UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

ELECTROMYOGRAPHIC ANALYSIS OF THE TRICEPS BRACHII MUSCLE DURING A VARIETY OF TRICEPS EXERCISES

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Clinical Exercise Physiology

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ELECTROMYOGRAPHIC ANALYSIS OF THE TRICEPS BRACHII MUSCLE

DURING A VARIETY OF TRICEPS EXERCISES

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

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ABSTRACT

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A way to measure muscle activity is through electromyography (EMG) analysis. The purpose of this study was to determine, via EMG, which triceps exercise elicited the most muscle activation, and which could be defined as the most effective triceps exercise. Fifteen female college students (20-24 years old) volunteered and completed this study. On the first day of testing, a one-repetition max (1 RM) was determined for the following exercises: triceps kickbacks, overhead triceps extensions, bar pushdowns, rope pushdowns, closed grip bench press and lying barbell triceps extensions. Dips and triangle push-ups were excluded, as those exercises use body weight as resistance. During the second testing session, subjects performed two, 6-second isometric contractions to determine a maximal voluntary isometric contraction. Subjects performed one set of seven repetitions for each of the eight exercises. Subjects lifted 70% of their 1 RM. For the combined EMG values of the entire movement (average of the long head and lateral head), there was not a significant difference between the triangle push-up, kickbacks, and dips. Similarly, for both the long and lateral heads, there was not a significant difference between the triangle push-up, kickbacks, or dips. There was a significant difference ($p < .05$) between the long and lateral muscle activation during the rope pushdowns, bar pushdowns and lying barbell triceps extensions. This study concludes that triangle push-ups were the best triceps exercise, although kickbacks and dips were equally effective in targeting the triceps brachii muscle.

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I would like to extend my sincere gratitude and appreciate to my family who has been the greatest influence in my life. They have been my backbone since day one and I would like to dedicate this thesis to them. Thank you for having such a positive and profound impact on the person I am today.

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TABLE OF CONTENTS

PAGE

ABSTRACT……………………………………………………………………………...iii

ACKNOWLEDGEMENTS……………………………………………………………iv

LIST OF FIGURES……………………………………………………………………vi

INTRODUCTION……………………………………………………………...…1

METHODS……………………………………………………………………………..3

Subjects……………………………………………………………………....3

Procedures……………………………………………………………………3

Instrumentation and Data Collection…………………………………………….10

Statistical Analysis……………………………………………………………….11

RESULTS……………………………………………………………………………..12

Table 1. Descriptive Characteristics of Subjects…………………….………….12

Table 2. Average EMG of the Entire Movement (Concentric and Eccentric)…...13

DISCUSSION…………………………………………………………………………14

REFERENCES………………………………………………………………………..17

APPENDICES………………………………………………………………………...18

Appendix A: Informed Consent……………………………………….…....18

Appendix B: Review of Literature…………………………………………….....21

LIST OF FIGURES

FIGURE PAGE

1. Dips…………………………………………………………………………..4

2. Triangle Push-Ups………………………………………………….………..4

3. Triceps Kickbacks……………………………………………………….....5

4. Overhead Triceps Extensions……………………………………………..6

5. Bar Pushdowns……………………………………………………………6

6. Rope Pushdowns…………………………………………………………7

7. Lying Barbell Triceps Extensions………………………………………...8

8. Closed Grip Bench Press…………………………………………………8

INTRODUCTION

In today's society, people often live a fast-paced lifestyle, which often does not allow time for exercising. One of the major reasons people do not workout is due to a lack of time (2). Thus, when people do work out, they want to make sure they are doing the best exercise possible for a particular body part, so as to maximize the benefits.

One of the areas women want to tone is the triceps (triceps brachii muscle). The triceps muscle consists of three heads: long, lateral, and medial. The three triceps heads merge to form one muscle, which aids in elbow extension (8). In order to determine the effectiveness of an exercise, it is important to measure muscle activity and muscle recruitment patterns while performing the exercise. A way to measure muscle activity is through electromyography (EMG) analysis (6).

Electromyography has been used in the past to look at muscle recruitment in various muscles, including the triceps. For example, Lehman and colleagues (5) evaluated muscle activity during six variations of the push-up. They compared activity using a stable surface (bench) versus an unstable surface (Swiss ball). They found that performing a push-up with both hands placed on the exercise ball was significantly more effective than the other variations of the exercise (5). Similarly, Cogley and colleagues (3) compared EMG activity in the triceps during push-ups using three different hand positions (shoulder width base, wide base, and narrow base). They found that the narrow base hand placement during a push-up elicited the most muscle activity in the triceps.

Despite past research that has provided insight into the effectiveness of various variations of the push-up, little information is known about which triceps exercise could possibly be termed the “gold standard”. Therefore, the purpose of this study was to determine, via EMG, which triceps exercise elicited the most muscle activation, and which should be defined as the most effective triceps exercise. To our knowledge no studies have been conducted to compare muscle activity with various resistance exercises targeting the triceps brachii muscle. The results of this study could help personal trainers more accurately prescribe exercises for the triceps brachii muscles.

METHODS

Subjects

Fifteen female volunteers were recruited for this study. The subjects were apparently healthy University of Wisconsin-La Crosse students, between the ages of 20-24 years. Females were the population of choice because the triceps is a common area of concern for many women. All subjects had previous weight training experience to ensure better lifting technique and to reduce potential injury. Each subject provided an informed consent before beginning the testing. Prior to beginning the study, approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects was obtained.

Procedures

The subjects performed eight different triceps exercises during this study. Explanations of the eight triceps exercises that were performed are as follows (9):

1. Dips: This lift was conducted using a low bench; the subject placed their hands on either side of their hips so their palms were resting on the bench and their fingers were hanging over the edge. The subject then placed their feet together firmly on the floor, with their legs stretched out straight in front of them. Carefully they moved their buttocks off the bench, leaving their hands in place. Keeping their back straight and their head up, they slowly lowered their hips as far as they were able, bending their elbows backward so their arms remained close to their sides. The subject then lifted them self up to the starting position, using their arms.

Making sure not to push them self up with their legs and not sitting back down on the bench. Body weight was used as resistance in this lift.

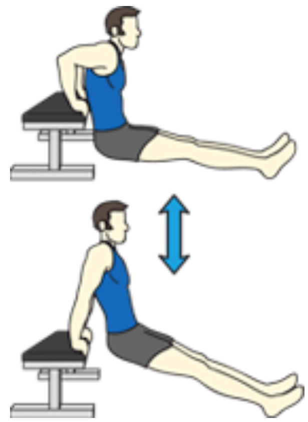

Figure 1. Dips

2. Triangle Push-ups: The subject started by placing both knees together and placing their hands flat on the floor with their thumbs facing inwards and almost touching; creating a triangle shape. A modified version was performed, therefore, both knees were kept on the floor at all times. Keeping the elbows tucked in close to their sides, they slowly lowered their body down about 2 inches from the floor, paused, and then pushed their body back up to the starting position. Body weight was used as the resistance for this exercise.

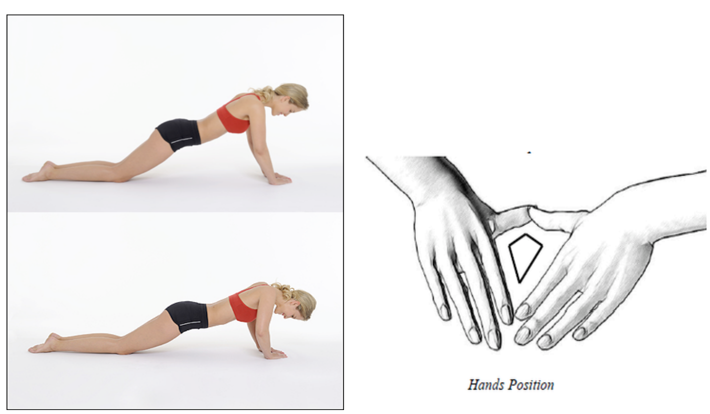

Figure 2. Triangle Push-ups

3. Triceps Kickbacks: A low bench was used for the subject to place one hand and knee on, bending forward at the waist, while holding a dumbbell in the opposite hand. The arm holding the dumbbell was held at a ninety-degree angle. The arm holding the dumbbell was brought up so that the elbow was slightly above the subject's back. The upper arm from shoulder to elbow remained stationary during the movement. Only the forearm and hand moved in an upward motion toward the ceiling until the arm was completely straight.

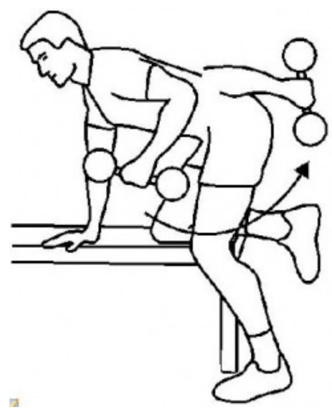

Figure 3. Triceps Kickbacks

4. Overhead Triceps Extensions: This exercise was done standing with feet hip width apart. The subject help the inner plate of the dumbbell with both hands and pressed the dumbbell straight into the air above their head. The bar of the dumbbell was perpendicular to the floor. At full extension above their head, with their upper arms as close to their ears as possible, established the starting position. The dumbbell was lowered slowly behind their head until their forearms were parallel to the floor. The subject then raised the weight slowly back above their head to the fully extended, starting position.

Figure 4. Overhead Triceps Extension

5. Bar Pushdowns: The subject stood in front of the pulley with their feet shoulder width apart. They grabbed the bar with a narrow overhand grip, keeping their elbows tucked close to their sides at all times during the exercise. They moved only their forearms, while pushing the bar down in an arc motion until their arms were straight. They held this position briefly while squeezing their triceps, and then slowly returned back up to the starting position (forearms parallel to the floor).

Figure 5. Bar Pushdowns

6. Rope Pushdowns: The subject stood in front of the pulley with their feet shoulder width apart. They grabbed the rope with a narrow overhand grip, keeping their elbows tucked close to their sides at all times during the exercise. They moved only their forearms, while pushing the bar down in an arc motion until their arms were straight. They held this position briefly while squeezing their triceps, and then slowly returned back up to the starting position (forearms parallel to the floor).

Figure 6. Rope Pushdowns

7. Lying Barbell Triceps Extensions: The subject laid supine on a bench. They gripped the barbell with a narrow grip. They began with the barbell extended over their head, and slowly lowered the bar towards their forehead bending their elbows. When the barbell neared their forehead, they moved their elbows back slightly to make sure they cleared their head and continued to lower the barbell. Then, they began to lift the weight by extending their arms following the same path as when lowering the weight. They continued to extend their arms until they were back in the starting position.

Figure 7. Lying Barbell Triceps Extensions

8. Closed Grip Bench Press: The subject laid supine on a flat bench with their chest lined up underneath the barbell. Feet were placed flat on the floor with their back flat against the bench. The subject was instructed not to arch their back. Then they grasped the barbell with a narrow or shoulder width grip. They lifted the bar off the pins, holding the barbell so that the bar was lined up across the middle of their chest. This position, with arms fully extended, marked the starting position. The subject slowly lowered the bar to their chest, keeping their elbows close to their sides. Then, they slowly lifted the bar off their chest and pushed back to get their arms fully extended. Returning to the starting position.

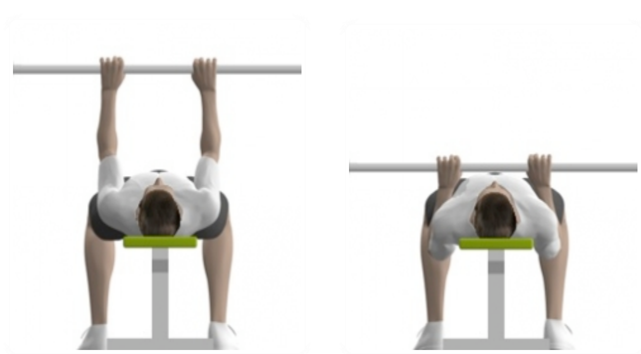

Figure 8. Closed Grip Bench Press

Subjects were asked not to weight train with their arms for 48 hours before the upcoming session in order to reduce fatigue. The subjects participated in two days of testing. Five days of rest were allowed between each testing session. On the first day of testing, a one-repetition max (1 RM) was determined for the following exercises: triceps kickbacks, overhead triceps extensions, bar pushdowns, rope pushdowns, closed grip bench press, and lying barbell triceps extensions. Dips and triangle push-ups were excluded, as those exercises use body weight as resistance. Prior to performing each exercise, subjects were given verbal and visual cues on proper form. Subjects had prior lifting experience, therefore, a 1 RM was determined by first performing 10 repetitions of an exercise using 50% of the weight they normally lift during their personal workouts. Next, eight repetitions were performed using approximately 70% of their usual workload. Finally, weight was incrementally increased until a 1 RM was established (7). EMG data was not collected on the first day of testing while the 1 RM was being established.

On the second day of testing, two sets of paired surface EMG electrodes were placed on the long and lateral heads of the triceps brachii muscle. Surface electrodes were placed on the belly of the right triceps muscle, halfway between the acromion process of the shoulder and olecranon process of the elbow. The surface of the skin was prepared using a disposable razor, 200-grit sandpaper, and alcohol swabs prior to the placement of the electrode in order to reduce skin resistance. Conduction gel was also used to capture a better EMG signal. The surface electrodes were placed 1.5 cm proximally and distally, as well as 2 cm medially and laterally from the midpoint of the triceps muscle. A ground electrode was placed on the acromion process of the shoulder. Input wires from the EMG telemetry system were attached to the electrodes. Data from these electrodes were amplified and digitally sampled at 1000 Hz.

To start the second testing session, subjects initially performed two maximal voluntary isometric contractions (MVIC) for the triceps muscle using a Lafayette Manual Muscle Tester (Model #01163, Lafayette Instrument, Lafayette, IN). The Lafayette Manual Muscle Tester was placed on a hard surface, which was adjustable so the subject's arm could rest comfortably at a 90-degree angle. Subjects performed two, 6-second isometric contractions. Maximal EMG levels were recorded during the MVIC trial. This measurement provided a baseline for EMG comparison trials for the testing session. The subjects rested for 2 minutes between MVIC. Subjects then performed one set of seven repetitions of the various exercises. All eight exercises were performed during the second testing session. Subjects lifted 70% of their previously determined 1 RM for the following exercises: triceps kickbacks, overhead triceps extensions, bar pushdowns, rope pushdowns, closed grip bench press, and lying barbell triceps extensions. Body weight was used to perform dips and triangle push-ups. Exercises were completed in random order and five minutes rest was given between each exercise for recovery time. EMG recordings from each exercise trial were represented as a percentage of the highest EMG obtained during the two MVIC trials.

Instrumentation and Data Collection

Electromyographic (EMG) data was collected using a MP150 Biopac System (Biopac System Inc., Santa Barbara, CA). The EMG signal was pre-amplified (gain x1000) using a differential amplifier (EMG 100C, bandwidth = 10-500 Hz). EMG electrodes consisted of four circular 4 mm diameter silver/silver chloride surface electrodes (BIOPAC Systems, Inc., Santa Barbara, CA) spaced 1.5 cm proximal and distal and 2 cm medial and lateral from the triceps brachii midpoint. The raw EMG signals were digitized at 1000 Hz and stored in a personal computer for subsequent analyses. Data was analyzed using software programs Acknowledge (v. 4.1.1) and LabVIEW 2009. All signal processing was performed using custom programs written with LabVIEW programming software (version 2009, National Instruments, Austin, TX).

Statistical Analysis

EMG data for the eight exercises were compared using repeated measures ANOVA. Paired t-tests were used to indicate any significant differences in muscle activity between the long and lateral heads of the triceps muscle. Alpha was set at .05 to achieve statistical significance for all analyses.

RESULTS

Fifteen subjects completed the entire study protocol. The descriptive characteristics of subjects are presented in Table 1.

Table 1. Descriptive Characteristics of Subjects

	$\bar{X} \pm SD$	Range
Age (yrs)	21.5 ± 1.36	20-24
Height (in)	65.4 ± 2.23	62-70
Weight (lbs)	139.5 ± 18.37	117-180

Concentric and eccentric muscle activation of the long and lateral heads of the triceps brachii muscle were recorded during each repetition of a seven-repetition set. Muscle activity of the complete movement (the concentric and eccentric action) of the third, forth, and fifth repetitions were averaged to yield a value for each exercise. Data for the long head, lateral head, and average of the long and lateral heads are presented in Table 2. Because the triangle push-ups elicited the highest average EMG activity in both the long and lateral heads, data for the remaining seven exercises were normalized to the triangle push-up EMG value. All data is represented as a percentage of the triangle push-up EMG value.

For the combined EMG values of the entire movement (average of the long head and lateral head), there was not a significant difference between the triangle push-up, kickbacks, and dips. Similarly, for both the long and lateral heads, there was not a significant difference between the triangle push-up, kickbacks, or dips. All other exercises yielded significantly lower EMG values compared to the triangle push-up.

When comparing the long head to the lateral head, the lateral head had significantly lower EMG values for the rope pushdowns, bar pushdowns, and lying barbell extensions.

Table 2. Average EMG of the Entire Movement (Concentric and Eccentric)

Triceps Exercise	Combined Means	Long Head	Lateral Head
Triangle Push-up	100	100	100
Kickbacks	87 ± 26.58	88 ± 33.0	87 ± 23.7
Dips	87 ± 19.87	87 ± 21.3	88 ± 20.0
Overhead Triceps Extensions	76 ± 16.09 *	81 ± 21.4 *	72 ± 16.5 *
Rope Pushdowns	74 ± 22.64 *	81 ± 32.3 *	67 ± 15.7 *#
Bar Pushdowns	67 ± 20.48 *	75 ± 29.3 *	59 ± 14.3 *#
Lying Barbell Triceps Extensions	62 ± 16.25 *	70 ± 20.9 *	55 ± 14.1 *#
Closed Grip Bench Press	62 ± 15.88 *	61 ± 16.9 *	63 ± 15.5 *

* Significantly lower than Triangle Push-up ($p < .05$)
# Significantly lower than the Long Head ($p < .05$)

DISCUSSION

In this study, EMG activity was examined in the triceps brachii muscle for eight different triceps exercises in order to determine which one would be deemed most effective in terms of muscle strengthening and toning. The triceps aids in elbow extension (8) and is composed of three heads: long, lateral, and medial (4). This study only looked at the long and lateral heads of the muscle.

This study found that muscle activity was highest during triangle push-ups. The remaining seven triceps exercises were normalized to the triangle push-up EMG value. There was no difference in average EMG values between triangle push-ups, dips, and kickbacks for the long head or lateral head. Thus, it was concluded that triangle push-ups, dips, and kickbacks can be used interchangeably to effectively work and tone the triceps muscle.

Significant differences in EMG muscle activity were found between the long and lateral heads during rope pushdowns, bar pushdowns and lying barbell extensions. Activity in the long head was significantly higher during those three exercises than in the lateral head. However, a higher degree of muscle activity was elicited during triangle push-ups, dips, and kickbacks in both the long and lateral heads. Thus, triangle push-ups, dips, and kickbacks would still be better exercises to target both heads of the triceps.

While performing 6 of the 8 exercises, approximately 70% of the subject's 1 RM was lifted to complete the exercise. However, to perform triangle push-ups and dips, bodyweight was used as resistance. It was observed that the subject's had a harder time completing the seven repetitions during both the triangle push-ups and dips. A rating of perceived exertion (RPE) was not taken while exercises were being performed. Had an RPE been recorded, a higher RPE may have been experienced during triangle push-ups and dips due to the higher amount of resistance compared to the exercises that only used 70% of their 1 RM.

The findings of this study are consistent with the findings of other studies (1, 3, 5). Cogley (3), found that a narrow based push-up elicited more EMG activity than normal and wide-based push-ups. Similarly, Weede and Kraemer (10) also found that performing push-ups with a narrow base position better isolates the triceps brachii muscle compared to wide-based push-ups.

A few studies have been completed comparing muscle activation during variations of the push-up; however, studies have not compared different triceps exercises directly to the push-up. A study conducted by Anderson and colleagues (1) tested variations of sitting push-ups and found that push-ups performed from a standard and elevated position were significantly more effective at isolating the triceps muscle than a mid-position push-up. The sitting push-up positions had a similar motion as the dip that was performed in this study.

It is important to note that two out of the three most effective triceps exercises, triangle push-ups and dips, use bodyweight as resistance. As a result, these are inexpensive and easy exercises to perform at home for an effective triceps workout. Exercise equipment is not needed to execute these exercises. Therefore, a person can get down on the floor and do triangle push-ups or use a chair to complete dips at home.

It was hypothesized that kickbacks were an effective exercise because, when performed correctly, the triceps is isolated during the movement. It is possible to cheat while performing some of the other exercises, such as bar pushdowns and rope pushdowns, by using the upper body to gain momentum in order to complete a repetition. Since the triceps muscle is so isolated while performing kickbacks, there is a greater total of motor units recruited in order to generate the movement, producing more muscle activity within the muscle.

Overall, eight exercises were tested and three were found to be equally effective at activating the triceps muscle. Triangle push-ups were used as the “gold standard” for this study and all exercises were normalized to that value. If a person were looking for the best triceps exercise, triangle push-ups would be the best. However, dips and kickbacks would produce non-significantly equal results.

REFERENCES

1. Anderson D, Jackson M, Kropf D, Soderberg, G. Electromyographic analysis of selected muscles during push-ups. *Physical Therapy*. 1984;64(1):24-28.

2. Cantwell S. Overwhelmed and running on empty: solutions for overcoming the obstacles, barriers, and excuses that keep you from exercising regularly. Act. Wom. Can. 2004;5:38-39.

3. Cogley R, Archambault T, Fibeger J, Koverman M, Youdas J, Hollman J. Comparison of muscle activation using various hand positions during the push-up exercise. Journal of Strength and Conditioning Research. 2005;19(31):628-633.

4. Lee J. Finally! Firm, stronger upper arms. Shape. 2007;*26*(5):88-92.

5. Lehman G, MacMillan B, MacIntyre I, Chivers M, Fluter M. Shoulder muscle EMG activity during push up variations on and off a Swiss ball. Dynamic Medicine. 2006;5(7):1-7.

6. Massó N, Rey F, Romero D, Gual G, Costa L, Germán A. Surface electromyography applications in the sport. Apunts Med Esport. 2010;45(165):121-130.

7. Ristvedt BE (J. Porcari). Electroymographic analysis of the different gluteal and hamstring muscles during various lower body exercises. MS in clinical Exercise Physiology. 2005:32.

8. Soubhagya R, Ashwin K, Madhan K, Latha V, Vasudha S, Merin M. Four-headed biceps and triceps brachii muscles, with neurovascular variation. Anatomical Science International. 2008;83:107–111.

9. EHow [Internet]. Sports & Fitness - How To Information | EHow.com; [cited 2010 July 28]. <http://www.ehow.com/sports/>.

10. Weede T, Kraemer WJ. Muscle and fitness blueprint for arms. Muscle Fitness Insert. 2002.

APPENDIX A

INFORMED CONSENT

INFORMED CONSENT

Electromyographic Analysis of the Triceps Brachii Muscle During a Variety of Triceps 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 (as measured by EMG analysis) during different triceps exercises in women.
- My participation in this study will involve two testing sessions, lasting approximately 45 minutes each.
- During the first session I will determine my maximal strength for six different triceps exercises. During the second session, I will complete one set of 5-10 repetitions for all eight exercises.
- During the second testing session, I will wear surface electrodes over my triceps muscle 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.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

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

Possible Benefits

- I, and other athletes, may benefit by gaining knowledge about which is the most effective triceps exercise.

Rights and Confidentiality

- My participation is voluntary.
- I can withdraw from the study at any time, for any reason, without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using group data only.
- All information will be kept confidential through the use of number codes.
- 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 this 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 concerned me and received clear answers so as to fully understand all aspects of this study.

If I have any other questions that arise I may feel free to contact the principal investigator: Brittany Boehler (605) 484-2111, 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 Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

Participant: ______________________________ Date________________

Investigator: ______________________________ Date________________

APPENDIX B

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In today's society, people live a fast paced lifestyle, which does not always allow ample time for exercising. Some people lack motivation due to unrealistic expectations of exercising, but one consistent major reason people give for not exercising is due to a lack of time (12). Creating workouts that maximize exercise benefits in a shorter amount of time may help keep people motivated and stay with an exercise program. Electromyography (EMG) analysis is a way to help determine the effectiveness of various strength-training exercises (2, 5, 8,13,14). This review of literature will discuss the role of EMG data in evaluating upper arm exercises.

Basis of EMG

Electromyography (EMG), or the study of activity patterns of muscles, is a relatively old technique and has been used extensively as a clinical research tool. EMG aids in the study of motor control as it provides insights into how the muscles are controlled by the nervous system, as evidenced by the coordination of muscles in a given movement (8). EMG provides easy access to physiological processes that cause the muscle to generate force, produce movement, and accomplish the countless functions that allow us to interact with the world around us (5).

Electromyography measures the electrical signal associated with muscle activation (14). The EMG activity of voluntary muscle contractions is related to muscle tension, but only during an isometric contraction. Muscle fibers contract when the action potential, which is the electrical signal responsible for stimulating muscle activation, of the motor nerve reaches a depolarization threshold. Depolarization creates an electromagnetic field and the potential is measured as a voltage (14). The EMG signal is the algebraic summation of the motor unit action potentials from a specific area where the electrode is placed (14).

The specific area under the electrode will generally include more than one motor unit. Any section of the muscle may contain fibers belonging to as many as 20-50 motor units. A single motor unit can have 3-2,000 muscle fibers. Muscles controlling fine movements have smaller numbers of muscle fibers per motor units (usually less than 10 fibers per motor unit) than muscles controlling large gross movements (100-1,000 fibers per motor unit) (14). There is a hierarchy arrangement during a muscle contraction as motor units with fewer muscle fibers are typically recruited first, followed by the motor units with larger muscle fibers (14).

As muscle fibers contract, myoelectric activity from the muscle fibers under the active electrodes is measured. As tension demand increases within a muscle, more motor units are recruited and therefore EMG levels increase (4).

A number of factors can influence activity level in the muscle making EMG studies difficult to interpret (4). For example, for any given external load on a muscle, EMG amplitudes will be greater for a concentric contraction than an eccentric contraction (4). When looking at muscle activity with regards to concentric and eccentric contractions, eccentric contractions produce less muscle activity than concentric contraction when working against equal force (14). As the muscle fatigues, there is typically larger amplitude of the muscle activity, despite a decrease muscle tension (14).

There are two types of electromyography: clinical, also known as diagnostic, and kinesiological (14). Physiatrists and neurologists most often use clinical EMG, which studies characteristics of a motor unit action potential for duration and amplitude. This is done to help diagnose neuromuscular pathology, evaluate spontaneous discharges of relaxed muscles and to isolate single motor unit activity (14). Kinesiological EMG is most often found in literature regarding movement analysis. Kinesiological EMG studies the relationship of muscular function to movement of body segments, timing of muscle activity with regard to movements, and examines strength and force production of muscles (14).

It is noteworthy that EMG is not a direct reflection of the force produced by a muscle. It simply provides insight into the motor unit activity necessary to perform the movement and the number of motor units represented beneath the active electrodes (4).

Electrodes

For kinesiological EMG there are two main types of electrodes: surface and fine wire (14). Surface EMG recordings are used for multiple purposes such as to describe basic motor unit recruitment and firing patterns, to measure differences in motor unit firing behavior among different force production tasks, to characterize changes in motor unit firing behavior during the development of muscular fatigue, and to explain changes in motor unit firing behavior in response to training (2).

Surface electrodes attach to the skin with double-stick adhesive collars. These electrodes detect the EMG signal through the skin using a conductive paste or gel, and are most often used in bipolar configuration. Surface electrodes have many advantages, including their noninvasive properties and simple attachment (6). There is minimal pain with application, they are more reproducible, and are very good for movement applications (14).

The disadvantages of surface electrodes include the large pick-up area and higher potential for cross-talk from adjacent muscles. Also, these electrodes can only be used for superficial muscles (14). Finally, the draping of the electrode wires on the subject can be distracting or restraining if not done carefully (6).

Fine wire electrodes require a needle for insertion into the belly of the muscle (14). Fine wire and needle electrodes are frequently used for diagnosis of muscle function and nerve conduction (6). These electrodes are made of platinum or stainless steel and are inserted directly through the skin into the muscle or via a 26-gauge needle carrier (6). The advantages of fine wire electrodes are an increased bandwidth, a more specific pick-up area, the ability to test deep muscles, and isolation of specific parts of larger muscles (14). They are also very sensitive to small levels of muscular contraction for adjacent motor units (6), which would be difficult to detect with a surface electrodes due to cross-talk (14).

The disadvantages include discomfort with needle insertion, which can increase the tightness or spasticity in the muscles, and the reliability, since it is difficult to place the needle/fine wires in the same area of the muscle each time (14).

Differences between the recording of the surface and fine wire electrodes are related to the differences in the bandwidths. Fine wire electrodes have a higher frequency and can pick-up single motor unit activity. Fine wire electrode bandwidth ranges from 2-1,000 Hz, whereas surface electrode bandwidth ranges from 10-600 Hz (14).

Electrode Placement

It is important to have a sound understanding of the anatomy of the human body as electrode location and placement is essential for accurate EMG recording. Each site must be cleaned in order to reduce any skin resistance (14). Cleaning the skin can be done by drying the skin with acetone, using a hydrating solution, or by cleaning the target sites with alcohol-saturated swabs (6).

Contrasting views remain regarding abrasion of the skin to reduce inter-electrode impedance. This process is usually inconvenient and bothersome for participants and it is potentially painful (6). However, nearly all texts on EMG technique recommend abrasion of the skin at the electrode site in order to lower inter-electrode impedance. Some researchers recommend rubbing the skin with fine sandpaper or gritty Redux paste (6), which can reduce resistance of the skin by 200% (14).

The conductive gels in EMG recording are used to stabilize the hydration and conductivity of the skin underlying the electrode (6). It also calms electrode-movement artifact by forming a stable, well-defined contact between the skin and the electrode surface (6).

The belly of the muscle is the most commonly used site for placing EMG electrodes (14). Agreement among researchers about electrode placements over target muscle groups is necessary to ensure that findings across studies are comparable (6). Bony landmarks can be used as a point of reference to assure repeatability of finding the specific placement site of the electrodes (14).

Reading EMG Measurements

EMG only measures timing patterns and relative increases and decreases in muscle activity (14). EMG data cannot determine how strong the muscle is, if one muscle is stronger than another muscle, if the contraction is a concentric or eccentric contraction, or if the activity is under voluntary control by the individual (14).

Cross-talk makes interpretation of the EMG signal difficult. Cross-talk is interference of the EMG signals from adjacent muscles or deeper muscles that are within the pick-up area of the electrode (14). Solutions to help control cross-talk are not currently available. Also, the size of the patient and size of the electrode lead plays a major role in the ability to decrease or increase cross-talk (14). If these factors occur, electrodes must be relocated before proper analysis can be performed (13).

Many sources of “noise”, which is any unwanted signal collected along side the wanted signal, exist and some of those sources include: electrostatic field (skin), electromagnetic fields (power lines), motion artifact due to loose electrodes at the skin interface, or loose leads on the wires (14). The majority of this noise can be removed from the system by a few simple precautions, including proper skin preparation, attaching all loose electrode leads, and making sure that there is some slack in the leads (14).

EMG and the Triceps Brachii Muscle

The triceps brachii muscle is composed of three heads: long, lateral, and medial (10). This entire muscle extends distally to insert into the olecranon process of the ulna and contributes mainly to extension of the forearm (15). Surface electrodes are placed on the active zone on the belly of the muscle, at the midline between the elbow and deltoid muscle (11).

Research Related to the Triceps Brachii Muscle

The standard push-up is often used to increase chest, shoulder, and arm strength. The primary purpose is to develop increased strength in the pectoralis major and triceps brachii muscles. Cogley and colleagues (4) compared EMG activity in the triceps during push-ups using three different hand positions (shoulder width base, wide base, and narrow base). Results of the study reveal that push-ups performed from the narrow base hand position elicit the greatest EMG activity in both the pectoralis major and triceps brachii muscles. The difference between the narrow base and wide base hand positions was statistically significant in both muscle groups. The narrow base hand push-up position is thus recommended to strengthen the pectoralis major and triceps brachii (4).

Similarly, Lehman and colleagues (11) evaluated muscle activity during six push-up variations on and off a Swiss ball: 1) Push-up with feet on an exercise bench, 2) Push-up with feet on exercise ball, 3) Push-up with hands on exercise bench, 4) Push-up with hands on exercise ball, 5) Push-up plus with hands on exercise bench: roll shoulders forward (scapular protraction), then lower the body while allowing scapular retraction, and 6) Push-up plus with hands on exercise ball - using the same movement as position 5 (11). A statistically significant increase in muscle activity of the triceps muscle occurred when using the Swiss ball during the push-up with the hands on the ball and during the push-up plus with the hands on the ball (11).

A study done by Junior and colleagues (9) compared EMG activity of the pectoralis major, anterior deltoids, and triceps brachii muscles during the barbell bench press. Values found during the barbell bench press were statistically lower for the triceps brachii muscle than the pectoralis major, but not different compared to the anterior deltoids (9). These findings are opposite to the reports by Clemons and Aaron (3), who found greater muscular activity of the triceps brachii in relation to the pectoralis major during the barbell bench press.

In a similar study, Gentil and colleagues (7) found that the pectoralis major had significantly higher muscle activation than the triceps brachii muscle during the chest press exercise. There were no significant differences in EMG signal amplitude between the anterior deltoids and triceps brachii during chest press (7).

Studies have not been published that report the use of EMG to assess the performances of several muscles during the seated push-up (1), therefore, Anderson et al (1) designed a study to determine if differences in EMG from the latissimus dorsi, pectoralis major, and triceps brachii muscles occurred between male and female subjects performing push-ups from three different sitting positions: 1) standard wheelchair position (S), 2) long sit with elbows flexed 90 degrees (M), and 3) long sit with maximum elbow flexion and shoulder abduction (E). Analysis of variance for the triceps brachii muscle revealed no significant interaction between sex and position. The t-tests, used to compare differences between positions, revealed that push-ups performed in the S and E positions did not produce significantly different EMG activity in the triceps brachii muscle. However, activity evoked in the S and E positions, were significantly greater than EMG activity evoked in the M position (1).

Lastly, a study was conducted to investigate differences in triceps brachii endurance and electrical activity between elite marathon and recreational wheelchair athletes with paraplegia (16). There was no difference in maximum strength of the triceps brachii between marathoners and recreational athletes. There was, however, a significant difference in endurance. The marathoner's triceps brachii muscle displayed a significantly improved endurance than recreational athletes (16).

Summary

There have been many studies on muscle recruitment patterns of upper arm and shoulder muscles during exercise, but none of the studies have compared multiple triceps exercises. EMG is a traditional method of recording muscle activity, and is one of the most widely used electrophysiological techniques. Measuring the amount of muscle activity that is produced in a muscle during exercise can help determine which exercises deem the most effective. A person can use that information to compile a workout that best suits his or her specific needs.

REFERENCES

1. Anderson D, Jackson M, Kropf D, Soderberg G. Electromyographic analysis of selected muscles during push-ups. Physical Therapy.1984;64(1):24-28.

2. Christie A, Inglis JG, Kamen G, Gabriel D. Relationships between surface EMG variable and motor unit firing rates. Eur J Appl Physiol. 2009;107:177-185.

3. Clemens JM, Aaron. Effect of grip width on the myoelectrical activity of the prime movers in the bench press. J Strength Cond Res. 1997;1:82-87.

4. Cogley R, Archambault T, Fibeger J, Koverman M, Youdas J, Hollman J. Comparison of muscle activation using various hand positions during the push-up exercise. Journal of Strength and Conditioning Research. 2005;19(31):628-633.

5. De Luca C. The use of surface electromyography in biomechanics. Journal of Applied Biomechanics. 1997;13(1):135-163.

6. Fridlund A, Cacioppo J. Guidelines for human electromyographic research. Psychophysiology. 1986;23(5),567-589.

7. Gentil P, Oliveira E, Junior V, Carmo J, Bottaro M. Effects of exercise order on upper-body muscle activation and exercise performance. Journal of Strength and Conditioning Research. 2007;21(4):1082-1086.

8. Herrel A, Schaerlaeken V, Ross C, Meyers J, Nishikawa K, Abdala V, Manzano A, Aerts P. Electromyography and the evolution of motor control: Limitations and insights. Integrative and Comparative Biology. 2008;48(2):261-271.

9. Junior V, Gentil P, Oliveira E, Carmo J. Comparison among the EMG activity of the pectoralis major, anterior deltoidis and triceps brachii during the bench press and peck deck exercises. Rev Bras Med Esporte. 2007;13(1):43-46.

10. Lee J. Finally! Firm, stronger upper arms. Shape. 207;*26*(5):88-92.

11. Lehman G, MacMillan B, Macintyre I, Chivers M, Fluter M. Shoulder muscle EMG activity during push up variations on and off a Swiss ball. Dynamic Medicine. 2006;5(7):1-7.

12. Lunau K. All the right moves. Maclean’s. 2010;123(18).

13. Nishihara K, Kawai H, Gomi T, Terajima M, Chiba Y. Investigation of optimum electrode locations by using an automatized surface electromyography analysis technique. IEEE Transactions on Biomedical Engineering. 2008;55(2):636-642.

14. Rash G. Electromyography fundamentals. Gait and Clinical Movement Analysis Society. 2002:1-10.

15. Soubhagya R, Ashwin K, Madhan K, Latha V, Vasudha S, Merin M. Four-headed biceps and triceps brachii muscles, with neurovascular variation. Anatomical Science International. 2008;83:107–111.

16. Umezu Y, Shiba N, Tajima F, Mizushima T, Okawa H, Ogata H, Nagata K, Basford J. Muscle endurance and power spectrum of the triceps brachii in wheelchair marathon racers with paraplegia. Spinal Cord. 2003;41:511-515.