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An EMG Comparison of Muscle Recruitment Associated with the Wide Grip Pull-Up and the Lat Pull-Down Exercise

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AN EMG COMPARISON OF MUSCLE RECRUITMENT ASSOCIATED WITH THE WIDE GRIP PULL-UP AND THE LAT PULL-DOWN EXERCISE

by

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The purpose of this study was to describe and compare the prime mover muscles used in the wide grip pull-up and lat pull-down exercises. Ten Western Michigan University students performed the 2 exercises, using a resistance equal to their body weight for 3 sets of 3 repetitions, with 2 min rest between sets. The 2nd repetition of each set was analyzed for each exercise. Research variables included phases (concentric, coupling, and eccentric), exercises, trials, and muscles. The dependent variables were relative time to peak recruitment, peak recruitment, and phase time. Findings revealed that the concentric and eccentric phases were slower for the lat pull-down than the pull-up. The relative time to reach peak recruitment was shorter for the lat pull-down than for the pull-up. The magnitude of the peak EMG was the same for the pull-up and the lat pull-down during the concentric phase. During the eccentric phase, the magnitude of the peak EMG was different for the pull-up than for the lat pull-down for 4 of the 5 muscles studied.

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CHAPTER I

INTRODUCTION

Athletes spend much time and effort in various training activities for the purpose of improving performance. Training exercises used for this purpose often evolve by trial and error. Although knowledge based on experience is valuable, it remains the task of specialists to validate training exercises.

Few investigators have compared the physiological demands of upper body muscular strength development exercises. There are many ways to develop strength in the upper body. Almost any form of resistance exercise will stimulate some degree of strength gain. In the selection of exercises for the upper body musculature, the wide grip lat pull-down and wide grip pull-up are two exercises that would ensure comprehensive muscular development.

The musculature of the upper body adapts to the resistance that is imposed upon it. Both the wide grip lat pull-down and wide grip pull-up impose such a resistance. Throughout the execution of each exercise, the dynamic resistive torque imposed by the exercise device determines the amount of muscle recruitment that occurs. This recruitment is related to the resistive torque. The resistive torque will change throughout each exercise. The variable moment arms encountered through the range of motion for both exercises provide proportionally less resistive torque at weaker joint positions and proportionally more resistive torque at stronger joint positions. Therefore, the greatest resistance that can be lifted is associated with the weakest joint position for both exercises.

The control of the upper body musculature during strength-training exercises involves the sequential recruitment of muscles. The muscle recruitment pattern can be measured by electromyography (EMG). Both the wide grip pull-up and wide grip lat pull-down incorporate the same prime mover muscles of the shoulder girdle, shoulder joint, and elbow joint. This supposition is supported by the EMG data from previous studies (Ricci, Figura, Felici, & Marchetti, 1988; Willis, Signorile, Perry, Tremblay, & Kwiatkowski, 1994).

Statement of the Problem

The problem of this study was to investigate selected EMG parameters for the upper body musculature during two different strength-training exercises: (1) the wide grip pull-up and (2) the wide grip lat pull-down. Specifically, the researcher investigated EMG responses in five upper body muscles during the performance of the wide grip lat pull-down and wide grip pull-up. The five muscles were: (1) latissimus dorsi, (2) pectoralis major, (3) anterior deltoid, (4) trapezius, and (5) biceps brachii.

Purpose of the Study

The purpose of this study was to provide information for the improvement of training regimens for practitioners. Muscular development and strength-training programs are validated by research studies that investigate the technical aspects of specific training exercises. Specifically the investigator described and compared the prime mover muscles used in the wide grip pull-up and wide grip lat pull-down exercises. Both exercises are often utilized in strength-training programs. Controversy exists concerning whether these two exercises produce similar results. This study should help determine whether differences exist between the prime mover muscles used when the lifts are performed.

Delimitations

The following delimitations were established for this study:

1. The 10 subjects were Western Michigan University male students between the ages of 22 and 35 years.

2. The subjects performed two different exercises: (1) a wide grip lat pull-down and (2) a wide grip pull-up.

3. The subjects had no history of shoulder girdle, shoulder joint, or elbow joint injuries in the 6 months prior to participating in the study.

4. Only five muscles of the shoulder girdle, shoulder joint, and elbow joint were analyzed by surface electrode EMG: (1) latissimus dorsi, (2) trapezius, (3) anterior deltoid, (4) pectoralis major, and (5) biceps brachii.

5. The time to peak activity and recruitment order were the only dependent variables used in this study.

6. Three phases of motion were defined for each exercise: (1) concentric, (2) eccentric, and (3) coupling.

7. The study was performed in a laboratory setting.

Limitations

The study was limited by the following facts:

1. The subjects had varying levels of experience with each training exercise.

2. The subjects were not randomly selected.

3. The placement of electrodes from subject to subject was estimated as accurately as possible in relation to each anatomical landmark.

Assumptions

The basic assumptions of the research were as follows:

1. The subjects were properly warmed-up at the time the trials were performed.

2. The subjects performed to the best of their capabilities on all trials.

3. The electromyograph, camera, computer, and software were all operating properly.

Research Hypotheses

The study was conducted to test the following hypotheses:

1. The muscle recruitment order will be different for the different exercises (wide grip lat pull-down and wide grip pull-up).

2. The time to peak recruitment of the five muscles will be different for the two exercises.

3. The phase time for the concentric, eccentric, and coupling phases will be different for the two exercises.

Definition of Terms

The following definitions and terms are important to the understanding of this study:

1. Concentric phase: the muscle movement that occurs in the same direction as the change in joint angle, the mechanical work performed is positive (Komi, 1984).

2. Coupling phase: the period of time from the end of the concentric phase to the beginning of the eccentric phase.

3. Eccentric phase: the muscle movement that occurs in the direction opposite to the change in joint angle, the mechanical work is negative (Komi, 1984).

4. Electromyography: a technique to measure muscle activity that is noninvasive (Gray, 1974).

5. Prime mover muscles: major contributors to the desired motion.

6. Recruitment: the number of active motor units required to produce a specific gradation of a muscle's force (Burke, 1984).

7. Shoulder girdle: consists of two bones, the clavicle and scapula, to which 17 muscles of the upper extremity are attached (Gray, 1974).

8. Stabilizer muscles: muscles that stabilize one joint so that the desired movement can occur at an adjacent joint.

9. Wide grip lat pull-down: using an overhand grip (palms forward) with the bar grasped wider than shoulder width and the head aligned directly under the pulley, the bar is slowly pulled down to the chest and returned to the starting position (Schwarzenegger, 1985).

10. Wide grip pull-up: using an overhand grip (palms away) with the body completely extended (hanging), the body is raised until the chin clears the bar and then lowered to a full hang, as in the starting position; extraneous body movements (horizontal displacement or swaying) are

prohibited.

CHAPTER II

REVIEW OF LITERATURE

Introduction

It was evident from a number of studies over the past century, that muscle function has been of keen interest to the biomechanist and physiologist in the sport and fitness arena. According to Wilkie (1984), the need to relate muscular structure to its mechanical function has been apparent for centuries. The perfection of knowledge held in the realm of gross anatomy, the increased interest and understanding of the chemistry and physics of the muscular system, and the observations made of living muscle are areas that stimulate the interests of biomechanists and physiologists.

Strength and power performances are not only determined by the quantity and quality of muscle mass in an individual; it, is related also to the extent to which the muscle mass may be activated by a voluntary effort (Sale, 1984). The prime movers must be fully activated, synergists must simultaneously be appropriately activated and agonists must be appropriately inhibited. Strength and power training may change the coordination and recruitment of specific muscles because it is known that a neural adaptation can take place.

In movements, humans share common physical constraints in which the pattern of movement produced will depend on the goal of the movement (Sale, 1984). Human movement may be optimized by neural adaptation and may be determined at the mechanical level by muscular properties. By considering the goals of various training regimens and comparing these goals with movements, some insight may be gained in the area of upper body muscular strength and development.

Muscle Physiology

The skeletal muscles throughout the human body are activated by numerous impulses from two primary sources: (1) voluntary contractions and (2) involuntary contractions or reflexes. Voluntary contractions are those that involve muscle shortening, during which the muscles attempt to overcome external forces. If there are additional forces that the muscle is unable to actively resist, the muscle lengthens involuntarily.

The skeletal muscle functions in a systematic way when actin and myosin myofilaments within a sarcomere of a single muscle fiber slide past one another to create a shortening of the muscle. The shortening consequently pulls the insertion of the muscle closer to its origin (place of attachment) and facilitates a skeletal movement.

Mechanical Characteristics

The mechanical characteristics of muscle are best represented by a model in three dimensions: (1) a contractile component (CC), (2) a parallel elastic component (PEC), and (3) a series elastic component (SEC) interact to produce a force output (McCollum, 1994). The CC is typically the focal point of motor control of the concentric phase of muscle movement. The PEC and the SEC play an integral role in providing support and integrity to the individual fibers when a muscle is lengthened (eccentric phase). During the lengthening phase of muscular contraction, energy is stored in the form of kinetic energy.

Movement Phases

The term contraction is used when speaking of strength training. A contraction may be understood as the state of muscle when a number of actin-myosin crossbridges generate tension (Komi, 1984). Muscle contractions can be classified into three types: (1) concentric, the muscle shortens; (2) eccentric, the muscle lengthens; and (3) isometric, there is no change in muscle length. These contractions are often used to define the phases of a movement.

Concentric Contraction

In a concentric contraction, the muscle movement is in the same direction as the change in joint angle, and mechanical work performed is positive. The muscle shortens and the net muscle moment (torque) is in the same direction as the change in joint angle. To generate a particular force in the concentric phase requires much more motor unit activation than to generate the same force in the eccentric contraction (Komi, 1984).

Eccentric Contraction

It is in the eccentric mode that the force and power capacities of the skeletal muscle are greatest (Komi, 1984). In an eccentric contraction, the movement is in the opposite direction to the change in joint angle, and the mechanical work is negative. The greater force output in an eccentric contraction was demonstrated by Edman, Elzinga, and Noble (1978), who showed that the force of an isolated sarcomere increased when the fibril was being stretched after the isometric maximum was reached with a constant stimulation. It has been suggested that when human skeletal muscle is stretched after the maximum force has been reached, EMG activity is also increased (Burhle, Schmidtbleicher, & Ressel, 1983). To attain a certain force level requires much less motor unit activation in eccentric than in concentric contractions. According to Asmussen (1952), the findings indicated that input-output relationships of the two exercise types are very different.

Isometric Contraction

A contraction is classified as isometric when no motion occurs in the joint angle or the attachments (insertions) that act to produce specific joint motions. Thus, the mechanical work of an isometric contraction is 0 (Komi, 1984). Isometric contractions are common to the postural muscles of the body and assist with proper alignment and static stances of strength training exercises.

Analysis of Exercises

The shoulder represents the initial linkage in the mechanical chain of levers that extend from the shoulder to the fingertips. The glenohumeral joint connects the arm to the thorax (Zuckerman & Matsen, 1989). The combination and coordination of the movements which occur about the three distinct articulations: glenohumeral, acromioclavicular, and sternoclavicular allow the arm to be positioned in space for efficient function. The result of these articulations is a range of motion that exceeds the range of any other joint in the human body (Zuckerman & Matsen, 1989).

Analysis of the Pull-Up Movement

Thompson (1965) separated the pull-up into two movements for analysis: (1) movement from the hanging position to the chinning position, the concentric phase; and (2) movement from the chinning position to the hanging position, the eccentric phase. Execution of a pull-up displaces the body's mass upward, positive work, and then displaces body mass downward, negative work.

The pull-up motion uses a forward grip in which the hands are pronated, palms positioned away from the face. The width of the grip is a variable that must be considered when analyzing the pull-up motion. The distance between the hands causes variation in the recruitment patterns of the muscles used to execute the pull-up motion.

During the concentric phase, the wrist and elbow flex as the glenohumeral joint extends. Elbow joint flexion during the concentric phase causes the following muscles to create positive work: biceps brachii, brachialis, brachioradialis, and pronator teres. Glenohumeral extension during the concentric phase causes the following muscles to contract causing positive work to occur: latissimus dorsi, teres major, posterior deltoid, pronator teres, and long head of biceps brachii. Also, during this phase the glenohumeral adduction and sternoclavicular depression cause positive work to occur in the lower trapezius and pectoralis minor.

The muscular forces involved in the initial thrust of the body mass in the pull-up varies among muscles (Ricci et al., 1988). In the research of Ricci et al., the data indicated the initial output of force which was essential to impart momentum to the body mass. The initial increase in acceleration of the body mass was necessary for the successful execution of the pull-up.

Analysis of the Pull-Down Movement

The pull-down motion occurs in a sitting position. The shoulder and arms extend upward toward the bar, which is attached to the cable system. The lower portion of the body is restrained by the t-bar, which eliminates movement of legs or lower extremity upward when downward motion occurs in the concentric phase.

The two motions associated with the lat pull-down exercise occur about the shoulder articulations. The extended position of the arms, in a near vertical position, allows placement of hands on the bar. The extension of the arms to: (a) the downward flexion and displacement of the bar to the chest, the concentric phase; and (b) the upward displacement of the bar along with the shoulder and arms, the eccentric phase; differentiate the phases of the pull-down exercise. The movement of the bar downward, positive work, occurs first, and the negative work, resisting the weight of the pulley (cable) system against gravity follows the downward motion.

The pull-down motion uses a forward grip in which the hands are pronated, palms positioned away from the face. The width of the grip is a variable that must also be considered when analyzing the pull-down motion.

During the concentric phase, the wrist and elbow flex as the bar is moved downward. Elbow joint flexion during the concentric phase causes the following muscles to create positive work: biceps brachii, brachialis, brachioradialis, and pronator teres. Glenohumeral extension during the concentric phase causes the following muscles to contract, causing positive work to occur: latissimus dorsi, teres major, posterior deltoid, pronator teres, and biceps brachii.

Muscle Function

Muscles of the shoulder girdle are of great importance in the pull-up movement and primarily affect the scapulae. In order to predict the muscle function anatomically, muscles are described by the origin (proximal attachment), insertion (distal attachment), and the action produced at the specific joint. To classify the function of muscles, the terms agonist, prime mover, antagonist, synergist, assistant mover, neutralizer, fixator, and stabilizer are applied to clearly identify the role of the muscle or group of muscles. To clearly determine if a muscle is or is not contracting, EMG or palpation is used.

A muscle or group of muscles, which by their contraction are considered to be the principle mover producing a joint movement or maintaining correct form, are referred to as agonists or prime movers. The prime mover always contracts actively to produce a concentric, isometric, or eccentric contraction (Lehmkuhl & Smith, 1983).

Biceps Brachii

The biceps brachii is a prime mover in both the pull-up and lat pull-down exercises. This long fusiform muscle occupies the entire anterior surface of the arm. The long head arises from the upper region of the glenoid cavity with the tendon arching over the head of the humerus. The biceps brachii's elongated muscular belly is unique to the anatomy and inserts into the back part of the radius. The shortening of the biceps brachii in a concentric contraction causes the simultaneous flexion of the elbow. By means of the two-joint mechanism (elbow and shoulder), this muscle maintains favorable tension while flexing the elbow through a large range. The combination of the elbow flexion and shoulder movement is used in pulling activities and contributes to the overall flexion occurring in the elbow (Lehmkuhl & Smith, 1983).

Latissimus Dorsi

The latissimus dorsi is a broad flat muscle that covers the lumbar and the lower half of the dorsal region on the back. The muscle gradually narrows and inserts on the humerus. It originates from the spinous processes of the six inferior vertebrae. It attaches to the spines of the lumbar and sacral vertebrae and to the supraspinous ligament, with the upper portion covered by the trapezius. The latissimus dorsi, when acting on the humerus, inwardly rotates it, draws it backward, and adducts it (Gray, 1974). These are the motions occurring during the concentric phase of the lat pull-down and pull-up exercises.

Anterior Deltoid

The deltoid is the large, thick, triangular muscle that fully encompasses the shoulder, giving it a rounded outline. The anterior portion, when assisted by the pectoralis major, draws the arm forward.

Trapezius

The trapezius is the broad, flat, triangular muscle, found immediately beneath the skin, that covers the upper and back part of the neck and shoulder. It arises from the external occipital protuberance of the occipital bone, from the spinous processes of the seventh cervical vertebrae, and from all the dorsal vertebrae. From the origin, fibers proceed downward and outward. The trapezius inserts onto the outer part of the posterior border of the clavicle; the middle fibers insert into the inner margin of the acromion process and into the posterior border of the scapula, and other fibers insert at the spine.

The trapezius plays a critical role in scapular positioning during flexion or abduction of the humerus and is significant in the analysis of the pull-up motion (Grabiner, 1989). The whole trapezius retracts the scapula and holds the shoulder back. The middle and lower fibers of the muscle rotate the scapula, causing elevation of the acromion process.

Pectoralis Major

The broad, thick musculature of the pectoralis major is positioned at the upper and front part of the chest. The origin occurs on the anterior surface, medial half, of the clavicle, and the fibers from this extensive origin converge toward the insertion. The anterior surface of the pectoralis major overlaps the biceps and deltoid. The pectoralis major serves as a prime mover in exercises in which the hand is in contact with an object in front of the body, as with the pull-up and lat pull-down. The pectoralis major exerts its pull on the humerus and significantly contributes to elbow extension. The contraction of the pectoralis major extends the elbow and stabilizes it for light pushing activities or for the eccentric phase of the exercises described in this study.

Muscle Recruitment

It is logical that those muscles that best serve a movement with the least amount of energy expended would be selected by the nervous system when an exercise is performed. For any movement combination, the best selection of muscles is achieved only by highly skilled individuals. Unskilled individuals are less likely to select the same set of muscles. The result is wasted energy because muscles not necessary for movement were recruited. Perfection of a skill results in less fatigue and smoother movements.

The number of muscles and motor units involved in a given exercise is also determined by the level of effort that must take place (Green, 1984). The greater the resistance encountered, the greater the recruitment. Increased resistance affects muscles attached to joint(s) where the movement(s) take place. The increased level of resistance or weight results in muscle activity further away from the scene of action in most exercises.

Electromyography (EMG) allows practitioners to examine a muscle's activity. Recording electrodes are placed on the skin overlying a muscle in order to monitor the changes in the electric field produced by the production of muscle action potentials (Lehmkuhl & Smith, 1983).

Lehmkuhl and Smith (1983) reported that Einthoven developed a string galvanometer to record the action potentials generated by cardiac muscle. They reported that Adrian and Bronk's exploration of this technique in 1929 led to the development of a device for measuring the electrical response of skeletal muscle. The gathering of information by this means, with surface, needle, or wire electrodes, is called electromyography. Each pair of electrodes connects to a channel on a recording amplifier. The eight- channel amplifier allows the simultaneous monitoring of several muscles. The sequence of activation and relaxation can be monitored and evaluated throughout a range of motion or during an isometric state, in which no motion occurs.

Firing Patterns

Orderly patterns of recruitment occur in voluntary contractions, in which the lowest threshold units ordinarily show the smallest EMG potential amplitudes (Burke, 1984). Recruitment orders are defined within a functional pool of motor units. Burke indicated that recruitment probably occurred according to the size principle. Some movements may require patterns of motor unit activity that are inconsistent with minimal metabolic cost.

Peak EMG

The power potential of a range of muscles can be compared by normalizing the mass of the muscle. The sarcomere arrangement with respect to one another in turn is a property of the force and peak EMG recorded. The muscle's force potential or recruitment in an exercise is proportional to the number of active sarcomeres in parallel.

Theoretically, peak power per unit mass of muscle should be similar for all muscle groups, assuming the muscle groups have similar biochemical properties and have similar architectural features. The fiber lengths do differ significantly. This variable makes it difficult to relate the peak power (EMG) of a muscle group.

CHAPTER III

METHODS AND PROCEDURES

Strength is often used by coaches and trainers as an indicator of athletic ability. In many sports, strength is a factor in the ability of the athlete to perform. Therefore, a good understanding of muscle activity in strength-training exercises is needed. In this study, selected EMG parameters were compared for two strength-training exercises: (1) the wide grip pull-up and (2) the wide grip lat pull-down. The investigator used surface EMG synchronized with video to analyze the EMG in relation to the phases of motion associated with the two techniques. The following topics are covered in this chapter: (a) subjects, (b) equipment, (c) research design, (d) data collection procedures, and (e) statistical analysis.

Subjects

The subjects for this study were 10 male student volunteers who attended Western Michigan University. The ages of the subjects were 22 to 35 years. Each subject signed an informed consent form (see Appendix A). Approval to conduct this study was required by Western Michigan University's Human Subject Institutional Review Board (see Appendix B).

The subjects had no history of shoulder girdle, shoulder joint, or elbow joint injuries in the 6 months prior to participating in the study. The subjects performed two different exercises: (1) a wide grip lat pull-down and (2) a wide grip pull-up. Only subjects who were capable of performing both exercises, using a resistance equal to their body weight for 3 trials of 3 repetitions, with 2 min of rest between trials, were selected for participation.

Equipment

Bipolar surface electrodes, Medi trace, 1 cm, silver-silver chloride (ECE 1801 Graphic controls, Buffalo, NY) were placed on each subject. The EMG electrodes were linked to a Myosystem 2000 EMG data collection system (Noraxan, Phoenix, AZ) integrated with the analog-digital board used by Peak Motion Analysis hardware-software package (Peak Performance Technologies, Inc., Englewood, CO).

Each subject executed the pull-ups on a wide grip pull-up station (Badger Magnum, Inc., Milwaukee, WI). The lat pull-downs were executed on a lat pull-down machine, supplied by Fitness Things West, Inc. (Grand Rapids, MI). The VCR utilized to digitize was a Panasonic A67350P with a Sony PMV-1341 monitor. Data manipulation and analysis was accomplished on an IBM-compatible Tenex, Model 486 DX-2 with Peak 5V 1.2 software. The integrated EMG signal was filtered using a Butterworth data-smoothing procedure (6 Hz). The filtered EMG data were then transferred to the Myosoft EMG analysis on the Tenex 486 DX-2.

Kinematics of the shoulder joint, shoulder girdle, and elbow joint were assessed through the use of a Panasonic WV-D5100HS camera (Panasonic Broadcast & Television Systems Company, Secaucus, NJ) set at a frequency of 60 Hz. Fuji S-VHS ST-120N videotape was used. The video data were synchronized to the EMG data through an event synchronization unit (ESU) (Peak Technologies, Inc., Englewood, CO).

Research Design

This investigation was comprised of three research variables: (1) upper body strength-training exercises, (2) prime mover muscles, and (3) trials. Both the wide grip pull-up and wide grip lat pull-down strength-training exercises were analyzed for each subject. The EMG responses in the following five muscles were measured during the execution of both exercises: (1) latissimus dorsi, (2) trapezius, (3) anterior delotoid, (4) pectoralis major, and (5) biceps brachii. Each subject completed three trials for each training exercise. The dependent variables for the investigation were time to peak recruitment and recruitment order. The research design was repeated measures. Subjects repeated both exercises, and the five muscles were analyzed for both exercises. The exercises were presented to each subject in a random order.

Data Collection Procedures

Data collection took place in the Exercise Physiology and Biomechanics Laboratories in the Student Recreation Center at Western Michigan University on December 1, 1995. The subjects removed their shirts to facilitate the placement of electrodes. Each subject was capable of performing a trial of three consecutive repetitions using a wide grip and forward grip for each exercise. Three trials of three repetitions were executed for each exercise. The second repetition of each trial was analyzed. The subjects were allowed a 2-min rest between trials. The rest period between exercises was 4 min. Procedures the subjects followed were as follows:

1. Subjects were given a 5-min warm-up prior to executing the lat pull-down and pull-up. The warm-up consisted of the following: (a) a 5-min ride on a stationary cycle and (b) specific static stretches for the upper body (anterior shoulder stretch and posterior shoulder stretch).

2. Subjects performed three trials for the two exercises. The three trials consisted of three repetitions, a total of 18 repetitions for the day.

3. For each exercise, both hands were placed with palms facing away from the body (forward grip).

4. For the wide grip lat pull-down, the hands grasped the bar so that the distance between them was wider than shoulder width (35 degree

angle), and the head was aligned directly under the pulley. The bar was pulled down to the chest and returned to the starting position.

5. For the wide grip pull-up, the body was extended in a hanging position. The body was raised until the chin cleared the bar. The chin was held over the bar for a brief period of time, then the body was lowered back to the starting position.

6. The rest period between trials for each exercise was 2 min.

7. For each trial, the researcher signaled when to begin the movement.

Electromyography Procedures

Bipolar surface electrodes (Medi trace, 1 cm, silver-silver chloride) were placed at a point half the distance between the center of the innervation zone (motor point) and the distal tendon of the muscle. The electrode detection surfaces were spaced approximately 1 cm apart, parallel with the muscle fibers, and near the midline of the muscle. All placement sites were carefully identified, shaved, and prepped prior to electrode placement. Resistance levels were checked with a multi-meter. Successful placement resulted in an electrode resistance level of less than 10 kohms.

The EMG electrodes were connected to a Myosystem 2000 EMG unit that was interfaced with the Peak Motion Analysis analog-digital module. The system provided integrated EMG signals that were matched to the video.

The integrated EMG signal was filtered using a Butterworth data smoothing procedure (6 Hz). The video matched EMG data files were analyzed by the Myosoft EMG software. The EMG response for each muscle during the phases of the movement were analyzed to determine the point of peak recruitment and the recruitment order.

Filming Procedures

Kinematics of the shoulder girdle, shoulder joint, and elbow joint were assessed through the use of a Panasonic WV-D5100HS camera set at a frequency of 60 Hz. The video data were synchronized to the EMG data through an event synchronization unit (ESU: Peak Technologies, Inc.). The ESU unit was equipped with a switch to electrically trigger a light-emitting diode (LED). This electrical signal was simultaneously recorded on the video and the EMG outputs. Thus, the data from film were matched to the EMG data at a specific point in time.

The ESU controlled the EMG data collection. The LED was triggered by a hand-held switch. EMG data were set to begin recording 1.0 s prior to the LED signal and to end recording 4.0 s following the signal. The EMG data were collected at a rate of 480 Hz. Thus, there were eight EMG data points per video frame.

A two-dimensional video analysis of each exercise was used to help separate the trial into three phases. The camera was mounted on a tripod at a distance of 45 m from the subject. The video camera was set so that the focal length of the lens was perpendicular to the sagittal plane, right side, of the subject. The camera lens was 1 m above the ground. Subjects performed in front of a contrasting background, so that bony landmarks could be seen and digitized.

A meter stick was used to scale digitized data to a meaningful linear measure during the digitizing process. The motion of the second repetition in each trial for both the pull-up and lat pull-down was analyzed. The data were collected during one session in 1 day.

Video Digitizing Analysis

After data collection occurred, the digitizing process was initiated. The videotape was projected onto the screen to digitize. Single frames were digitized in order to obtain the landmark anatomical trajectories. It was necessary to digitize different anatomical points for each exercise. For the pull-up, the anatomical points were wrist, elbow, and shoulder. The pull-down utilized the same anatomical points plus an additional point, the pull-down bar. The importance of using the bar as a point was to identify the point at which the concentric phase, downward motion, ended. Data defining the beginning and ending of each phase was recorded on data collection sheets (Appendix C).

The motion was analyzed for the second repetition of each trial for both exercises. The analysis began with the initiation of the concentric phase and ended when the eccentric phase was completed.

The phases for the lat pull-down are defined below:

1. Concentric Phase: The concentric phase began with one or both of the following: (1) vertical downward movement of the bar and (2) shoulder girdle depression. This phase ended when the bar's vertical downward displacement ceased.

2. Eccentric Phase: The eccentric phase began with one or both of the following: (1) movement of the bar and (2) shoulder girdle elevation. This phase ended when the bar's vertical upward displacement ceased.

3. Coupling Phase: The coupling phase represented the time period that may or may not occur between the concentric and eccentric phases. It represented a period of time when no motion existed in the bar, shoulder girdle, shoulder joint, or elbow joint.

The phases for the pull-up are defined below:

1. Concentric Phase: The concentric phase began with the first signs of motion in one of the following: (a) the shoulder girdle, (b) shoulder joint, or (c) elbow joint. This phase ended when the angular displacement at the shoulder girdle, shoulder joint, and elbow joint ceased.

2. Eccentric Phase: The eccentric phase began with the first signs of motion in one of the following: (a) the shoulder girdle, (b) shoulder joint,

and (c) elbow joint. This phase ended when the angular displacement of the shoulder girdle, shoulder joint, and elbow joint ceased.

3. Coupling Phase: The coupling phase represented the time that may or may not occur between the concentric and eccentric phases. It represented a period of time when no motion existed in the shoulder girdle, shoulder joint, or elbow joint.

Statistical Analysis

Data were analyzed by descriptive statistics and by inferential statistics. A randomized block analysis of variance (ANOVA) design with three main effects was computed for the dependent variable, time to peak recruitment. The three main effects were: (1) strength training exercises, (2) trials, and (3) muscles. The level of significance used to interpret the ANOVAs was set at .05. Descriptive statistics, means, standard deviations, and percentages, were used to identify the phase time and point within the phase at which peak recruitment occurred.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The problem of this study was to investigate selected EMG parameters for the upper body musculature during two different strength training exercises: (1) the wide grip pull-up and (2) the wide grip lat pull-down. Specifically, the researcher investigated EMG responses in five upper body muscles during both the wide grip lat pull-down and the wide grip pull-up. This chapter will address: (a) the overall time spent in each phase (concentric, coupling, and eccentric) during the exercises, (b) relative time to peak EMG recruitment for the five muscles, (c) order of peak recruitment of the five muscles during each exercise, and (d) magnitude of peak recruitment during both the concentric and eccentric phases for both exercises. The level of significance used to interpret the results of this investigation was .05.

Results

Characteristics of Subjects

The 10 male subjects were student volunteers who attended

Western Michigan University. The subjects ranged in age from 22 to 35 years, with a mean of 25.1 years. The mean weight for the subjects was 175.4 lb., with a range of 140 to 212 lb. Each subject was capable of performing both exercises, the wide grip pull-up, and the wide grip lat pull-down, using a resistance equal to his body weight for 3 sets of 3 repetitions, with 1 min rest between sets.

All 10 subjects executed all trials of both exercises with proper form. The second repetition of each set was analyzed for each exercise.

Phase Time

The video was synchronized with the EMG data to determine the beginning and ending points of the phases of the exercises: (a) concentric, (b) coupling, and (c) eccentric. The mean time spent in each phase of the lat pull-down was 1082.22 ms for the concentric phase and 1348.70 ms for the eccentric phase. The mean pull-up times for the concentric and eccentric phases were 870.98 ms and 1083.10 ms, respectively.

The lat pull-down's concentric and eccentric mean phase times were greater than the respective phase times for the pull-up. In the lat pull-down, the motion occurring about the shoulder and elbow was the result of pulling (concentric phase) or resisting (eccentric phase) the bar.

A coupling phase was present in each exercise. The mean coupling phase time for the lat pull-down and pull-up were 53.88 ms and 55.12 ms, respectively. The summary for phase time across trials is reported in Table 1.

ANOVAs were calculated to determine if the concentric and eccentric phase times were different among the 3 trials of the two exercises. The ANOVA consisted of two factors: (1) two exercises, lat pull-down and pull-up; and (2) three trials for each exercise. The results of these ANOVAs are reported in Table 2.

The following results were deemed important:

1. A significant difference was found between the two exercises for the concentric phase time, $F(1, 54) = 13.14$, $p = .00$.

2. No significant difference was found between the trials for the concentric phase time, $F(2, 54) = 0.30$, $p = .74$.

3. No significant difference was found for the first-order interaction effect, exercises by trials, $F(2, 54) = 0.16$, $p = .86$.

4. A significant difference was found between the two exercises for the eccentric phase times, $F(1, 54) = 17.96$, $p = .00$.

5. No significant difference was found between the trials for the eccentric phase times, $F(2, 54) = 0.28$, $p = .76$.

6. No significant difference was found for the first-order interaction effect, exercises by trials, $F(2, 54) = 0.07$, $p = .76$.

Table 1

Means and Standard Deviations for the Phase Time for the Lat Pull-Down and Pull-Up Exercises

	Trials			
Phase	1	2	3	Marginal
Concentric				
Lat pull-down	1131.70	1074.98	1039.99	1082.22
	319.96	286.66	177.48	261.37
Pull-up	884.66	85.66	871.63	870.98
	162.33	152.99	199.06	171.46
Coupling				
Lat pull-down	59.96	58.34	43.34	53.88
	36.94	56.27	31.62	41.61
Pull-up	55.34	46.65	63.37	55.12
	72.09	23.31	49.53	48.31
Eccentric				
Lat pull-down	1367.71	1364.64	1313.76	1348.70
	252.59	167.74	181.09	200.47
Pull-up	1122.50	1065.21	1061.59	1083.10
	287.06	294.22	244.46	275.25

Note. The standard deviation is listed below each mean.

Table 2

ANOVA Summary for Phase Time During the Concentric and Eccentric Phases

Source	SS	df	MS	F	p
Concentric					
Exercise (E)	669335.12	1	669335.12	13.14	.00
Trials (T)	30914.57	2	15457.29	.30	.74
E X T	15852.29	2	7926.15	.16	.86
Residual	2748855.27	54	50904.73		
Eccentric					
Exercise (E)	1058177.15	1	1058177.15	17.96	.00
Trials (T)	33010.68	2	16505.34	.28	.76
E X T	8702.94	2	4351.47	.07	.76
Residual	3181198.66	54	58911.09		

Order of Recruitment

The relative time to peak recruitment as a percentage of phase time was calculated for the five muscles for the lat pull-down and pull-up. The mean relative time was calculated across 3 trials for both the concentric and eccentric phases. Recruitment order relative to the percentage of phase time was not the same in the concentric and eccentric phases. The results of the mean order of relative time to peak recruitment for the concentric and eccentric phases are presented in Table 3.

The mean order of relative percentage of time to peak recruitment in the concentric phase of the lat pull-down was 35.02%, 57.02%, 64.11%, 64.18%, and 85.44%, for the latissimus dorsi, anterior deltoid, pectoralis major, bicep brachii, and tricep, respectively. The mean order of relative time to peak recruitment for the concentric phase of the pull-up was 47.17%, 70.63%, 74.29%, 82.15%, and 94.59%, for the latissimus dorsi, pectoralis major, bicep brachii, anterior deltoid, and tricep, respectively.

The mean order of relative percentage of time to peak recruitment in the eccentric phase of the lat pull-down was 53.85%, 59.80%, 62.18%, 67.33%, and 74.99%, for the bicep brachii, anterior deltoid, tricep, pectoralis major, and latissimus dorsi, respectively. The mean order of relative time to peak recruitment for the eccentric phase of the pull-up was 68.10%, 36.91%, 42.12%, 45.29%, and 68.10%, for the tricep, anterior deltoid, bicep brachii, pectoralis major, and latissimus dorsi, respectively.

Relative Time to Peak EMG

ANOVAs were calculated to determine if the relative time to peak EMG recruitment was different for the concentric and eccentric phases across the 3 trials of the two exercises. The ANOVA consisted of three factors: (1) two exercises, lat pull-down and pull-up; (2) three trials for each

Table 3

Order of Peak EMG Recruitment as a Percentage of the Phase Time

	Lat		Pull-Up	
Phase	Muscle	% of Phase	Muscle	% of Phase
Concentric				
	Lat	35.02	Lat	47.17
	Ant. Delt.	57.02	Pec	70.63
	Pec	64.11	Bicep	74.29
	Bicep	64.18	Ant. Delt.	82.15
	Tricep	85.44	Tricep	94.59
Eccentric				
	Bicep	53.85	Tricep	68.10
	Ant. Delt.	59.80	Ant. Delt.	36.91
	Tricep	62.18	Bicep	42.12
	Pec	67.33	Pec	45.29
	Lat	74.99	Lat	68.10

Note. Lat = Latissimus dorsi, Ant. Delt. = Anterior deltoid, Pec = Pectoralis major, and Bicep = Bicep brachii.

exercise; and (3) the five muscles.

Concentric Phase

The results of this ANOVA are reported in Table 4 for the concentric phase. The following results were deemed important:

1. A significant difference was found between the two exercises for the concentric phase for relative time to peak EMG recruitment, $F(1, 192) = 11.12$, $p = .00$.

2. No significant difference was found among the trials for the concentric phases for relative time to peak EMG recruitment, $F(2, 192) = 0.51$, $p = .61$.

3. A significant difference was found among the muscles for the concentric phase of the exercises for relative time to peak EMG, $F(4, 192) = 27.41$, $p = .00$.

4. No significant difference was found for the first-order interaction effect, exercises by trials, $F(2, 192) = 0.27$, $p = .76$.

5. No significant difference was found for the first-order interaction effect, muscles by exercises, $F(4, 192) = 1.20$, $p = .31$.

6. No significant difference was found for the first-order interaction effect, muscles by trials, $F(8, 192) = .72$, $p = .67$.

7. No significant difference was found for the second-order interaction effect, muscles by exercises by trials, $F(8, 192) = .17$, $p = .99$.

Table 4

ANOVA Summary for Relative Time to Peak Recruitment
During the Concentric Phase

Source	SS	df	MS	F	p
Exercise (E)	1.07	1	1.07	11.12	.00
Trials (T)	0.98	2	0.05	0.51	.61
E X T	0.05	2	0.03	0.27	.76
Muscles (M)	6.51	4	1.64	27.41	.00
M X E	0.29	4	0.07	1.20	.31
M X T	0.35	8	0.43	0.72	.67
M X E X T	0.08	8	0.01	0.17	.99
Residual	11.45	192	0.06		

Eccentric Phase

An ANOVA was calculated to determine if the time to peak EMG recruitment was different for the eccentric phase across the 3 trials of the two exercises. The results of this ANOVA are reported in Table 5. The following results were deemed important:

1. A significant difference was found between the two exercises for the eccentric phase for relative time to peak EMG recruitment, $F(1, 192)$ =

Table 5

ANOVA Summary for Relative Time to Peak Recruitment During the Eccentric Phase

Source	SS	df	MS	F	p
Exercise (E)	2.35	1	2.35	12.32	.00
Trials (T)	0.17	2	0.09	0.45	.64
E X T	0.58	2	0.29	1.53	.64
Muscles (M)	2.30	4	0.57	7.91	.00
M X E	0.46	4	0.11	1.57	.18
M X T	0.59	8	0.07	1.02	.42
M X E X T	0.53	8	0.07	0.91	.51
Residual	13.93	192	0.07		

12.32, $p = .00$.

2. No significant difference was found among the trials for the eccentric phase for relative time to peak EMG recruitment, $F(2, 192) = 0.45$, $p = .64$.

3. A significant difference was found among the muscles for the eccentric phase of the exercises for relative time to peak EMG, $F(4, 192) = 7.91$, $p = .00$.

4. No significant difference was found for the first-order interaction

effect, exercises by trials, $F(2, 192) = 1.53$, $p = .64$.

5. No significant difference was found for the first-order interaction effect, muscles by exercises, $F(4, 192) = 1.57$, $p = .18$.

6. No significant difference was found for the first-order interaction effect, muscles by trials, $F(8, 192) = 1.02$, $p = .42$.

7. No significant difference was found for the second-order interaction effect, muscles by exercises by trials, $F(8, 192) = 0.91$, $p = .51$.

Peak EMG

ANOVAs were calculated to determine if the magnitude of peak EMG across the phases were different between the two exercises, the lat pull-down and pull-up. The ANOVA consisted of three factors: (1) two exercises, lat pull-down and pull-up; (2) three trials for each exercise; and (3) the five muscles.

Concentric Phase

The results of the ANOVA for the concentric phase are reported in Table 6. The following results were deemed important:

1. No significant difference was found between the two exercises for the concentric phase for magnitude of peak EMG, $F(1, 216) = 0.41$, $p = .53$.

2. No significant difference was found among the trials for the concentric phases for magnitude of peak EMG among trials, $F(2, 216) =$

Table 6

ANOVA Summary for Magnitude of Peak EMG
During the Concentric Phase

Source	SS	MS	df	F	p
Exercise (E)	116584.65	116584.65	1	0.41	.53
Trials (T)	11729.33	5684.66	2	0.02	.98
E X T	72406.09	36203.04	2	0.13	.88
Muscles (M)	69523682.45	417380920.61	4	177.92	.00
M X E	99766.25	24941.56	4	0.26	.91
M X T	185657.27	23082.16	8	0.24	.99
M X E X T	325114.91	40639.36	8	0.42	.91
Residual			216		

0.02, $p = .98$.

3. A significant difference was found between the muscles for the concentric phase of the exercises for magnitude of peak EMG, $F(4, 216) = 177.92$, $p = .00$. The means for the lat pull-down were 636.10 mv, 638.50 mv, 135.33 mv, 1572.60 mv, and 404.60 mv for the latissimus dorsi, tricep, anterior deltoid, bicep brachii, and pectoralis major, respectively. The means for the pull-up were 567.33 mv, 553.67 mv, 106.70 mv, 1537.00 mv, and 425.20 mv for the latissimus dorsi, tricep, anterior deltoid, bicep

brachii, and pectoralis major, respectively. A summary of descriptive data for peak recruitment is in Table 7.

4. No significant difference was found for the first-order interaction effect, exercises by trials, $F(2, 216) = 0.13$, $p = .88$.

5. No significant difference was found for the first-order interaction effect, muscles by exercises, $F(4, 216) = 0.26$, $p = .91$.

6. No significant difference was found for the first-order interaction effect, muscles by trials, $F(8, 216) = 0.24$, $p = .99$.

7. No significant difference was found for the second-order interaction effect, muscles by exercises by trials, $F(8, 216) = 0.42$, $p = .91$.

Eccentric Phase

The results of the ANOVA for the eccentric phase are reported in Table 8. The following results were deemed important:

1. A significant difference was found between the two exercises for the eccentric phase for magnitude of peak EMG, $F(1, 216) = 5.00$, $p = .03$.

2. No significant difference was found among the trials for the eccentric phase for magnitude of peak EMG, $F(2, 216) = 0.51$, $p = .60$.

3. A significant difference was found among the muscles for the eccentric phase of the exercises for magnitude of peak EMG, $F(4, 216) = 90.64$, $p = .00$. The means for the lat pull-down were 506.37 mv, 218.53 mv, 75.10 mv, 614.33 mv, and 207.40 mv for the latissimus dorsi, tricep,

Table 7

Means Across Trials for the Magnitude of Peak Recruitment for the Concentric and Eccentric Phases of the Lat Pull-Down and Pull-Up Exercises

	Lat				Pull-Up			
	Trials				Trials			
Muscle	1	2	3	Marginal	1	2	3	Marginal
Concentric								
Lat	654.90	609.90	643.50	636.10	587.40	544.30	569.70	567.33
Tricep	701.20	615.10	599.20	638.50	534.00	537.20	589.80	553.67
Ant. Delt.	88.20	81.70	236.10	135.33	104.70	106.20	109.20	106.70
Bicep	1630.90	1591.20	1495.70	1572.60	1412.90	1618.30	1579.80	1537.00
Pec	404.20	410.10	399.50	404.60	423.60	410.20	441.80	425.20

Table 7--Continued

	Lat				Pull-Up			
	Trials				Trials			
Muscle	1	2	3	Marginal	1	2	3	Marginal
Lat	583.20	442.10	493.80	506.37	565.40	482.30	460.50	502.73
Tricep	277.90	197.70	180.00	218.53	300.70	309.50	194.70	268.30
Ant. Delt.	61.70	66.40	97.20	75.10	125.60	80.60	87.60	97.93
Bicep	639.90	588.40	614.70	614.33	863.00	866.70	942.60	890.77
Pec	207.00	198.50	216.70	207.40	350.80	307.80	265.80	308.10

Table 8

ANOVA Summary for Magnitude of Peak EMG
During the Eccentric Phase

Source	SS	MS	df	F	p
Exercise (E)	597104.85	597104.85	1	5.00	.03
Trials (T)	122443.52	61221.76	2	0.51	.60
E X T	21172.67	10586.33	2	0.09	.92
Muscles (M)	16405515.52	4101378.88	4	90.64	.00
M X E	746503.28	186625.82	4	4.12	.00
M X T	178854.08	22356.76	8	0.49	.86
M X E X T	87382.20	10922.78	8	0.24	.98
Residual			216		

anterior deltoid, bicep brachii, and pectoralis major, respectively. The means for the pull-up were 502.73 mv, 268.30 mv, 97.93 mv, 890.77 mv, and 308.10 mv for the latissimus dorsi, tricep, anterior deltoid, bicep brachii, and pectoralis major, respectively.

4. No significant difference was found for the first-order interaction effect, exercises by trials, $F(2, 216) = 0.09$, $p = .92$.

5. A significant difference was found for the first-order interaction effect, muscles by exercises, $F(4, 216) = 4.12$, $p = .00$.

6. No significant difference was found for the first-order interaction effect, muscles by trials, $F(8, 216) = 0.49$, $p = .86$.

7. No significant difference was found for the second-order interaction effect, muscles by exercises by trials, $F(8, 216) = 0.24$, $p = 98$.

Discussion

Phase Time

The phase time among trials for the 10 subjects was consistent. The phase time consistency indicated that the subjects were familiar with performing the lat pull-down and pull-up exercises.

The phase times for the two exercises were different. The mean concentric phase time was longer for the lat pull-down than the for pull-up. The time required to shorten the muscles in order to accomplish the positive work for both exercises was consistent across trials, see Table 1. In the lat pull-down exercise, a resistance equal to the subject's body mass was displaced as the weight machine pulley system was activated by the muscles. In comparison, the subject's body mass was displaced upward as the pull-up exercise was completed. The time for these concentric phases between the exercises was significantly different.

The short interval following the upward displacement of the weight stack or body for the concentric phase allowed a short transition period before the lengthening of the muscles in the eccentric phase. This coupling phase was present in both exercises. The marginal mean times were 53.88 ms and 55.12 ms, for the lat pull-down and pull-up, respectively. The marginal standard deviations were 41.61 ms and 48.31 ms, for the lat pull-down and pull-up, respectively. The standard deviations were large in comparison to the mean coupling phase time. The subjects may have immediately begun the eccentric phase, or they may have had a much larger transition time before motion occurred for the eccentric phase. In other words, subjects exhibited more variability in the time of the coupling phase than in the eccentric or concentric phases for both exercises.

A greater phase time for the eccentric contraction was found in the lat pull-down. The mean eccentric phase time decreased across trials for both exercises. As the muscles fatigued, less time was spent in the lengthening of the muscles, and therefore, the time spent in this phase was reduced across trials. The average means across trials for both exercises remained consistent.

The concentric and eccentric phases were slower for the lat pull-down than for the pull-up. The range of motion was greater in the lat pull-down than in the pull-up. Also, some subjects leaned back at the end of the concentric phase, making the displacement greater. The trunk inclination may have made a difference in phase time. The greater range of motion and the trunk inclination may have increased the concentric and eccentric phase time of the lat pull-down.

Order of Recruitment Based on Time to Peak EMG

The order of recruitment in relation to the phase time was determined for the concentric and eccentric phase of both exercises. The recruitment order of each of the five muscles was measured as a percentage of the time spent in the concentric and eccentric phases of the exercises.

Concentric Phase

For the concentric phase of the exercises (lat pull-down and pull-up), a significant mean difference in relative time to peak recruitment existed. Also, a significant difference existed in relative time to peak recruitment for the five muscles. The relative time to peak recruitment was consistent among the trials.

The relative time to peak recruitment of all five muscles in the concentric phase was shorter for the lat pull-down than for the pull-up. Examination of the concentric phase data for the lat pull-down and pull-up revealed that the latissimus dorsi was the initial muscle to reach peak recruitment. As stated above, the length of time to reach peak recruitment was shorter for the lat pull-down than for the pull-up. Because this muscle is multipennated and thus, capable of producing great force, it was used to overcome the inertia in the beginning of the concentric phase. The lat pull-down exercise may have reached peak recruitment more rapidly in the concentric phase due to the inertia of the weight stack. The weight stack was fixed at rest, thus no movement occurred; no momentum was present to assist the upper body muscles to displace the weight. In contrast, during the pull-up exercise, the lower body may have had horizontal displacement (sway). The horizontal displacement may have assisted the motion, making it easier by changing the moments of the body, the resistance. In a study by Ricci et al. (1988), similar conclusions were made with respect to the pull-up. Their data clearly indicated that the initial increase in horizontal sway was necessary for the successful execution of the pull-up. The mechanical advantage of the body motion assisted the prime movers to upwardly displace the body from a moving position in the pull-up exercise, rather than initiating the movement from a state of rest. The multipennate feature of this muscle assisted inward rotation and adduction, which caused the movement of the lat pull-down bar or the movement of the body in the pull-up exercise.

The latissimus dorsi muscle recruitment relative to the phase time in the concentric phase of the lat pull-down was succeeded by the anterior deltoid, pectoralis major, bicep brachii, and tricep, respectively. In the pull-down exercise, the muscles that followed the latissimus dorsi in relation to total phase time were the pectoralis major, bicep brachii, anterior deltoid, and tricep, respectively. The latissimus dorsi and tricep were the only two muscles which followed a similar recruitment pattern between the two exercises.

Eccentric Phase

For the eccentric phase of the exercises (lat pull-down and pull-up), a significant mean difference in relative time to peak recruitment existed. Also, a significant difference existed in relative time to peak recruitment for the five muscles. The relative time to peak recruitment was consistent among the trials.

The relative time to peak recruitment for the five muscles during the eccentric phase of the pull-up revealed an inverse relationship from the concentric phase peak recruitment. The relative time to peak recruitment for the five muscles during the eccentric phase of the lat pull-down did not follow any logical order. The inverse order of relative time to peak recruitment for the five muscles for the pull-up may be due to the control of the lowering of the body mass. In the lat pull-down, the subjects may have released the bar upward with little control or resistance against the weight stack, thus, the relative time to peak recruitment for the five muscles would vary.

The specific order of recruitment relative to phase time was the same for three muscles in both exercises. The anterior deltoid, pectoralis major, and latissimus dorsi were recruited in succession across exercises relative to the phase time, second, fourth, and fifth, respectively. The pectoralis major and latissimus did not reach peak recruitment until the end of the phase for both exercises relative to phase time. This indicated that the musculature of the arm and elbow is being used primarily in the same way. In both exercises, for the eccentric phase of the exercise, these muscles are used to lower the weight stack or the subject's body.

Magnitude of Peak EMG

Peak EMG results were compared for three effects, exercise, trials, and muscles, for the concentric and the eccentric phases of the exercises. For the concentric phase no differences were found between the exercises, among the trials, or among any of the interaction effects. These results suggested several observations:

1. The magnitude of the peak EMG was the same for the pull-up and the lat pull-down during the concentric phase. Therefore, if the resistance of the lat pull-down is equal to the weight of the body, the five muscles, latissimus dorsi, pectoralis major, anterior deltoid, trapezius, and biceps brachii tended to produce the same force. Thus, the concentric phases of the two exercises can be considered to be equivalent from a force magnitude point of view.

2. Peak EMG was the same across the three trials. This result supported the reliability or consistency of the subjects when they performed the middle repetition of three sets of three repetitions. This further supported the reliability of performance previously discussed with respect to time to peak recruitment.

3. The nonsignificant interaction effects, exercises by trials, muscles by exercises, muscles by trials, and exercises by trials by muscles support observations 1 and 2 above.

For the eccentric phase: (a) a difference was found between the exercises and the interaction effect muscles by exercises, and (b) no differences were found among the trials or among the remaining interaction effects. The results of the eccentric phase suggested that:

1. The magnitude of the peak EMG was different for the pull-up compared to the lat pull-down. The mean magnitudes reported in Table 7 indicated that the means were greater for the pull-up than the to the lat pull-down for four of the five muscles studied. This difference could have been caused by the difference between the two resistances for the exercises. For the pull-up the resistance was the subject's body weight; for the lat pull-down the resistance was a weight stack equal in magnitude to the subject's body weight. The movement of the body as a resistance in the eccentric phase of the pull-up may have been controlled to eliminate a sudden impact at the end of the range of motion. The time of the eccentric

phase is a finding that supports this conclusion; the time of the eccentric phase of the pull-up was longer than the eccentric phase of the lat pull-down. If this movement was not controlled, the potential trauma to the joints of the body would increase.

2. Peak EMG was the same across the three trials for the eccentric phase. This result supported the point of reliability or consistency previously mentioned for the concentric phase.

3. The interaction effects, exercises by trials, muscles by trials, and muscles by exercises by trials support the reliability or consistency mentioned above.

4. The significant interaction effect, muscles by exercises, support observation 1 above, suggesting that the eccentric phases of the exercises were different.

For both the concentric and the eccentric phases the main effect of muscles was significant. This result was expected for several reasons. First, the muscles are different with respect to: (a) muscle fiber structure, (b) muscle fiber type, (c) length-tension relationship, (d) sources of elasticity, (e) force-velocity relationship, (f) muscle power, and (g) angle of pull. According to Kreighbaum and Barthels (1995), these factors contribute to the force a muscle is capable of producing. Second, a comparison of muscles among subjects could not be conducted because the EMG data were not normalized. Third, the magnitude of EMG activity is affected by electrode placement and skin resistance. This makes intramuscular comparisons difficult.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary

This study was conducted to compare and describe the physiological demands of the upper body muscles used as the prime movers for the wide grip lat pull-down and wide grip pull-up exercises. The control of the upper body musculature during strength-training exercises involves the sequential recruitment of muscles. Both the wide grip pull-up and wide grip lat pull-down incorporate the same prime mover muscles of the shoulder girdle, shoulder joint, and elbow joint.

The subjects for this study were 10 male student volunteers who attended Western Michigan University. The subjects performed two different exercises: (1) a wide grip lat pull-down and (2) a wide grip pull-up. Each subject was capable of performing a trial of three consecutive repetitions using a wide grip and forward grip for each exercise.

Bipolar surface electrodes were used to record the EMG response of five muscles: (1) latissimus dorsi, (2) pectoralis major, (3) anterior deltoid, (4) trapezius, and (5) biceps brachii. The EMG was synchronized with a video camera. The system provided integrated signals that were matched to the video. The EMG response for each muscle during the phases (concentric, coupling, and eccentric phase) of the two exercises were analyzed to determine the point of peak muscle recruitment and the recruitment order.

Kinematics of the shoulder girdle, shoulder joint, and elbow joint were assessed through the use of a video. The two-dimensional video analysis of each exercise was used to help separate the motion of each trial into the three phases. Single frames of motion were digitized in order to obtain the landmark anatomical trajectories. The analysis began with the initiation of the concentric phase and ended when the eccentric phase was completed.

The design consisted of four research variables: (1) two strength-training exercises, (2) three trials, (3) five muscles, and (4) three phases. The dependent variables were: (a) phase time, (b) relative time to peak recruitment, and (c) peak recruitment. Descriptive statistics and inferential statistics were used to analyze the data.

Findings

The relevant findings for the dependent variable phase time for this study included:

1. A significant difference was found between the two exercises for the concentric phase time, $F(1, 54) = 13.14$, $p = .00$.

2. A significant difference was found between the two exercises for the eccentric phase time, $F(1, 54) = 17.96$, $p = .00$.

The relevant findings for the dependent variable relative time to peak EMG for this study included:

1. A significant difference was found between the two exercises for the concentric phase for relative time to peak EMG recruitment, $F(1, 192) = 11.12$, $p = .00$.

2. A significant difference was found among the muscles for the concentric phase of the exercises for relative time to peak EMG, $F(4, 192) = 27.41$, $p = .00$.

3. A significant difference was found between the two exercises for the eccentric phase for relative time to peak EMG recruitment, $F(1, 192) = 12.32$, $p = .00$.

4. A significant difference was found among the muscles for the eccentric phase of the exercises for relative time to peak EMG, $F(4, 192) = 7.91$, $p = .00$.

5. No significant differences were found among trials for the concentric or the eccentric phase.

The relevant findings for the dependent variable peak EMG for this study included:

1. No significant difference was found between the two exercises for the concentric phase for magnitude of peak EMG, $F(1, 216) = 0.41$, $p = .53$.

2. A significant difference was found between the muscles for the concentric phase of the exercises for magnitude of peak EMG among the five muscles, $\underline{F}(4, 216) = 177.92$, $\underline{p} = .00$. The summary of the magnitude of peak recruitment is found in Table 7.

3. A significant difference was found between the two exercises for the eccentric phase for magnitude of peak EMG, $\underline{F}(1, 216) = 5.00$, $\underline{p} = .03$.

4. A significant difference was found between the muscles for the eccentric phase of the exercises for magnitude of peak EMG among the five muscles, $\underline{F}(4, 216) = 90.64$, $\underline{p} = .00$.

5. A significant difference was found for the first order interaction effect, muscles by exercises, $F(4, 216) = 4.12$, $p = .00$.

6. No significant differences were found among trials for the concentric or the eccentric phases of the motions.

Conclusions

Based on the results of this investigation, the following conclusions were drawn:

1. The concentric and eccentric phases were slower for the lat pull-down than for the pull-up.

2. The range of motion was greater for the lat pull-down than for the pull-up.

3. The relative time to reach peak recruitment was shorter for the

lat pull-down than for the pull-up.

4. For the pull-up, the recruitment order for the five muscles for the eccentric phase showed an inverse relationship to the order found in the concentric phase.

5. The magnitude of the muscles' force response was the same for the concentric phases of the two exercises, but different for the eccentric phases.

Recommendations

The following are recommendations for further research in this area:

1. Different grip positions should be investigated to determine what effect they have on muscle recruitment order and peak EMG values.

2. The mechanics of the exercise should be used to group subjects. The effects of technique could be related to the recruitment order and the peak EMG responses of the muscles.

3. The subject pool should be more heterogenous. Future studies should consider females, experienced lifters, and inexperienced lifters.

4. The effect of variable resistances to the EMG response should be investigated.

Appendix A

Informed Consent Form

Western Michigan University
Department of Health, Physical Education, and Recreation
Principal Investigator: Dr. Mary Dawson & Dr. Roger Zabik
Research Associate: Marla Bauermeister

I have been invited to participate in a research project entitled "An Electromyography (EMG) Comparison of Muscle Recruitment Associated With the Wide Grip Pull-Up and the Wide Grip Lat Pull-Down Exercises." I understand that this research is being used to analyze two strength-training exercises and how they affect muscle recruitment. Furthermore, I understand this project is for Marla S. Bauermeister's Master's thesis.

My consent to participate in this project indicates that I am willing to attend one, 1 hour session with Marla Bauermeister. The one session will involve performance of the two exercises. The session will involve specific information about the testing and directions on how to perform the techniques. At this one session a total of nine repetitions for both the wide grip lat pull-down and wide grip pull-up exercises will be performed. Between each trial of three repetitions, I will be given 2 min to rest. Between the two exercises, I will be given 4 min of rest. At this session, I will provide information about myself such as age, height, and weight. I understand that my performance will be videotaped for the purpose of analysis. I also understand that surface electrodes will be attached to my upper body for recording EMG data. Both the EMG and kinematic data will be stored on computer disk and videotape, respectively.

I understand that there are unforeseen risks associated with participation. If an accidental injury occurs, appropriate emergency measures will be taken, as posted in the lab. However, no compensation or treatment will be made available to me except as otherwise specified in this consent form. I understand that one potential risk of my participation in this project is that I may strain a muscle or aggravate a portion of my shoulder joint, shoulder girdle, or elbow joint. I understand that I may experience soreness 2 to 3 days after my participation.

I understand that the current testing may be of no benefit to me. The results of this study may provide exercise specialists and trainers with further knowledge concerning training regimens that are essential for muscular strength development programs.

I understand that all the information collected from me is confidential. That means that my name will not appear on any paper associated with this study. The data sheets will all be coded, and the researchers will keep a separate master list with names of the participants along with their assigned code numbers.

After having collected and analyzed the data, all forms and lists will be destroyed. All other forms used in the study will be retained for 3 years in a locked file in the principal investigator's laboratory. At the end of the 3 years, all recorded data will be destroyed (video and computer data).

I understand that I may refuse to participate at any time during the study without prejudice or penalty. If I have any questions or concerns about this study, I may contact either Marla S. Bauermeister at 343-0941 or Dr. Mary Dawson at 387-2711. I may also contact the Chair of the Human Subjects Institutional Review Board at 387-8293 or the Vice President for Research at 387-8298 with any concerns that I have. My signature below indicates that I understand the purpose and requirements of the study and that I agree to participate.

------------------------------------ ------------

Signature Date

Appendix B

Human Subjects Institutional Review Board Approval

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: November 15, 1995

To: Marla Bauermeister

From: Richard Wright, Chair

Re: HSIRB Project Number 95-11-15

This letter will serve as confirmation that your research project entitled "An electromyography (EMG) comparison of muscle recruitment associated with the wide grip pull-up and lat pull-down exercises" has been **approved** under the **expedited** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you must seek specific approval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: November 15, 1996

xc: Mary Dawson, HPER

Appendix C

Data Collection Sheets

Time Phase Recording Log

	BEGIN CONCENTRIC	BEGIN ECCENTRIC
S1C1T1		
S1C1T2		
S1C1T3		
S1C2T1		
S1C2T2		
S1C2T3		
S2C1T1		
S2C1T2		
S2C1T3		
S2C2T1		
S2C2T2		
S2C2T3		
S3C1T1		
S3C1T2		
S3C1T3		
S3C2T1		
S3C2T2		
S3C2T3		
S4C1T1		
S4C1T2		
S4C1T3		
S4C2T1		
S4C2T2		
S4C2T3		

Time Phase Recording Log

LEAD	3	4	5	6	7
TRIAL	Latissimus Dori MV/Time (ms)	Trapezius MV/Time (ms)	Anterior Deltoid MV/Time (ms)	Biceps Brachii MV/Time (ms)	Pectoralis Major MV/Time (ms)
S1C1T1	/	/	/	/	/
S1C1T2	/	/	/	/	/
S1C1T3	/	/	/	/	/
S1C2T1	/	/	/	/	/
S1C2T2	/	/	/	/	/
S1C2T3	/	/	/	/	/
S2C1T1	/	/	/	/	/
S2C1T2	/	/	/	/	/
S2C1T3	/	/	/	/	/
S2C2T1	/	/	/	/	/
S2C2T2	/	/	/	/	/
S2C2T3	/	/	/	/	/
S3C1T1	/	/	/	/	/
S3C1T2	/	/	/	/	/
S3C1T3	/	/	/	/	/
S3C2T1	/	/	/	/	/
S3C2T2	/	/	/	/	/
S3C2T3	/	/	/	/	/
S4C1T1	/	/	/	/	/
S4C1T2	/	/	/	/	/
S4C1T3	/	/	/	/	/
S4C2T1	/	/	/	/	/
S4C2T2	/	/	/	/	/
S4C2T3	/	/	/	/	/

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