid attaches to the acromion and lifts the arm outward to the side (Evans, 2007). The posterior deltoid attaches to the scapula and moves the arm backward (Evans, 2007).

The functional stability of the shoulder is provided through the integrated functions of the joint capsule, ligaments, the deltoid muscles, and particularly the rotator cuff muscles. The rotator cuff muscles consist of the supraspinatus, infraspinatus, teres minor and subscapularis (Evans, 2007). These muscles maintain stability by compressing the humeral head into the concave glenoid fossa during upper extremity motion (Reinold, et al., 2004). Despite being a barely visible muscle group, the rotator cuff is essential to shoulder stability and strength.

Related Studies

Various studies have been conducted comparing shoulder muscle activation during various shoulder exercises. Previous studies have tested varying ranges of motion and grip variation, but none have tested and ranked the most popular shoulder exercises by their gross deltoid activation. For example, Saeterbakken and Fimland (2013) compared EMG activity during barbell and dumbbell shoulder presses performed seated and standing. They found standing shoulder press with dumbbells demonstrated the highest neuromuscular activity of the deltoid muscles, although it was the exercise with the lowest 1RM strength.

Schoefeld et al. (2013) conducted a study on the effect of hand position on EMG activity of the posterior deltoid during a horizontal abduction exercise. The popular machine rear deltoid flye was used to test pronated grip versus neutral. Results showed that mean EMG activity for the posterior deltoid was significantly greater in neutral compared to a pronated grip.

Kohler et al. (2010) compared barbell and dumbbell presses and reported similar EMG activity in the anterior and medial deltoid, despite the fact that the dumbbell load was only ~86% of the barbell load. Saeterbakken and Fimland (2013) reported that when comparing dumbbell vs. barbell shoulder presses while standing and seated, the exercise with the greatest stability requirement (standing and dumbbells) demonstrated the highest neuromuscular activity of the deltoid muscles. Paoli et al. (2010) investigated the effects of elbow range of motion on the EMG activity of eight shoulder muscles during the seated military press. The results showed the highest EMG activity was obtained by performing the exercise with a complete range of motion. Barnett et al. (1995) looked at variations in torso inclination and hand spacing on EMG activity of five muscles acting on the shoulder joint. Anterior deltoid activity tended to increase as trunk inclination increased.

The methods of this study will compare favorably to the results of the previous related studies. Determining which exercise activates the deltoid muscle to the greatest degree could result in minimizing the amount of time needed for resistance training, Therefore, improving exercise adherence.

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