A BIOMECHANICAL COMPARISON OF THE FRONT AND REAR LAT PULL- DOWN EXERCISE

By

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A THESIS PRESENTED TO THE GRADUATE SCHOOL
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The purpose of this study was to compare upper latissimus dorsi, lower latissimus dorsi, lower trapezius, anterior deltoid, posterior deltoid, pectoralis major, and biceps brachii muscle activity and range of motion during the front and rear lat pull-down exercises. Twenty healthy male and female subjects (age: 23.5 ±3.6yrs; height: 170.9±12.5cm; weight: 72.5 ±17.3kg) completed 5 trials each of front and rear lat pull-down exercises using a randomized counter-balanced design. The resistance used for each exercise was equivalent to 70% of the respective one repetition maximum. Electromyography (EMG) and motion analysis data were normalized using maximal voluntary isometric contractions and maximal active range of motion respectively. Analyses of variance (ANOVA) with repeated measures revealed significant differences in upper latissimus dorsi [$F(1,17)=5.050$, $p=.038$] and posterior deltoid [$F(1,17)=7.55$, $p=.014$] activity with the front pull-down when comparing the two exercises. Likewise, the dependent T-tests revealed that a significantly greater degree of horizontal abduction

($T(19)=-6.163$, $p<.001$) occurred during the rear pull-down, while no differences were observed in the degree of external rotation ($T(19)=-1.177$, $p=.254$). Although some differences were observed, the results of this study suggest that the front and rear lat pull-down exercises are similar with regards to muscle activity and shoulder motion.

CHAPTER 1
INTRODUCTION

Resistance exercise is a specialized method of conditioning, involving progressive use of resistance to increase one's ability to exert or resist force.[2] The specific exercise performed is based on the action of a target muscle group. This is often motion specific in athletes. As an example, in order to better an athlete's tennis serve or baseball throw, the latissimus dorsi would be the focus of the resistance exercises.[6] A number of exercises can be performed to strengthen the latissimus dorsi, such as pull-ups, pullovers, rows, bent-over rows, and lat pull-downs.[2,6] All of these exercises have clearly defined techniques, except the lat pull-down. Fahey[6] suggested that the lat pull-down be performed behind the head, while Baechle and Earle[2] suggested that it be preformed in front of the head. There are no scientific data to show which technique is best for training the latissimus dorsi. Furthermore, researchers have yet to investigate if either of the techniques might affect predisposition to injury of the shoulder by placing the shoulder in a compromised position.

Statement of the Problem

The lat pull-down exercise is an exercise used to strengthen the latissimus dorsi muscle.[2] This exercise can be performed in front of the head (front pull-down) or behind the head (rear pull-down).[2] However, it is unknown which of these techniques generates more muscle activity, thus being preferred for training the latissimus dorsi. While researchers have identified the muscles involved in the execution of the pull down exercises,[2] limited studies have focused on the electromyographic (EMG) activity of those muscles when the lifts are performed.[21,28]

The kinematics involved with each technique of the lat pull-down were not investigated in previous studies. The rear lat pull-down is hypothesized to place the shoulder in horizontal abduction and external rotation. This is the same position described by Arnheim and Prentice[1] to test shoulder instability. He also states this as a mechanism for shoulder dislocation. When in this position, stress is transferred across the anterior aspect of the shoulder.[26] With repeated stress, this might lead to greater strain and resulting laxity of the anterior stabilizers of the shoulder.

Because there is a lack of scientific support for the use of one technique of the lat pull-down over another, their use is usually based on opinion and anecdotal evidence. Thus, the purpose of this study was to determine if the front lat pull-down generates more muscle activity in the upper latissimus dorsi (UL), lower latissimus dorsi (LL), lower trapezius (LT), anterior deltoid (AD), posterior deltoid (PD), pectoralis major (PM), and biceps brachii (BB), as measured by EMG, than the rear lat pull-down, because of differences in the motion. Secondly, it investigated the degree of external rotation and horizontal abduction at the glenohumeral joint during each of the two movements.

Research Hypotheses

The following hypotheses were investigated in this thesis.

1. Subjects performing front lat pull-down will significantly increase recruitment of the upper and lower latissimus dorsi, lower trapezius, anterior and posterior deltoid, pectoralis major, and biceps brachii as measured by EMG activity.

2. Subjects performing rear lat pull-down will significantly increase the amount of external rotation at the glenohumeral joint as measured by video analysis.

3. Subjects performing rear lat pull-down will significantly increase the amount of horizontal abduction at the glenohumeral joint as measured by video analysis.

Definition of Terms

It was necessary to define the following terms for the purposes of this investigation:

Concentric muscle action: activation of a muscle during which the length of the muscle decreases.[23]

Eccentric muscle action: activation of a muscle during which the length of the muscle increases.[23]

Elbow-to-Elbow distance: distance measured across the back from olecronon process to olecronon process with the shoulders abducted to 90% and elbows flexed to 90%.[2]

External Rotation: the process of turning on an axis away from the midline.[22]

Front Pull Down: lateral pull-down exercises in which the end point is in front of the head at the top of the chest.[2]

Horizontal Abduction: movement of a limb toward the median plane of the body through the transverse plane.[22]

Horizontal Adduction: movement of a limb away from the median plane of the body through the transverse plane.[22]

Internal Rotation: the process of turning on an axis toward the midline.[22]

Maximal Voluntary Isometric Contraction: an individual's own ability to produce force for a given muscle group and held for a specified period of time.[18]

Muscle Activity: an individual's own ability to produce force for a given muscle group and held for a specified period of time.[18]

Rear Pull Down: lateral pull-down exercise in which the end point is behind the head at the base of the neck.[2]

Repetition: Amount of times a specific exercise is preformed in a given set.[2]

Set: a grouping of repetitions of a specific exercise.[22]

Limitations

The following limitations of this study were identified.

1. Results will be related to front and rear pull down exercises only.
2. Only one type of lateral pull down equipment will be used.
3. Only the latissimus dorsi, trapezius, deltoids, pectoralis major, and biceps brachii muscles will be examined.
4. Results will be related to healthy population only.
5. The experience and skill level for those performing these exercises will vary across subjects.
6. Movement of skin and electrodes over the muscle.

Assumptions

In order to successfully complete this investigation, the following assumptions were made.

1. It is assumed that all subjects will answer all questions honestly on the pretest screening form.
2. It is assumed that all subjects will closely follow instructions.

Significance

This study may provide educators, athletic trainers, physical therapist, coaches, and athletes the knowledge to better train athletes. It adds valuable research to help further exercise prescription and research pertaining to exercise technique. This study provided scientifically tested procedures for the proper execution of the lat pull-down. Knowing which muscles were more active with which exercise will enhance specification of exercise prescription.

CHAPTER 2
REVIEW OF LITERATURE

Though the lat pull-down is used in many exercise programs, limited research has been published investigating this exercise.[21, 28] Thus, exercise prescription has been primarily based on hypothetical notions. These ideas have been related to the movement at the shoulder, the anatomy of the shoulder, the actions of the muscles, and mechanisms of shoulder injuries. Though the hypothetical ideas may be sound, the question remains as to which version of the pull-down is most beneficial and safe, front or rear. The following literature review generated the basis of these theories, and the great need for further investigation.

Anatomy

The head of the humerus and glenoid cavity of the scapula form the glenohumeral joint. It is a synovial joint and classified as a ball and socket joint type.[4,8,13,15,24] Due to the loose articular capsule, and shallow glenoid cavity in relation to the large head of the humerus, it is the most mobile joint in the body. The movements at the glenohumeral joint consist of flexion, extension, abduction, adduction, internal rotation, external rotation, and circumduction.[16,24,26] The increased mobility of the joint compromises stability.[16,24] Both ligaments and muscles provide support for the glenohumeral joint. Their complex interplay as static and dynamic stabilizers, respectively, allow for shoulder motion.[16,23,26] The static restraint is provided by the capsuloligamentous complex.[23] The dynamic stabilizers are collectively called the rotator cuff muscles. They are comprised of the supraspinatus, infraspinatus, teres minor, and subscapularis.[2,4,8,13,15,16,20,23,24,26]

A number of muscles function synergistically to provide movement of the humerus. Some of the key muscles that will be studied here consist of the latissimus dorsi, trapezius, deltoids, pectoralis major, and biceps brachii. These muscles all aid in humeral adduction and medial rotation and the glenohumeral joint.[2,4,8,15,23,26] The following sections will explain these muscles in more detail.

Muscles

The latissimus dorsi originates from the spines of the inferior six thoracic vertebrae (T6-T12), lumbar vertebrae (L1-L5), crests of sacrum and ilium, and the inferior four ribs. It inserts at the intertubercular groove of the humerus. It acts to extend, adduct, and medially rotate the arm at the glenohumeral joint.[4,8,13,15,20,23,24,27]

The trapezius originates from the superior nuchal line of the occipital bone, ligamentum nuchae, spine of seventh cervical and first-twelfth thoracic vertebrae. It inserts at the clavicle, acromion, and spine of the scapula. It is divided into three sections (upper, middle, and lower). The superior fibers elevate the scapula and can extend the head, the middle fibers adduct the scapula, and the inferior fibers depress the scapula. The superior and inferior fibers can act together to rotate the scapula upward. They collectively act together to stabilize the scapula.[4,8,15,23,24]

The anterior deltoid originates from the acromial extremity of the clavicle and inserts at the deltoid tuberosity of the humerus. It acts to flex and medially rotate the arm at the glenohumeral joint.[4,8,13,15,24]

The posterior deltoid originates from the spine of the scapula and inserts at the deltoid tuberosity of the humerus. It acts to extend and lateraly rotate the arm at the glenohumeral joint.[4,8,13,15,24]

The pectoralis major originates from the clavicle, sternum, and the cartilages of the second to sixth ribs. It inserts at the greater tubercle and intertubercular groove of the humerus. It acts as a whole to adduct and medially rotate the humerus at the glenohumeral joint.[4,8,13,15,23,24]

The biceps brachii has two heads (long head and short head). The long head originates from the supraglenoid tubercle of the scapula. The short head originates from the coracoid process of the scapula. They insert at the radial tuberosity and bicipital aponeurosis. They act to flex the forearm at the elbow joint, supinate the forearm at the radioulnar joint, and flex the arm at the shoulder joint.[4,8,15,16,23,24]

The Lat Pull-Down

Purpose of the Lat Pull-Down

Performance of the lat pull-down exercise consists of pulling a bar from an overhead position down toward the body. It is primarily used to train the latissimus dorsi, middle trapezius, and rhomboids, with the focal muscle being the latissimus dorsi.[2] There are two primary versions of the lat pull-down; the front lat pull-down and the rear lat pull-down.

Motion of the Lat Pull-Down

Humeral adduction is the primary motion of the lat pull-down.[2] To begin this movement, the athlete grasps the bar with a closed, pronated grip wider than shoulder width. The athlete then sits down on the seat facing the machine and positions the thighs under the pads, thus placing the feet flat on the floor. The resulting position will place the hands overhead with shoulders abducted and elbows fully extended. This is the beginning position for the lat pull down.[2] The downward movement phase is then performed by pulling the bar down toward the body. This motion is accomplished by concentric muscle contraction, adducting the shoulders and flexing the elbows. The accessory motion occurs once the bar is drawn down to the superior aspect the head. To complete the downward phase, the bar is then pulled down to either the front of the head and touches the chest, or behind the head and touches the base of the neck. This completes the downward phase and concentric muscle contraction. Throughout this downward phase, some degree of scapular retraction and downward rotation (returning from a protracted and upwardly rotated position) occurs.

The upward movement phase is then performed. This involves eccentric muscle contractions. The bar is slowly allowed to rise above the body to the beginning position. This eccentric contraction involves shoulder abduction and elbow extension, as well as scapular protraction and upward rotation.[2] Once the weights are resting on the remaining weight stack, the athlete releases the bar from their grasp.[2]

The exercise should be done in a slow, even manner. The trunk should remain in a stabilized position throughout both motions. Generally any movement of the trunk is considered "cheating" as the movement creates momentum in the bar and aids the motion. While this aids in allowing for greater weight to be moved, the emphasis is taken away from the target muscles and placed on the trunk muscles. This can also result in injury.

Normal glenohumeral accessory motions that occur may be a cause for concern. These motions can be medial (internal) rotation or lateral (external) rotation. If the lat pull-down ends with the bar in front of the head, the motion is internal rotation of the humerus at the glenohumeral joint. If the lat pull-down ends with the bar behind the head, the motion is external rotation of the humerus at the glenohumeral joint.[2] In addition to the accessory motion of external rotation can be trunk flexion. This can be seen as the bar is pull behind the head.

Injuries

The shoulder is particularly prone to injury during weight training, due to both its structure and the forces to which it is subjected during lifting.[2,9] The accessory motion of external rotation while performing the lat pull-down is one of concern. As the bar is pulled behind the head toward the base of the neck, the shoulder is placed in horizontal abduction and external rotation. Additionally, as the athlete leans forward, by means of trunk flexion, the shoulder experiences even more external rotation and horizontal abduction. With this position of the glenohumeral joint, anterior glenohumeral dislocation[1], anterior glenohumeral instability,[3, 19] and impingement[17] may occur. Impingement can further lead to biceps tendonitis or bicepital tenosynovitis.[17] Anterior glenohumeral dislocation can possibly tear capsular and ligamentous tissue, avulse tendons of the rotator cuff muscles, tear or detach the glenoid labrum, or result in significant hemorrhage.[1] The anterior translation associated with the glenohumeral dislocation in sports is often related to an anterior force. The force can be a result of a blow to the posterior aspect of the shoulder. The pull of the muscles on the anterior aspect of the glenohumeral joint may increase as the shoulder is placed in this unstable position. It has been shown that an anterior force of 380 N in addition to compressive force and joint laxity, has been shown to lead to anterior glenoid labral tear.[7]

Anterior glenohumeral instability was suggested by Rupp et al.[19] to be due to laxity of the anterior inferior aspect of the capsuloligamentous structure, caused by repetitive overload.[19] This overload may result from any number of factors including the shoulder being placed in extreme external rotation, abduction, and horizontal abduction.[19] Bak et al.[3] further explained this non-traumatic instability might be the result of antero-inferior capsuloligamentous complex wearing, which may also have the same mechanisms of injury.

Anterior glenohumeral laxity, coupled external rotation, abduction, and horizontal abduction was reported to increase internal impingement.[11,12,9] Meister's[14] findings support impingement at maximum shoulder external rotation of the undersurface of the rotator cuff against the glenoid labrum. The repeated extreme movements and resulting contact were reported to produce tearing of the posterior or superior labrum, undersurface tearing of the rotator cuff, and changes on the posterior humeral head, such as expanded bare area and cyst formation. It was also reported that this contact is possible in a normal stable shoulder.[14] The overhead athlete, especially the throwing athlete, was reported to have a decrease in normal posterior translation, resulting in further increase in rotator cuff undersurface impingement as opposed to posterior humeral head.

Summary

According to the actions of the muscles that have been reported to be involved in the lat pull-down, the front pull-down would result in more muscle activity in the latissimus dorsi due to the increased internal rotation. However, the range of motion necessary to perform the rear pull-down exercise may place greater stress on the glenohumeral capsule and ligaments, which might then predispose the athlete to either traumatic or overuse shoulder injury. At this time, an in depth analysis of the front and rear pull-down has not been performed. Thus, an investigation such as this would provide very valuable information regarding the safest most effective way of training the latissimus dorsi and other muscles.

CHAPTER 3
METHODS

Subjects

Twenty healthy volunteers were recruited as a sample of convenience from the University of Florida population to be included in the study. The subjects had full and pain free active range of motion in the upper extremity and prior resistance training experience. Subjects were required to be between the ages of 18 and 30 years. This requirement eliminated the possibility of age related confounds. Subjects had not trained the muscle groups tested for 48 hours prior to the testing.

Instrumentation

Lat Pull Down Machine

This study made use of the BODY MASTERS lat pull-down exercise machine (Body Masters Sports Industries, Inc., Rayne, LA). It consisted of a weight stack, cable, two pulleys, a metal bar, and a seat housed in/on a metal frame. (Figure 3-1)

Electromyography (EMG)

A Myopac EMG system (Run Technologies, Laguna Hills, CA) was used to collect the raw EMG signal. The unit specifications for the EMG included an amplifier gain of 1-mV/V, a frequency bandwidth of 10-1000 Hz, CMRR 110 dB, input resistance of 1 MΩ, and a sampling rate of 1000 Hz. (Figure 3-2) Following sampling, EMG data underwent an analog to digital conversion and were stored on a PC-type computer using the DATAPAC 2000 (Run Technologies, Laguna Hills, CA) analog data acquisition, processing, and analysis system.

Figure 3-1. BODY MASTERS lat pull-down machine

Figure 3-2. Myopac Electromyography System

Kinematics

Two 60Hz JVC cameras, synchronized by a Peak Motus 2000 (Peak Performance Technologies, Inc., Englewood, CO) software system, were used to collect kinematic data. (Figures 3-3 & 3-4) The cameras were placed 45 degrees anterior and posterior to the frontal plane on the right side of all subjects. (Figure 3-5) Both cameras viewed all retroreflective markers during each exercise, thus enabling three-dimensional analysis. Before data collection, a 16-point calibration frame was videotaped for each camera view to ensure that all points were visible by both cameras. Global positioning was done to ensure the alignment of the X, Y, and Z axis. Each point was digitized from both cameras, and a calibration error of less than 0.5% was deemed acceptable to proceed with data collection.

Figure 3-3. 60 Hz JVC Camera

Figure 3-4. Peak Motus 2000 Software System

Measurements

Muscle Activity

Muscle activity during the front and rear pull-down exercises was assessed using EMG. To begin the procedure, the skin overlying the upper latissimus dorsi (UL), lower latissimus dorsi (LL), lower trapezius (LT), anterior deltoid (AD), posterior deltoid (PD), pectoralis major (PM), and biceps brachii (BB) muscles were prepared by shaving and cleaning with isopropyl alcohol. Bipolar 1-mm x 10-mm Ag/AgCl surface electrodes with an interdetection surface distance of 1.5-cm were then placed in parallel with the muscle fibers at a midpoint between the motor point and the musculotendinous junction. All electrode placements were confirmed with manual muscle testing and checked for cross-talk with real time oscilloscope displays.

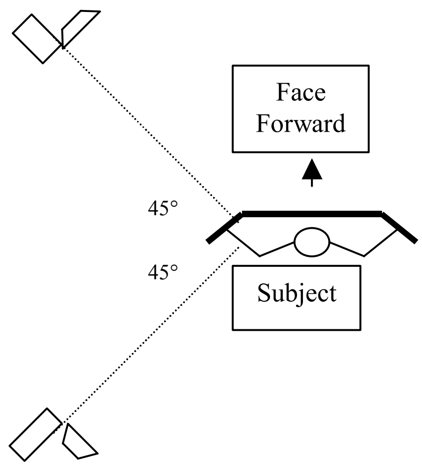

Figure 3-5. Camera Setup

Maximal EMG activity of the muscles were then measured and recorded for each of the muscles during a 5-sec maximal voluntary isometric contraction (MVIC) using standard manual muscle testing procedures as described by Hislop and Montgomery.[10]

Hislop and Montgomery[10] suggested:

> The UL and LL should be tested with the subject prone with shoulder abducted to ninety degrees. Tester stands at test side, stabilizing ipsilateral hip with one hand to prevent any lateral movement. The tester's other hand for resistance is placed over the medial aspect of the elbow. The subject adducts their shoulder.
>
> The LT should be tested with the subject prone with the shoulder at edge of table. Shoulder is abducted to 90° and externally rotated. Elbow is flexed to 90°. Tester stands at test side, stabilizing the contralateral scapular area with one hand to prevent trunk rotation. The tester's other hand for resistance is placed over the

distal end of the humerus, and resistance is directed downward toward the floor. Subject horizontally abducts arm and retracts scapula.

The AD be tested with the subject short sitting with arms at side, elbows slightly flexed, forearm pronated. Tester stands at test side, stabilizing the shoulder with one hand. Tester's hand giving resistance is contoured over the distal humerus just above the elbow. Subject flexes shoulder without rotation or horizontal movement.

The PD will be tested with the subject prone with the forearm off edge of table. Shoulder is abducted to 90°, and elbow is flexed to 90°. Tester stands at test side, hand giving resistance is contoured over the distal end of the humerus, and resistance is directed downward toward the floor. Subject horizontally abducts arm.

The PM will be tested with the subject supine. For whole muscle, the shoulder is abducted to 90°, and elbow is flexed to 90°. Tester stands at test side, hand giving resistance is contoured around the forearm just proximal to the wrist, and resistance is given as the subject horizontally adducts the shoulder.

The BB should be tested with the subject short sitting with arms at side and forearm in supination. Tester stands in front of subject toward the test side. Hand giving resistance is contoured over the flexor surface of the forearm proximal to the wrist. The other hand applies counterforce by cupping the palm over the anterior superior surface of the shoulder. Resistance is given as the subject flexes the elbow.

After a brief rest period of two minutes, muscle activity was recorded during the concentric and eccentric phase of the selected exercise. Another two minute rest period was given before performing the other exercise. The acquired raw signals were digitally processed using a symmetric root mean square (RMS) algorithm, with a 10-msec time constant. All muscle activity recorded during testing was expressed as a percentage of the normalization base, % MVIC.

Kinematics

Retroreflective markers were placed on the right side of the body at the medial aspect of the head of the ulna, olecranon process, acromio-clavicular joint, posterior aspect of the zygomatic arch, and greater trochanter. The positional data recorded from these points were analyzed to determine the degree of external or internal rotation and horizontal abduction or adduction at the shoulder. Rotation was calculated by projecting the wrist, elbow, and shoulder markers onto the sagittal (XY) plane. The angle was calculated as follows:

$$\theta = \tan^{-1}_{IR/ER}((X_{wrist} - X_{elbow})/(Y_{wrist} - Y_{elbow})).$$

The value was then expressed as a percentage of the maximal voluntary range of motion. The amount of horizontal abduction was calculated by projecting the wrist, elbow, and shoulder markers onto the transverse (XZ) plane. The inverse tangent of the change in X on the shoulder and elbow, divided by the change in Z of the shoulder and elbow, was calculated.

$$\theta = \tan^{-1}_{HABD/HADD}((X_{shoulder} - X_{elbow})/(Z_{shoulder} - Z_{elbow}))$$

The value was then expressed as a percentage of the maximal voluntary range of motion. These data were collected at the same time as the EMG activity.

Procedure

Approval by the Institutional Review Board at the University of Florida was first acquired. The purpose of the study and study procedures were explained to all subjects upon reporting to the Biomechanical Research Laboratory. Subjects then completed the Informed Consent Form (Appendix A). Height, weight, and elbow-to-elbow distance were collected and recorded. The experiment was conducted in one visit. All subjects were acquainted with the lateral pull down machine, EMG equipment, and retroreflective markers, and had the sites prepared for electrode placement.

Muscle activity was simultaneously collected with the subject’s movement using motion analysis. The motion was divided into two phases of downward movement, focusing on both the concentric and eccentric muscle contraction. The phases consisted of the main motions described earlier. Phase one consisted primarily of glenohumeral adduction. It began with the arms abducted above the head. (Figure 3-6) That phase stopped at ninety degrees of glenohumeral (GH) abduction. (Figure 3-7) Phase two consisted primarily of the accessory motion of glenohumeral rotation with allowed the bar to continue through the downward phase of the exercise (below ninety degrees). (Figures 3-8 & 3-9). Subjects lifted 70% of their 1RM (Appendix B) to elicit similar exertion levels and still allow for proper lifting technique. A distance of 110% of elbow-to-elbow distance, distance from olecranon process to olecranon process with the shoulders abducted to 90% and elbows flexed to 90%, was used to standardize grip width.

All subjects were set up on the lat pull-down per manufacturer's instruction and performed maximal internal and external rotation with shoulders abducted to 90° and elbows flexed to 90°, and horizontal abduction with shoulders abducted to 90° and elbows flexed to 90°. With a grip width equivalent to 110% of their elbow-to-elbow distance, subjects then performed five repetitions of rear or front pull down at the specified percentage of their respective 1RM for the front and rear pull-down. Following an adequate rest period of 2 minutes[1], the subjects performed the contrasting treatment with the same weight and for the same number of repetitions. The order of exercise was randomly assigned and counterbalanced by drawing out of a hat with ten front pull-downs and ten rear pull-downs. Papers were not returned to the hat after being chosen. All data were then recorded and saved for analysis.

Figure 3-6. Starting Position

Figure 3-7. 90° of GH Abduction

Figure 3-8. Front Pull-Down

Figure 3-9. Rear Pull-Down

Design and Data Analysis

The dependent variables assessed in this investigation were EMG activity of the muscles and degree of movement, expressed as percentage of max. Three independent variables were included in this investigation, type of exercise, phase of movement, and muscle action. This experiment was set up as a within subject design. It consisted of three within factors, exercise type with two levels (front and rear pull-down), phase of movement (phase one and phase two), and muscle action (concentric and eccentric). Seven 2 X 2 X 2 ANOVA with repeated measures were used to analyze the data for significance. An ANOVA was performed for the EMG activity for each of the seven muscles. Significant interactions were further analyzed using the Tukey Honestly Significant Difference (HSD) post hoc testing procedure. Two Paired-Sample T-Tests were performed for the range of motion measures (external rotation, and horizontal abduction). A boundary with an $\alpha = 0.05$ was used for statistical comparison.

CHAPTER 4
RESULTS

This study examined the differences between the front and rear lat pull-down. Using electromyography and motion analysis, we attempted to assess muscle activity and shoulder motion while subjects performed either the front or rear lat pull-down. Additionally, we distinguished between concentric and eccentric muscle actions, as well as the two phases of each exercise.

The effect of exercise, muscle action, and phase of movement on the dependent variables were examined for each muscle using repeated measures ANOVA. Significant interactions were further analyzed using the Tukey Honestly Significant Difference (HSD) post hoc testing procedure. The effect of exercise on the dependent variables was examined for the movement of the shoulder using Paired-Sample T-tests. All ANOVA, Tukey HSD post hoc testing procedure, and Paired-Sample T-test tables are respectively presented in Appendixes C, D & E.

Subject Demographics

Twenty health subjects with a mean age of 23.5 ±3.6 years participated in this study. The subjects had a mean height of 170.9 ±12.5 cm and mass of 72.5 ±17.3 kg. Eleven subjects were female and nine were male. All subjects were free of any upper extremity pathologies.

Normalized EMG Activity

A 2 X 2 X 2 repeated measures ANOVA was used to determine if muscle activity differed as a result of the three independent variables. Tests of within-subjects effects resulted in significant differences for a number of given sources of variation.

Anterior Deltoid

Normalized mean EMG activity for the anterior deltoid is presented in Table 4-1. Significant main effects were observed for muscle action [$F(1,17)=17.00$, $p=.001$] and the phase of movement [$F(1,17)=16.04$, $p=.001$]. Greater muscle activity occurred during the concentric muscle action (4.05 ±3.23 %) as compared to the eccentric (2.61 ±2.03 %) muscle action and muscle activity was greater during the second phase (3.51 ±3.20 %) of the movement as compared to the first (3.16 ±2.31 %). A significant action by phase interaction [$F(1,17)=17.386$, $p=.001$] was also observed for the anterior deltoid (Table 4-2). No other significant main effects or interactions were observed.

Table 4-1. Normalized EMG Activity of the Anterior Deltoid During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	3.42 ±2.77	5.06 ±3.89	3.04 ±2.34	4.70 ±3.52
Eccentric	1.94 ±1.47	3.11 ±2.20	2.33 ±2.24	3.07 ±2.06

Table 4-2. Normalized EMG Activity of the Anterior Deltoid (values are shown as a % of MVIC)

Action	Phase I	Phase II
Concentric	3.22 ±2.53	4.88 ±3.66*
Eccentric	3.09 ±2.10†‡	2.14 ±1.88†

* Significantly greater than concentric phase I ($p<.05$)
† Significantly less than the concentric ($p<.05$)
‡ Significantly greater than eccentric phase II ($p<.05$)

Bicep Brachii

Normalized mean EMG activity for the bicep brachii is presented in Table 4-3. A significant main effect was observed for muscle action [F(1,17)=67.35, p<.001]. Greater muscle activity occurred during the concentric muscle action (27.69 ±16.43 %) as compared to the eccentric (11.32 ±8.65 %) muscle. A significant action by phase interaction [F(1,17)=17.19, p=.001] was observed for the bicep brachii (Table 4-4). No other significant main effects or interactions were observed.

Table 4-3. Normalized EMG Activity of the Bicep Brachii During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	30.13 ±15.73	21.87 ±15.81	31.94 ±17.50	26.82 ±16.17
Eccentric	9.82 ±9.02	10.88 ±10.22	11.09 ±6.48	13.47 ±8.80

Table 4-4. Normalized EMG Activity of the Bicep Brachii (values are shown as a % of MVIC)

Action	Phase I	Phase II
Concentric	31.04 ±16.42*	24.34 ±15.96
Eccentric	12.18 ±9.49	10.46 ±7.77

* Significantly greater than eccentric phase I (p<.05)

Lower Latissimus Dorsi

Normalized mean EMG activity for the lower latissimus dorsi is presented in Table 4-5. Significant main effects were observed for muscle action [F(1,17)=173.05, p<.001] and the phase of movement [F(1,17)=137.56, p<.001]. Greater muscle activity occurred during the concentric muscle action (48.59 ±34.07 %) as compared to the eccentric (17.99 ±14.32 %) muscle action and muscle activity was greater during the second phase (41.46 ±39.39 %) of the movement as compared to the first (25.11 ±12.41 %). A significant action by phase interaction [F(1,17)=84.77, p<.001] was also observed for the lower latissimus dorsi (Table 4-6). No other significant main effects or interactions were observed.

Table 4-5. Normalized EMG Activity of the Lower Latissimus Dorsi During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	22.60 ±11.07	72.96 ±34.51	23.91 ±10.05	74.87 ±26.71
Eccentric	7.59 ±4.48	25.04 ±15.04	10.24 ±9.33	28.86 ±13.08

Table 4-6. Normalized EMG Activity of the Lower Latissimus Dorsi (values are shown as a % of MVIC)

Action	Phase I	Phase II
Concentric	23.25 ±10.44	73.92 ±30.43*
Eccentric	26.97 ±14.00*‡	9.01 ±7.36†

* Significantly greater than concentric phase I (p<.05)
† Significantly less than concentric phase II (p<.05)
‡ Significantly greater than eccentric phase II (p<.05)

Lower Trapezius

Normalized mean EMG activity for the lower trapezius is presented in Table 4-7. A significant main effect was observed for muscle action [F(1,17)=31.73, p<.001]. Greater muscle activity occurred during the concentric muscle action (35.80 ±22.66 %) as compared to the eccentric (24.31 ±18.66 %) muscle action. A significant action by phase interaction [F(1,17)=11.03, p=.004] was also observed for the lower trapezius (Table 4-8). No other significant main effects or interactions were observed.

Table 4-7. Normalized EMG Activity of the Lower Trapezius During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	35.86 ±20.14	28.70 ±25.46	45.52 ±24.24	33.13 ±18.49
Eccentric	22.78 ±20.90	20.50 ±15.31	26.28 ±18.12	27.67 ±20.50

Table 4-8. Normalized EMG Activity of the Lower Trapezius (values are shown as a % of MVIC)

Action	Phase I	Phase II
Concentric	40.69 ±22.50*	30.92 ±22.04
Eccentric	24.08 ±18.20†	24.53 ±19.36†

* Significantly greater than concentric phase II ($p<.05$)
† Significantly less than the concentric action ($p<.05$)

Posterior Deltoid

Normalized mean EMG activity for the posterior deltoid is presented in Table 4-9. A significant main effect was observed for muscle action [$F(1,17)=22.74$, $p<.001$]. Greater muscle activity occurred during the concentric muscle action (41.85 ±36.39 %) as compared to the eccentric (19.63 ±16.43 %) muscle. Significant pull by phase [$F(1,17)=5.80$, p=028] and pull by action by phase [$F(1,17)=7.55$, $p=.014$] interactions were observed for the posterior deltoid (Table 4-10). No other significant main effects or interactions were observed.

Table 4-9. Normalized EMG Activity of the Posterior Deltoid During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	38.25 ±31.24	50.35 ±46.19*‡	43.00 ±33.48	35.80 ±34.19
Eccentric	16.64 ±12.35†	24.41 ±21.16†	17.95 ±11.99†	19.53 ±16.21†

* Significantly greater than concentric phase I of the front pull-down ($p<.05$)
† Significantly less than the concentric action ($p<.05$)
‡ Significantly greater than concentric phase II of the rear pull-down ($p<.05$)

Table 4-10. Normalized EMG Activity of the Posterior Deltoid (values are shown as a % of MVIC)

Exercise	Phase I	Phase II
Front	31.33 ±27.22	33.50 ±37.45*
Rear	31.26 ±29.23	26.87 ±26.82†

* Significantly greater than front phase I (p<.05)
† Significantly less than the rear phase I (p<.05)

Pectoralis Major

Normalized mean EMG activity for the pectoralis major is presented in Table 4-11. Significant main effects were observed for muscle action [$F(1,17)=20.21$, $p<.001$] and the phase of movement [$F(1,17)=16.07$, $p=.001$]. Greater muscle activity occurred during the concentric muscle action (18.83 ±18.28 %) as compared to the eccentric (9.99 ±8.42 %) and muscle activity was greater during the second phase (14.58 ±16.80 %) of the movement as compared to the first (14.24 ±12.74 %). No other significant main effects or interactions were observed.

Table 4-11. Normalized EMG Activity of the Pectoralis Major During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	19.60 ±15.41	27.05 ±23.71	10.82 ±13.80	17.85 ±16.28
Eccentric	7.75 ±4.95	15.69 ±10.96	5.67 ±4.27	10.85 ±8.53

Upper Latissimus Dorsi

Normalized mean EMG activity for the upper latissimus dorsi is presented in Table 4-12. A significant pull by action by phase interaction [$F(1,17)=5.050$, $p=.038$] was observed for the upper latissimus dorsi. No other significant main effects or interactions were observed.

Table 4-12. Normalized EMG Activity of the Upper Latissimus Dorsi During the Front and Rear Pull-Down Exercises (values are shown as a % of MVIC)

	Front Pull-Down		Rear Pull-Down	
Action	Phase I	Phase II	Phase I	Phase II
Concentric	123.52 ±110.10	123.53 ±109.84	124.44 ±110.39‡	123.71 ±110.03
Eccentric	125.26 ±109.73*†	124.56 ±109.89†	123.17 ±110.05	123.18 ±110.02

* Significantly greater than concentric action (p<.05)
† Significantly greater than rear pulldown (p<.05)
‡ Significantly greater than eccentric action (p<.05)

Shoulder ROM

Normalized shoulder range of motion was tested for significance using Paired-Sample T test. Horizontal abduction of the shoulder increased significantly [T(19)=-6.163, p<.001]. No other significant differences were observed. Normalized shoulder range of motion for front and rear pulls of all movements are presented in Table 4-13.

Table 4-13 Normalized Shoulder ROM During the Front and Rear Pull-Down Exercises (values are shown as a % of maximal active range of motion)

Movement	Front	Rear
Horizontal Abduction	28 ±42	118 ±60*
External Rotation	48 ±15	51 ±10

* Significantly greater than front (p < .05).

CHAPTER 5
DISCUSSION

To our knowledge, this study is the first to utilize both electromyography (EMG) and motion analysis to evaluate the front and rear lat pull-down exercises. For a complete assessment, muscle action and phase of movement were also factored into the analysis. When comparing the two exercises, the upper latissimus dorsi and the posterior deltoid differed in activity. The following chapter will discuss these differences as well as those observed when comparing muscle actions and phases of movement.

EMG Activity

It was hypothesized that the EMG activity of the upper (UL) and lower latissimus dorsi (LL), lower trapezius (LT), anterior (AD) and posterior deltoid (PD), pectoralis major (PM), and biceps brachii (BB) would be greater during the front pull-down. This hypothesis was supported for the UL and PD only, as both muscles had significantly greater activity during the front lat pull-down. It must be noted that the greater activity in the UL was only observed when the muscle was contracting eccentrically. When comparing concentric activity, no differences were observed. However, greater activity was observed during the concentric contraction of the PD, but only when comparing the second phase of the two exercises. No other muscles differed in activity when comparing the front and rear pull-down.

Latissimus Dorsi

The functions of the latissimus dorsi include adduction of the arm from an abducted position, horizontal adduction, and extension from a flexed position. For our study, we separated the muscle into its upper and lower segments. During the rear pull-down, the concentric activity was greater than the eccentric activity as expected. However, in the first phase of the front pull-down, the UL was observed to have significantly greater eccentric muscle activity than concentric. This was unexpected, as eccentric activity is generally lower than concentric activity at a given load.[2] It is important to note that this was unique to the UL and it only occurred during the first phase of the front pull-down. A possible explanation for this observation could be a change in the speed of the final phase of the eccentric movement. The subjects were to maintain a constant cadence in time with a metronome. It is possible that subjects might have deviated from this cadence, which would have affected the velocity of motion and deceleration. Using the equation force = mass x acceleration, an increase in velocity would result in a greater deceleration force. The resultant increase of force would necessitate greater muscle activity.

As stated above, our hypothesis was supported by the UL as greater activity was observed during both phases of the front pull-down as compared to the rear pull-down. However, this was only observed during the eccentric muscle actions. The motion that occurs during the eccentric action should be identical to that of the concentric, but in the opposite direction. Therefore, the joint motions should pass through the same plane and through an equivalent range of motion. Thus, any differences between exercises observed eccentrically should also be observed concentrically. Once again, the likely explanation for this would be a greater velocity of motion during the eccentric action resulting in greater velocity of motion during the eccentric action resulting in greater deceleration forces.

No significant differences were observed in the LL when comparing the front (72.96 ±34.51%) and rear (74.87 ±26.71%) pull-down exercises. However, when the two exercises were combined, differences were observed when comparing muscle action and phase of movement. Concentric activity was greater during the second phase as compared to the first, while eccentric activity was greater during the first. Though the results do not support our hypothesis, it can be concluded that either exercise can be used to strengthen the LL, as the muscle was fairly active during both exercises (approximately 74% of activity during MVIC). The similar activity levels could be a result of the main action of the lat pull-down, adduction. It was thought that rotational differences might increase activity of the LL, but no differences were noted. Without motion changes, changes in muscle activity would not be expected.

Posterior Deltoid

The functions of the posterior deltoid include extension of the arm, horizontal abduction, and external rotation. As expected, concentric activity was greater than eccentric activity during each phase of the two exercises. When comparing the two exercises, concentric activity was greater in the front pull-down than the rear. However, this was only observed during the second phase of the movement. Any differences between exercises occurring during the concentric muscle action would be expected during the eccentric muscle action as well. This did not occur, as eccentric muscle activity did not differ. As mentioned previously, it is possible that differences in subject cadence may account for the lack of significant difference in eccentric action between exercises. It would also be expected that the greater horizontal abduction observed during the rear pull-down would be associated with greater posterior deltoid activity. Not only did this not occur, but the opposite occurred. This would suggest that musculature other than the posterior deltoid was responsible for the horizontal motion and that other motions, such as extension, occurred to a greater extent during the rear pull-down.

Anterior Deltoid

The functions of the anterior deltoid include flexion of the arm and internal rotation. It was initially thought that the lesser degree of external rotation during the front pull-down (or greater internal rotation) would result in greater anterior deltoid activity. However, no differences were observed when comparing exercises. When the two exercises were combined, differences were observed when comparing muscle action and phase of movement. As expected, there was greater concentric activity as compared to eccentric during both phases of movement. Similar to some of the other muscles, greater concentric activity occurred during the second phase as compared to the first, while eccentric activity was greater during the first phase. The anterior deltoid was theorized to have greater activity because it functions as an internal rotator. As previously stated, no significant difference was observed with internal rotation between front and rear lat pull-down. This observation supports the lack of significant differences with muscle activity during the front and rear pull-down. Regardless, our results also suggested that neither exercise would provide a sufficient stimulus for training the anterior deltoid, as the mean activity was only 5.06 ±3.89% of the MVIC during the front pull-down and 4.70 ±3.52% during the rear pull-down.

Pectoralis Major

The pectoralis major functions to adduct and internally rotate the arm. These movements are similar in both exercises. It was thought that internal rotation would increase during the front pull-down, thus increasing activity of the pectoralis major. However, no significant differences were found when comparing pectoralis major activity during the front and rear pull-down exercises. When the two exercises were combined, differences were observed when comparing muscle action and phase of movement. The pectoralis major was observed to have significantly greater muscle activity during concentric muscle action and during phase II than eccentric muscle action and phase I, respectively, of the exercises. In general, it can be stated that the pectoralis major functions as an assisting muscle with these exercises as the activity was only 27.05 ±23.71% and 17.83 ±16.28% during the front and rear pull-down respectively.

Accessory Muscles

Performance of the pull-down exercise also requires scapular retraction and downward rotation and elbow flexion. The scapula motion is provided in part by the lower trapezius while the elbow flexion is provided by the biceps brachii and other elbow flexors. These assisting actions were supported in this study, as lower trapezius activity was 28.70 ±25.46% and 33.13 ±18.49% and biceps brachii activity was 21.87 ±15.81% and 26.82 ±16.17% of the MVIC during the front and rear pull-down.

Range of Motion

Both the front and rear pull-down exercises begin with the arms in an overhead extended position. The primary action during each of these exercises is shoulder adduction with both following a similar plane of motion. However, during the lower phase of the front pull-down, the bar passes in front of the head to the upper chest, while it passes behind the head to the upper trapezius area during the rear pull-down. Because of the motion needed to perform the exercise, we initially hypothesized that a greater amount of external rotation would be required to perform the rear pull-down as compared to the front pull-down. This hypothesis was not supported, as no significant differences were observed when comparing the maximal amount of external rotation achieved during each exercise. It was also hypothesized that a greater amount of horizontal abduction would be required to perform the rear pull-down. This was supported, as a greater degree of horizontal abduction was observed during the rear pull-down as compared to the front. These findings are consistent with those of Signorile et al.,[21] who reported an increase in horizontal abduction with the wide grip posterior position, and a more linear movement with the wide grip anterior position. The described position is approximately the same as our front lat pull-down. An assessment technique is not described in that study, thus it appears that their report only provides anecdotal evidence. They also fail to discuss rotational range of motion in that paper, so we are unable to make comparisons with our results. The difference in the degree of horizontal abduction we observed might also explain the similar amount of external rotation observed during each exercise. It is possible that the greater horizontal abduction utilized during the rear pull-down might have provided adequate posterior movement of the bar, allowing it to clear the head without having to further rotate the shoulder.

It is important to note that the range of motion values used in the analysis were calculated relative to the maximal active range of motion allowed when the shoulder was abducted to 90°. However, when the external rotation and horizontal abduction measurements were made during exercise, the shoulder was no longer in that abducted position. This might have had an effect on the measurement. It was observed that the mean horizontal abduction was greater than the tested max (118%). Horizontal abduction is only one component of the lat pull-down. This motion was coupled with movement outside the transverse plane, such as the sagittal plane with shoulder extension. The calculation of the angle was in reference of the elbow to the shoulder. The lat pull-down was observed to have posterior movement at the elbow in reference to the shoulder, but not specific to true horizontal abduction. The observed difference between the exercises could be accounted for with extension of the shoulder. These movements would, however, be calculated and reported as horizontal abduction, thus possibly resulting in a greater value than the tested max of true horizontal abduction.

Conclusions

Based on the study at hand, the following conclusions were made. The first hypothesis stated there would be a significant increase in muscle activity of the upper and lower latissimus dorsi, lower trapezius, anterior and posterior deltoid, pectoralis major, and biceps brachii during the front lat pull-down. The following conclusions were made:

1. UL activity was significantly higher during front lat pull-down
2. LL activity was not significantly greater during front lat pull-down
3. LT activity was not significantly greater during front lat pull-down
4. AD activity was not significantly greater during front lat pull-down
5. PD activity was significantly higher during front lat pull-down
6. PM activity was not significantly greater during front lat pull-down
7. BB activity was not significantly greater during front lat pull-down

The second hypothesis stated subjects performing rear lat pull-down will significantly increase the amount of external rotation at the glenohumeral joint as measured by video analysis.

- ER was not significantly greater during rear lat pull-down

Subjects performing rear lat pull-down will significantly increase the amount of horizontal abduction at the glenohumeral joint as measured by video analysis.

- HABD was significantly greater during front lat pull-down

Summary

This study examined muscle activity and range of motion during the front and rear lat pull-down exercises. Our results suggest that both exercises utilize similar scapular and glenohumeral motions. Our third hypothesis was supported, and stated that greater horizontal abduction would be required to complete the rear pull-down exercise. This finding assists in the explanation of the results related to the other two hypotheses, by accounting for the posterior movement needed to pull the bar behind the head. This observation suggests that external rotation would not be required to complete the rear pull-down exercise. Furthermore, only the upper latissimus dorsi and the posterior deltoid results were found to support our hypothesis. This supports the increase in the extension and horizontal abduction of the glenohumeral joint. Similar activity in the other muscles study mirrors the similar scapular and glenohumeral motions. These results support the prescription of the front lat pull-down by athletic trainers and clinicians to train the upper latissimus dorsi and the posterior deltoid. Both exercises can be effectively used to train the lower latissimus dorsi, however, neither exercise is useful for train the anterior deltoid.

Implications for Future Research

One limitation found while conducting our study was the ability to truly account for motion at the shoulder. As discussed, the values were expressed as a percentage of the max, however the max angle of the motion that was tested was not the same angle of motion that was observed during the exercises. Additional research on the lat pull-down should examine the shoulder movement more carefully. Investigation of the resultant movement would allow for the pre-testing of the maximal degrees to help normalize across subjects.

Future research of the lat pull-down might include the use of fine wire intra-muscular electrodes while collecting EMG activity in order to better investigate the rhomboids and rotator cuff muscles (supraspinatus, infraspinatus, teres minor, and subscapularis). The role of these dynamic stabilizers of the shoulder may help in the prescription of the lat pull-down during rehabilitation of shoulder injuries.

APPENDIX A
INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to take part in a research study. This form provides you with information about the study. The Principal Investigator (the person in charge of this research) or a representative of the Principal Investigator will also describe this study to you and answer all of your questions. Before you decide whether or not to take part, read the information below and ask questions about anything you do not understand. Your participation is entirely voluntary.

1. Name of Participant ("Study Subject")

____

2. Title of Research Study

A biomechanical comparison of the front and rear lat pull-down exercise.

3. Principal Investigator and Telephone Number(s)

GM Pugh
Graduate Student
Department of Exercise and Sport Sciences
338-0250

Michael E. Powers, PhD, ATC, CSCS
Assistant Professor
Department of Exercise of Sport Sciences
392-0584 x1332

4. Source of Funding or Other Material Support

University of Florida

5. What is the purpose of this research study?

The purpose of this study is to determine if you use the muscles of your upper back, shoulders, and arms (upper latissimus dorsi, lower latissimus dorsi, teres major, trapezius, anterior deltoid, posterior deltoid, pectoralis major, and biceps brachii) to a greater extent during a front lat pull-down exercise as compared to a rear lat pull-down exercise. Another purpose of this study is to determine which exercise causes your shoulder to move through a greater range of motion when pulling the bar down.

6. What will be done if you take part in this research study?

You will be eligible to participate in this study if you have not suffered an injury to the shoulder or arm that would prevent you from performing the front or rear lat pull-down exercise. You will be asked to report to the Biomechanical Research Laboratory located in Florida Gymnasium on one occasion. Once you arrive we will measure your height, weight and the distance from one elbow to the other while you hold your arms up so they are out to the side and parallel with the floor. After this is done you will be familiarized with the lat pull-down machine, muscle measuring and motion measuring equipment. The muscles of your back, shoulder, anr arm will then be prepped and eight (8) adhesive electrodes will be placed on the skin over them. If necessary a small area will be shaved to allow for electrode placement and the skin will be cleaned with alcohol. These electrodes allow us to measure the muscle activity (how much it contracts) when you pull the bar down. They only collect or read the electrical activity of the muscle, thus they do not transmit an electrical current into your body. We will also place reflective markers on the outside of your shoulder, elbow, wrist, hip, and on the back of your neck using tape. These are used to measure the motion of your body during the exercise.

You will then be asked to perform five front lat pull-downs and five rear lat pull-downs. The order of the lifts will be random. If you are male, the amount of weight you pull will be equal to 75% of your body weight. If you are female, the amount of weight you pull will be equal to 50% of your body weight. You will be video taped while you perform these exercises. The video tape and the reflective markers will allow us to determine how much movement occurs at you shoulder. When you have completed all ten pull-downs, the electrodes and reflectors will be removed and your participation will be complete. Your entire participation should take approximately one hour.

7. What are the possible discomforts and risks?

There are no potential health risks associated with this study.

8a. What are the possible benefits to you?

There are no direct benefits to the subjects.

8b. What are the possible benefits to others?

The knowledge gained from this study may increase the safety of current weight lifting and training techniques.

9. If you choose to take part in this research study, will it cost you anything?

There are no potential financial risks steming from this study.

10. Will you receive compensation for taking part in this research study?

There are no potential financial benefits steming from this study.

11. What if you are injured because of the study?

All risks will be minimized by having National Athletic Trainers' Assiciation Board of Certification (NATABOC) certified athletic trainers present.

12. What other options or treatments are available if you do not want to be in this study?

You may participate in another research project.

13a. Can you withdraw from this research study?

You are free to withdraw your consent and to stop participating in this research study at any time. If you do withdraw your consent, there will be no penalty, and you will not lose any benefits you are entitled to.

If you decide to withdraw your consent to participate in this research study for any reason, you should contact GM Pugh at (352) 338-0250 or Dr. Michael Powers at (352) 392-0584 x1332.

If you have any questions regarding your rights as a research subject, you may phone the Institutional Review Board (IRB) office at (352) 846-1494.

13b. If you withdraw, can information about you still be used and/or collected?

NO

13c. Can the Principal Investigator withdraw you from this research study?

You may be withdrawn from the study without your consent for the following reasons: You are unable to complete the protocol.

14. How will your privacy and the confidentiality of your research records be protected?

Authorized persons from the University of Florida, the hospital or clinic (if any) involved in this research, and the Institutional Review Board have the legal right to review your research records and will protect the confidentiality of them to the extent permitted by law. Otherwise, your research records will not be released without your consent unless required by law or a court order.

If the results of this research are published or presented at scientific meetings, your identity will not be disclosed.

15. How will the researcher(s) benefit from your being in this study?

In general, presenting research results helps the career of a scientist. Therefore, the Principal Investigator may benefit if the results of this study are presented at scientific meetings or in scientific journals.

16. Signatures

As a representative of this study, I have explained to the participant the purpose, the procedures, the possible benefits, and the risks of this research study; the alternatives to being in the study; and how privacy will be protected:

____

Signature of Person Obtaining Consent   Date

You have been informed about this study's purpose, procedures, possible benefits, and risks; the alternatives to being in the study; and how your privacy will be protected. You have received a copy of this Form. You have been given the opportunity to ask questions before you sign, and you have been told that you can ask other questions at any time.

You voluntarily agree to participate in this study. By signing this form, you are not waiving any of your legal rights.

APPENDIX B
1 REPETITION MAXIMUM

1. Instruct the athlete to warm up with a light resistance that easily allows 5-10 repetitions.
2. Provide a 1-min rest period.
3. Estimate a warm-up load that will allow the athlete to complete 3-5 repetitions by adding:
    a. 10-20 lb or 5-10% for upper-body exercise.
    b. 30-40 lb or 10-20% for lower-body exercise.
4. Provide a 2-minute
5. Estimate a conservative, near-maximum load that will allow the athlete to complete 2-3 repetitions by adding:
    a. 10-20 lb or 5-10% for upper-body exercise.
    b. 30-40 lb or 10-20% for lower-body exercise.
6. Provide a 2- to 4- min rest period.
7. Make a load increase:
    a. 10-20 lb or 5-10% for upper-body exercise.
    b. 30-40 lb or 10-20% for lower-body exercise.
8. Instruct the athlete to attempt a 1RM.
9. If the athlete was successful provide a 2- to 4- minute rest period and go back to step 7.

If the athlete failed, provide a 2- to 4- minute rest period, decrease the load by subtracting:

a. 5-10 lb or 2.5% for upper-body exercise
b. 15-20 lb or 5-10% for lower-body exercise

And then go back to step 8.

Continue increasing or decreasing the load until the athlete can complete on repetition with proper exercise technique. Ideally, the athlete's 1RM will be measured within five testing sets.[2, 3]

APPENDIX C
ANOVA TABLES

Table C-1 Repeated Measures ANOVA for AD: Tests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	3.653E-05	1	3.653E-05	.201	.659
Error	3.083E-03	17	1.813E-04		
Action	7.458E-03	1	7.458E-03	17.002	.001
Error	7.458E-03	17	4.387E-04		
Phase	6.085E-03	1	6.085E-03	16.044	.001
Error	6.448E-03	17	3.793E-04		
Pull * Action	2.709E-04	1	2.709E-04	3.006	.101
Error	1.532E-03	17	9.014E-05		
Pull * Phase	3.511E-05	1	3.511E-05	.674	.423
Error	8.856E-04	17	5.210E-05		
Action * Phase	4.326E-04	1	4.326E-04	17.386	.001
Error	4.230E-04	17	2.488E-05		
Pull * Action * Phase	4.581E-05	1	4.581E-05	.934	.347
Error	8.340E-04	17	4.906E-05		

Table C-2 Repeated Measures ANOVA for BB: Tests for Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	2.539E-02	1	2.539E-02	2.954	.104
Error	.146	17	8.595E-03		
Action	.965	1	.965	67.348	.000
Error	.244	17	1.433E-02		
Phase	2.226E-02	1	2.226E-02	2.231	.154
Error	.170	17	9.977E-03		
Pull * Action	1.891E-03	1	1.891E-03	.552	.468
Error	5.819E-02	17	3.423E-03		
Pull * Phase	4.482E-03	1	4.482E-03	1.353	.261
Error	5.631E-02	17	3.312E-03		
Action * Phase	6.377E-02	1	6.377E-02	17.188	.001
Error	6.308E-02	17	3.710E-03		
Pull * Action * Phase	7.388E-04	1	7.388E-04	.321	.578
Error	3.912E-02	17	2.301E-03		

Table C-3 Repeated Measures ANOVA for LLTests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	2.193E-02	1	2.193E-02	.386	.543
Error	.966	17	5.681E-02		
Action	3.372	1	3.372	173.047	.000
Error	.331	17	1.949E-02		
Phase	4.236	1	4.236	137.565	.000
Error	.523	17	3.079E-02		
Pull * Action	2.627E-03	1	2.627E-03	.214	.650
Error	.209	17	1.229E-02		
Pull * Phase	5.659E-04	1	5.659E-04	.039	.846
Error	.247	17	1.452E-02		
Action * Phase	.963	1	.963	84.774	.000
Error	.193	17	1.137E-02		
Pull * Action * Phase	3.466E-05	1	3.466E-05	.007	.935
Error	8.628E-02	17	5.075E-03		

Table C-4 Repeated Measures ANOVA for LT: Tests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	.138	1	.138	1.091	.311
Error	2.148	17	.126		
Action	.476	1	.476	31.729	.000
Error	.255	17	1.500E-02		
Phase	9.399E-02	1	9.399E-02	3.139	.094
Error	.509	17	2.994E-02		
Pull * Action	2.648E-03	1	2.648E-03	.219	.646
Error	.206	17	1.212E-02		
Pull * Phase	5.416E-04	1	5.416E-04	.047	.831
Error	.197	17	1.157E-02		
Action * Phase	7.822E-02	1	7.822E-02	11.033	.004
Error	.121	17	7.090E-03		
Pull * Action * Phase	1.785E-02	1	1.785E-02	2.591	.126
Error	.117	17	6.891E-03		

Table C-5 Repeated Measures ANOVA for PD: Tests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	4.022E-02	1	4.022E-02	.366	.553
Error	1.870	17	.110		
Action	1.777	1	1.777	22.738	.000
Error	1.328	17	7.813E-02		
Phase	4.560E-02	1	4.560E-02	1.849	.192
Error	.419	17	2.466E-02		
Pull * Action	8.725E-03	1	8.725E-03	1.016	.328
Error	.146	17	8.584E-03		
Pull * Phase	.146	1	.146	5.798	.028
Error	.428	17	2.519E-02		
Action * Phase	4.448E-03	1	4.448E-03	.396	.537
Error	.191	17	1.122E-02		
Pull * Action * Phase	3.869E-02	1	3.869E-02	7.549	.014
Error	8.712E-02	17	5.125E-03		

Table C-6 Repeated Measures ANOVA for PM: Tests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	.140	1	.140	3.824	.067
Error	.621	17	3.650E-02		
Action	.281	1	.281	20.213	.000
Error	.237	17	1.392E-02		
Phase	.171	1	.171	16.074	.001
Error	.181	17	1.066E-02		
Pull * Action	2.753E-02	1	2.753E-02	2.901	.107
Error	.161	17	9.488E-03		
Pull * Phase	2.285E-03	1	2.285E-03	.356	.559
Error	.109	17	6.417E-03		
Action * Phase	4.278E-04	1	4.278E-04	.117	.736
Error	6.214E-02	17	3.655E-03		
Pull * Action * Phase	1.240E-03	1	1.240E-03	.524	.479
Error	4.021E-02	17	2.365E-03		

Table C-7 Repeated Measures ANOVA for UL: Tests of Within-Subjects Effects (n=18)

Source of Variation	SS	DF	MS	F	Sig of F
Pull	1.266E-03	1	1.266E-03	.546	.470
Error	3.944E-02	17	2.320E-03		
Action	2.189E-04	1	2.189E-04	.090	.768
Error	4.150E-02	17	2.441E-03		
Phase	4.477E-04	1	4.477E-04	4.402	.051
Error	1.729E-03	17	1.017E-04		
Pull * Action	4.710E-03	1	4.710E-03	2.305	.147
Error	3.475E-02	17	2.044E-03		
Pull * Phase	1.087E-07	1	1.087E-07	.001	.979
Error	2.599E-03	17	1.529E-04		
Action * Phase	3.467E-07	1	3.467E-07	.003	.957
Error	2.010E-03	17	1.182E-04		
Pull * Action * Phase	4.828E-04	1	4.828E-04	5.050	.038
Error	1.625E-03	17	9.561E-05		

APPENDIX D
TUKEY HSD POST HOC TESTING PROCEDURE

(Calculation of critical values)

q = value used to determine critical value of the Studentized Range Distribution, based on the number of means and degrees of freedom corresponding to the denominator of the significant F

Critical Value $= q\sqrt{(MSerror/\#\text{ of scores in error})}$

Equation 1 Anterior deltoid action by phase interaction.

Q(4,17) = 4.05 $= 4.05\sqrt{(0.00002488/36)} = 0.003$

Equation 2 Bicep brachii action by phase interaction.

Q(4,17) = 4.05 $= 4.05\sqrt{(0.0371/36)} = 0.130$

Equation 3 Lower latissimus dorsi action by phase interaction.

Q(4,17) = 4.05 $= 4.05\sqrt{(0.01137/36)} = 0.072$

Equation 4 Lower trapezius action by phase interaction.

Q(4,17) = 4.05 $= 4.05\sqrt{(0.00709/36)} = 0.057$

Equation 5 Posterior deltoid pull by phase interaction.

$$Q(4,17) = 4.05 \qquad = 4.05\sqrt{(0.02519/36)} = 0.107$$

Equation 6 Posterior deltoid pull by action by phase interaction.

$$Q(8,17) = 4.90 \qquad = 4.90\sqrt{(0.005125/18)} = 0.083$$

Equation 7 Upper latissimus dorsi pull by action by phase interaction.

$$Q(8,17) = 4.90 \qquad = 4.90\sqrt{(0.0000956/18)} = 0.01$$

APPENDIX E
PAIRED-SAMPLE T-TEST TABLES

Table E-1 Paired-Samples T Test for HABD (n=20)

Source of Variation	T	DF	Sig of F
Pull	-6.163	19	.000

Table E-2 Paired-Samples T Test for ER (n=20)

Source of Variation	T	DF	Sig of F
Pull	-1.177	19	.254

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BIOGRAPHICAL SKETCH

Gary Michael "GM" Pugh was born in Jacksonville, Florida, in 1978. The oldest son of Bill and Carolyn Pugh, GM and his younger sibling were raised in Jacksonville Beach, Florida. He went to high school at Bishop Kenny in Jacksonville, Florida. GM was a member of the cross country and track teams in high school for all four years. After high school GM attended the University of North Florida, where he completed his Bachelor of Science in Health in 2001. GM was a collegiate scholar athlete for three years, running cross country and track. After changing his major from electrical engineering to athletic training, GM quit the cross country and track teams to become an athletic trainer. As a student athletic trainer at the University of North Florida, GM had the opportunity to work with a variety of teams at all levels, including division I women's basketball, arena II football, division II baseball, junior college men's and women's basketball and tennis, and a number of high school teams.

After graduation from the University of North Florida, GM entered the master's program in athletic training at the University of Florida. In his first year at the University of Florida, GM served as a graduate intern with the University of Florida Recreation and Intramural Department for the Athletic Training Sports Medicine Center, intramurals, and club sports. The following year he was the head athletic trainer at Santa Fe Community College for the men's and women's basketball, baseball, and softball teams. GM plans to pursue a career as an athletic trainer in collegiate athletics.