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A COMPARISON OF FAST AND SLOW CONTRACTION SPEEDS USING ELECTROMYOGRAPHY

by

Philip J. Melhorn

Bachelor of Science
The College of New Jersey
1996

A thesis submitted in partial fulfillment
of the requirements for the

Master of Science Degree
Department of Kinesiology
College of Health Sciences

Graduate College
University of Nevada, Las Vegas
August 1999

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ABSTRACT

A Comparison of Fast and Slow Contraction Speeds Using Electromyography

by

Philip J. Melhorn

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The purpose of this study was to determine if differences in EMG activity existed between fast and slow contraction speeds during isolated, one-armed biceps curls to muscle failure. Participants performed one set of biceps curls to muscular failure on two separate occasions at different contraction speeds. Constant load equal to 75% of 1RM was used for each test. The dependent variables were integrated EMG (iEMG), percent change in mean frequency, and time to muscular failure. Integrated EMG measurements revealed significantly greater muscle activity for the slow contractions ($t = 4.76$, $p < .001$). The time to muscular failure also showed significant differences having the fast contraction speed achieve muscle failure faster than the slow contraction speed ($t = 5.23$, $p < .001$). The comparison of frequency data failed to reach significance. A significant correlation ($r = .514$) was determined for iEMG and time to muscular failure. These results suggest that differences exist in iEMG and time to muscle failure between fast and slow contraction speeds.

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CHAPTER 1

INTRODUCTION

Exercise promotes cardiovascular fitness, muscular strength and endurance, as well as supports the maintenance of a healthy lifestyle. Strength training is an essential component of a well-rounded exercise program. Well-rounded exercise programs developed by fitness professionals can improve quality of life for participants. Benefits associated with exercise include increased physical work capacity, decreased resting heart rate, decreased resting blood pressure, increased HDL cholesterol, decreased LDL cholesterol, and increased strength for everyday activities.

An important component of physical fitness is muscular strength and endurance. Improvements in muscular strength and endurance typically occur during strength training programs. Strength training has been shown to improve bone density, muscular strength, and muscular endurance (Nieman, 1993). As stated above, the benefits attained with strength training affect the lifestyles of the participants in a variety of ways. For example, strength training improves confidence and ease of performance during daily activities (Brzycki, 1995).

Selection of the training method likely reflects the education of a chosen fitness professional and, or the literature examined by the participant. There are numerous training methods available, and considerable debate continues as to which protocols provide the optimal results.

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The controversy surrounding selection of an ideal strength training technique centers around the training speed, number of sets, and number of repetitions performed. Training specificity and the effectiveness of a program relates directly to the exercise protocols. The training specificity theory suggests development of muscular fitness by performing exercises that require a specific type of contraction, training intensity, and motor skill (Nieman, 1993). Supporters of the specificity theory suggest the most effective training results from velocity specific movements (Moffroid and Whipple, 1970; Matveyev, 1981). The results from these experiments provide evidence that a faster training speed increases the effectiveness of the protocol. Preferential recruitment of fast twitch muscle fibers has been cited for the increased effectiveness of training protocols using fast contraction speeds (Moffroid and Whipple, 1970; Komi and Karlsson, 1979). In contrast, some fitness professionals suggest identical results using slow and controlled contraction speeds (Brzycki, 1995). More importantly, the fitness professionals who support slow and controlled contraction speeds during training suggest that slow contraction speeds provide a safer exercise environment (Allman, 1979; Alexander, 1985).

Critical examination of contraction speeds used in strength training and their effectiveness requires a clear understanding of muscle fiber recruitment. When muscles contract, an orderly recruitment of slow twitch, intermediate, and fast twitch fibers take place (Henneman size principle) (Henneman, 1957, Vander, Sherman & Luciano 1994). Little evidence exists suggesting the reversal of the Henneman size principle where preferential recruitment of fast twitch fibers occurs during strength training (Komi and Karlsson, 1979; Young and Bilby, 1993). When muscles contract, neural activity recruits

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the fibers needed to overcome the force placed on the muscle. As motor unit activity increases due to increased resistance, recruitment moves from slow to intermediate to fast twitch fibers. This muscular activity can be measured using electromyography (EMG) (Basmajian and DeLuca, 1986; Enoka, 1988). Measurement of muscular activity has been related theoretically to the development of strength (Rosentswieg, Hinson, and Ridgeway, 1975). Justification for the relationship between muscular activity and strength development exists, however experiments involving EMG measurements have also produced contradictory evidence (Morrissey, Harman & Johnson, 1995; Moffroid and Whipple, 1970). Theoretically, increases in muscular activity, as measured by EMG, demonstrate more effective activation of muscular fibers. The increases in muscular activity suggest increased activation of muscular fibers leading to a more effective training method. The Henneman size principle supports the theory that increased muscular activity leads to increased recruitment of muscular fibers, however effectiveness of training can only be determined when strength is measured following training.

Training regimens have been shown to increase muscular strength and endurance. The different protocols consist of manipulations of such things as the number of sets, number of repetitions, speed of contraction, and training schedules to mention a few. Of these variables, speed of contraction will be the primary focus of this study.

Contraction speed is a frequently debated issue between fitness professionals who promote fast repetitions during training and those who support the use of slow repetition speeds during strength training. The supporters of fast repetition speeds during strength training emphasize more ballistic, explosive movements based on the assumption that fast

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contractions preferentially recruit fast twitch muscle fibers (Moffroid and Whipple, 1970; Matveyev, 1981). Fast twitch muscle fibers demonstrate the greatest increases in size and strength (Vander et al., 1994), therefore activating the fast twitch fibers leads to increased effectiveness of training. In addition, fast training speeds are believed to develop both speed and muscular components of movement. In contrast, fitness professionals who promote slow and controlled movements believe that speed and muscular strength must be trained separately. They also believe that regardless of the contraction speed, the fast twitch muscle fibers are recruited and strength training effects are increased using slower repetition speeds (Brzycki, 1995; Darden, 1992).

Weight training promotes muscular development, however a safe exercise environment may be of more concern to fitness professionals than maximal strength benefits. When injuries occur during weight training, the exercise program usually requires modification and exercise effects are decreased. Slow, deliberate contractions result in fewer injuries than fast, more ballistic contractions (Reid, Yeater & Ullrich, 1987; Alexander, 1985; Mazur, Yetman, & Risser, 1982). However, the effectiveness of the slow technique remains questionable.

Theoretically, increased muscular activity promotes effectiveness of training (Rosentswieg et al., 1975). The current study compared EMG activity between slow and fast contractions during isolated, one-armed biceps curls. This research may help to explain differences between contraction speeds found in previous studies and provide evidence for theories related to muscular activity and strength development. Increased muscular activity, as measured by EMG, in either of the conditions tested will provide evidence for theories related to contraction speed and it's effect on muscular activity.

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The muscular activity, however, does not provide an accurate demonstration of strength developed.

A direct comparison of a single subject's muscular response to different training speeds has not been thoroughly studied. Electromyography (EMG) allows researchers to measure the electrical activity of muscle which can indicate muscular response during physical activity (Rosentswieg et al.,1975; Enoka 1988). This technology allows researchers to compare muscular usage creating an environment favorable to unbiased research. The purpose of the current study was to determine if differences in EMG activity exist between fast and slow contraction speeds during isolated, one-armed biceps curls to muscle failure.

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CHAPTER 2

REVIEW OF LITERATURE

The purpose of the current study was to determine if differences in EMG activity exist between fast and slow contraction speeds during isolated, one-armed biceps curls to muscle failure. The literature related to resistance exercise, injury risk, weight training techniques, and methods of measurement involved in muscular research are presented in this chapter. Information concerning resistance exercise or weight training is presented first. Following the general information regarding weight training, literature related to injury risk involved in training is presented. The next section of the chapter is devoted to the different training techniques and the research presented in the debate between their efficiency and effectiveness. The final section presents the methods used to analyze muscular activity (EMG measurements), related literature involving EMG, and a chapter summary.

Resistance Exercise

Resistance exercise, or weight training, is a valued part of a comprehensive exercise program. Regular weight training can lead to increases in muscle size, contractile strength, bone density, tendon strength, and ligament strength (deVries and

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Housch, 1994). Weight training can also improve the body's ability to perform work (Brzycki, 1995).

Genetics determines muscle fiber composition, which directly affects a muscle's response to weight training. Muscle fiber can be grouped into three major categories: (1) slow twitch or type I fibers, (2) fast twitch/intermediate or type IIa fibers, and (3) fast twitch or type IIb fibers (Vander et al., 1994). Fiber types differ in regard to endurance capacity and contribution to force production. Slow twitch fibers have a high endurance, and are sometimes referred to as oxidative. They can maintain sustained use, however, their force production is relatively low. Fast twitch type IIb fibers fatigue more easily, but generate larger forces than do slow twitch fibers. Fast twitch fibers are referred to as glycolytic because of their predominant use of glycolysis for energy requirements. Finally, the type IIa fast twitch fibers, possess both oxidative and glycolytic characteristics. Type IIa fibers fatigue less than the type IIb fibers yet generate greater forces than the slow twitch fibers. An individual's skeletal muscles contain all fiber types and a predominance of muscle fiber type can play a major role in determining their potential for attaining muscular size and strength (Costill, Coyle, Fink, Lesmes & Witzmann, 1979; Graves and Pollack, 1992).

An increase in muscle size or hypertrophy can be attributed to weight training, however some individuals have a greater tendency for these increases. Individuals with a predominance of fast twitch muscle fibers have a greater potential for increases in muscle size and strength because the fast twitch fibers have an increased capacity for growth (Coyle et al., 1979; Gollnick, Armstrong, Saubert, Sembrowich & Shepard, 1979; Vander et al., 1994). This increased capacity for growth relates to the fact that fast twitch fibers

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produce greater forces than slow twitch fibers. Muscle hypertrophy can be attained by both fiber types, however the potential for growth increases with a predominance of fast twitch fibers (Gollnick, Armstrong, Saubert, Piehl & Saltin, 1979; Brzycki, 1995). An experiment performed by Gonyea found evidence supporting conversion of type IIa to type IIb fibers in animals (Gonyea, 1980), but human evidence suggests otherwise. With training, characteristics of the fiber types may be developed by the intermediate fibers, but no conclusive evidence exists to support fiber conversion.

Another genetic factor dealing with musculature is neurological efficiency. The efficiency for innervating muscles determines force generated, therefore innervation affects strength (Costill et al., 1979; Darden, 1992). Nervous system genetics determines the percentage of motor units a muscle will recruit. The innervation of a larger percent of muscular fiber increases the force generated by a muscle (Coyle, Costill & Lesmes, 1979; Tortora and Grabowski, 1993). The innervation of muscle fibers and fiber types are genetic determinants of muscular characteristics. These characteristics become evident during training, consequently identical results should not be expected by different individuals who perform the same training regime. As stated, individuals have different genetic make-ups and will respond to training in different ways.

Muscular development occurs according to an individuals genetic predisposition (Graves and Pollack, 1992). Muscular strength and endurance, however, can be optimally developed to an individual's potential. Strength training principles exist outlining methods for increasing muscular strength and endurance. Two well-established principles of weight training are the overload and progressive resistance principles. The overload principle states that in order to increase muscular size and strength, a muscle

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must be stressed with a workload that is beyond its present capacity (DeLorme and Watkins, 1948; Nieman, 1993). Muscular fatigue triggers an adaptive response resulting in muscular growth (Enoka, 1988, Brzycki, 1995, Tortora and Grabowski, 1993). With proper nourishment and recovery time, a muscle will adapt by increasing in size and strength. Strength training promotes muscle development, but the extent to which these adaptations occur is generally a function of a person's genetic predisposition (Graves and Pollack, 1992). The progressive resistance principle states that systematic increases in resistance or repetitions must be made in order to produce increases in muscular strength and endurance (DeLorme and Watkins, 1948; Nieman, 1993). These systematic increases will stress the musculature and promote effective development (Brzycki, 1995). The overload and progressive resistance training principles share a common bond. Each stresses a muscle above and beyond its normal capacity. This stress causes adaptations in the muscle and promotes muscular development.

A well-documented response to training, introduced by Selye in 1956, called the "General Adaptation Syndrome" (GAS) is a three step process that illustrates the physical effects of stress (fatigue) (deVries and Housch, 1994). The first stage details the physical effects of stress on the muscles. The stress causes microtrauma within the musculature. The second stage is the body's defense against the stress-induced damage. Adaptation, in the form of muscular size and strength occurs, protecting against further trauma. Finally, in the third stage, a negative response occurs when the stress placed on the muscle is prolonged and exceeds the muscle's ability to adapt. The muscular responses seen in the "GAS" occur because of weight training, however the increases in muscular size and strength develop because of a person's genetic predisposition.

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Another response to weight training is an increase in metabolic function. Muscular requirements for maintenance and rebuilding processes are high (deVries and Housch, 1994, Tortora and Grabowski, 1993). These requirements increase caloric expenditure, increasing the metabolic rate (Tortora and Grabowski, 1993). Overall, increases in muscular strength and endurance from weight training improve the body's ability to function and reduce risk for potential disease.

Injury Risk

The potential for injuries is always present during physical activity. Weight training introduces many different possibilities for causing injuries to muscles and especially joints (Wilmore, 1982). A proper balance between agonist and antagonist musculature also prevents overuse injuries that can result from muscles which are stronger or weaker than their counterparts (deVries and Housch, 1994). Arguments in the past have suggested dangers associated with weight training, but with proper technique the benefits exceed the potential for injury.

The injury potential involved in weight training should not be overlooked. Injuries usually happen due to lack of strength training knowledge (Allman, 1979). Proper technique represents a critical factor in weight training. Opinions vary on the techniques that should be used for weight training, but injuries incurred during weight training sessions most often happen during sudden movements (Alexander, 1985; Allman, 1979; Brady, Cahill, & Bodnar, 1982; Mazur et al., 1993; Brzycki, 1995). The forces a joint encounters during sudden movements occur when stress exceeds the structural limits of muscle, bone, or connective tissue (Brzycki, 1995). Research

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completed by Reid, Yeater, and Ullrich (1987) noted that a group weight training with ballistic movements had the highest injury rate among participants. This study investigated body composition and strength in two groups of participants. One group trained using slow, controlled repetitions while the other group used explosive lifting techniques. No significant differences were found between groups, however, mortality rate within the explosive training group neared 25% while the slow training group experienced a zero mortality rate. The study did not intend to investigate injury rate of specific training techniques, yet it clearly represents the inherent dangers involved with explosive lifting.

Weight Training Techniques

Since the advent of weight training, many techniques have been introduced, forgotten, and modified. A debate exists between fitness professionals who promote fast repetition speed and those who promote slow repetition speeds during weight training. Each technique has, within itself, variations , but the contraction speeds clearly represent exclusive ends of strength training beliefs.

Techniques involving fast, more ballistic repetitions have evolved throughout the past century. The training techniques began when Olympic competitors became strength coaches and trainers for athletes and soldiers (Brzycki, 1995). The primary variables in strength training are sets of repetitions, repetitions within a set, and the training speed. A light to heavy system entails progressing from light to heavy resistance (Berger, 1962). A heavy to light system is just the opposite of the light to heavy system, while a triangle program (pyramid training) is the combination of light to heavy to light resistance

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(Berger, 1962). Split routines, also part of the training techniques promoting fast contraction speeds, create a training schedule having specific body parts targeted for different days of the week (Nieman, 1993). The training techniques using fast contraction speeds also follow the specificity principle where weight training movements are specific to movements in competition (Nieman, 1993). All of the systems involved in this technique are found throughout the literature. Many of these systems have been tested and have shown great increases in muscle size, strength, and endurance (Matveyev, 1981; Moffroid and Whipple, 1970; and Berger, 1962).

Strength training techniques that focus on slow and controlled repetitions emerged throughout the 1970's with protocols geared to a safer, more practical exercise environment (Brzycki, 1995). The fitness professionals who promote slow, deliberate contractions emphasize controlled movements throughout all training regimens (Brzycki, 1995; Darden, 1992; Riley, 1980). The contractions used in these techniques can range from a minimum of two seconds to a maximum of ten seconds for the concentric phase of the contraction and have an eccentric contraction range of four to ten seconds (Brzycki, 1995; Darden, 1992; Hutchins, 1992; Riley, 1980). Another difference within the technique promoting slow contraction speeds is the number of sets performed. The techniques generally require the completion of one set of contractions to concentric muscle failure. The method allows for post-fatigue repetitions, but stresses one, not multiple sets.

The previous discussion outlined two popular weight-training techniques used today. Each technique has variations, however one significant difference that requires attention is training speed. Fitness professionals who promote fast, more ballistic

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contractions subscribe to the specificity principle. This specificity training technique suggests that muscles exercised be specific to the type of contraction used during an activity (Nieman, 1993). In other words, if an activity completed during competition must be performed explosively, the weight training should be done explosively for the promotion of speed development. Evidence of speed and strength gains from ballistic training have been produced. Moffroid and Whipple (1970) found evidence that fast training speeds produce significantly better results than slow training speeds for muscular power and endurance. The researchers measured the effects of two different training speeds on muscular force and muscular endurance. Thirty subjects were randomly assigned to a control group receiving no training, a group training with slow velocities, and a group training with high velocities. Each group was pre-tested for maximal hamstring and quadriceps strength. The subjects received the designated protocol and a post-test was administered. The speed of training was found to be specific for both muscular strength and endurance at and below the training speed. This experiment provides support for high speed training because strength increases were found for fast and slow training velocities, however, the slow training group did not increase strength when performing rapid movements. The previous research involving velocity specific contractions provides supporting evidence for the use of fast contraction speeds during training. These findings are, however, not directly related to the premise of the current research. Isokinetic exercise was used as the training modality. This technique is used because the isokinetic training equipment maintains constant angular force and velocity. These training methods have produced evidence suggesting the greatest effectiveness

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(Moffroid and Whipple, 1970; Morrissey et al., 1995), but they are not practical for fitness professionals, athletes, or the general population.

The current trend in research is to use free weights as the exercise modality. Only two studies have compared the effects associated with different movement velocities during free-weight training (Palmieri, 1987; Young and Bilby, 1993). Palmieri found no significant differences between vertical jump height or leg power, measured with one repetition maximum (1RM), when participants were trained on slow and fast protocols. In the study, Palmieri used fast contraction speeds (<3/4 second for a concentric contraction) and slow contraction speeds (>2 seconds for a concentric contraction). A total of 54 subjects participated in the study. The subjects were randomly assigned to three training groups: 1) slow repetition speed 2) fast repetition speed and 3) a combination of fast and slow repetition speeds. The subjects trained using free weights and Nautilus equipment. A squat, leg curl, leg extension, and calf raise were used as the strengthening exercises over a ten-week period. Pre, mid, and post-test measurements were recorded. As stated, no significant differences in vertical jump or leg power were found. It was concluded that training with slow or fast repetitions produce leg power equally (Palmieri, 1987). Vertical jump and 1RM squat were also used by Young and Bilby (1993) to measure differences in training effectiveness between fast and slow contraction speeds. The researchers randomly assigned 18 subjects into two training groups. Each group was instructed on the identical training protocol, however, repetition speed was different. The fast training group performed the repetitions in an explosive manner and the slow training group performed the repetitions in a slow and controlled manner. Squats were used as the training exercise performing 4 sets of 8-12 repetitions

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three times per week. The findings were similar to that of Palmieri with no significant differences for leg power and vertical jump. Young and Bilby also measured hypertrophy and isometric peak force. The results for these measures were also not significant. The researchers found no significant differences between groups, but they stated that the group training with fast contraction speeds demonstrated a higher percentage of increase for each of the dependent measures (Young and Bilby, 1993). The previous studies directly relate to the suggestions presented by the fitness professionals who support slow and controlled repetition speeds during training.

Emphasis on intensity becomes clear when performing contractions in a slow and controlled manner (Brzycki, 1995). As early as 1945, the best weight training achievements have been the result of high levels of intensity or reaching muscular failure during training (Brzycki, 1995; DeLorme and Watkins, 1948; Pollock, Graves, Carpenter, Foster, Legget & Fulton, 1993; Westcott, 1983). Muscular failure must be reached when training with slow contraction speeds. The use of post-fatigue exercises including negatives and regressions is stressed in these techniques (Brzycki, 1995). As mentioned earlier, the overload and progressive resistance training principles intend to stress a muscle above and beyond its normal capacity leading to increases in muscular size and strength. These principles are followed by supporters of the two techniques using fast and slow repetition speed, but the slow and controlled training philosophy treats the intensity as the factor most responsible for strength and endurance gains (Brzycki, 1995; Darden, 1992; Pipes, 1979; Riley, 1980).

The debate between different training methods also addresses physiological principles. The muscular fiber recruitment during weight training creates controversy

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between the supporters of the techniques that promote different contraction speeds during training. The fast contraction training method has suggested that weight training at higher velocities may recruit the essential type IIb (fast twitch) fibers before the type I (slow twitch) fibers (Young and Bilby, 1993; Moffroid and Whipple, 1970). The selective recruitment of fibers within the muscle has been cited by some researchers for results regarding increased effectiveness of strength training, however, no clear evidence exists to support this finding. Physiologically, muscle fibers are recruited in an orderly fashion according to the intensity of the force requirements (Henneman, 1957; Enoka, 1988; Desmedt and Godaux, 1977). The slow twitch muscle fibers meet the demands of low intensity exercise. When the slow twitch (type I) fibers fail to meet the force requirements needed to overcome the resistance, the fast (type IIa) fibers become essential. When these fibers fail to meet the force requirements needed, the fast (type II b) fibers become essential (Henneman, 1957; Enoka, 1988; Desmedt and Godaux, 1977). An early study by Fenn and Marsh (1935) demonstrates the fact that slow twitch fibers are capable of producing fast movements equal to the fast twitch fibers. The research experimented with frog and cat muscle fibers. Evidence was produced suggesting that each of the different fibers were capable of producing contraction speeds well beyond what normal functioning allows (Fenn and Marsh, 1935). These findings suggest that slow twitch fibers can produce a fast movement until the force placed against those fibers becomes too great to overcome.

The physiological function of muscle produces an orderly recruitment of fibers regardless of the movement speed (Henneman, 1957; Tortora and Grabowski, 1993; devries and Housch, 1994; and Vander, et al., 1994). Ballistic movements introduce

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momentum into the training. Some authors report that momentum decreases the productivity and efficiency of weight training (Pipes, 1979; Pollock et al., 1993). After an initial explosive movement, the resistance encountered by the muscles throughout the remaining range of motion becomes negligible (Allman, 1979). The momentum produced with ballistic weight training also produces undue forces on the muscles and joints (Brady et al., 1982; Mazur et al., 1993).

When performing ballistic weight training, a reduction of efficiency becomes apparent. High velocity movements are less productive when producing maximal tension on muscle (Young and Bilby, 1993) while low velocity movements produce longer periods of continuous muscle tension leading to increased muscular activity (Rosentswig et al., 1975). The effects on muscle tension and contraction speed also become clear on a physiological level. During fast movements, the energy a muscle uses increases due to crossbridge detachment (Enoka, 1988). Increasing muscular demands and decreasing muscular tension increases the gap between work output and energy input, leading to a less efficient system (Enoka, 1988). Physiological and practical evidence present concerns for safe, efficient weight training. Techniques promoting slow and controlled contraction speeds address these concerns because injuries most often occur when performing sudden movements, but the debate over training for speed and explosive power still exists.

Methods of Measurement

Research investigating different training methods has produced supporting evidence for each of the different training protocols. The training protocols used in the

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treatment of subjects represent many different beliefs within the fitness industry. Most of the research completed measures strength prior to and following specific training protocols using one repetition maximum. These measurements show increases in strength, however, there have been many inconsistencies between experiments. The experiments used separate training groups in many of the studies. A study where a single subject would be trained on different protocols would be ideal. Furthermore, strength increases change over time and a direct comparison of strength increases on a single subject would not accurately represent the effect of different training protocols.

The measurement of muscular response to training using electromyography (EMG) becomes useful in direct comparisons of subjects (Enoka, 1988). Electromyography, defined as: the study of muscle function through the inquiry of the electrical signal the muscle emanates (Basmajian and DeLuca, 1986), uses electrodes to detect the signal. The two main types of electrodes are surface (skin) or inserted (wire or needle) electrodes (Basmajian and DeLuca, 1986). The measurement of the electrical signal within the whole muscle uses surface electrodes to record the activity of motor units. Surface electrodes detect the firing of multiple motor units throughout the muscle leading to a waveform representative of the summation of activity for the different motor units (Basmajian and DeLuca, 1986). These waveforms represent the action potentials of the motor units and can also be used for analysis of muscular fatigue (Basmajian and DeLuca, 1986). EMG analysis has been used to investigate muscle activity during both isometric and isokinetic contractions with little research during isotonic movements. The measurements recorded during experiments involving isometric and isokinetic contractions can generally be related to the EMG analysis of isotonic and singly dynamic

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contractions (Arendt-Nielsen and Mills, 1988; Hagberg, 1981; Higbie, 1996; Rosentswieg et al., 1975; Vailas, Morris, Pink, Perry & Jobe, 1992).

Studies involving the measurement of isokinetic contractions share a common bond with experiments involving isotonic contractions. Both of these contraction types are dynamic in nature. The following section will describe studies measuring isokinetic contractions, their relation to the measurement of isotonic contractions, and explain the information directly related to measurements of isotonic contractions.

In a study by Vailas et al. (1992), isotonic or free weight exercises were compared to isokinetic exercise using EMG analysis. The research investigated muscular activity of the biceps and triceps. A 3-D motion analysis was conducted to separate the flexion and extension of the upper arm into arcs of motion. Muscular activity for each 15 degree arc of motion was compared and the increases and decreases in the two muscles were correlated with the isotonic or isokinetic motion. The biceps isotonic movement showed a gradual increase in muscular activity throughout the full range of motion. A significant increase in activity at the 55-69 degree arc of motion was observed. The increase in activity relates to the maximal resistance experienced during this isotonic movement. Similarly, the triceps isotonic movement showed a gradual decrease in muscular activity from flexion to extension. A significant change in muscular activity was produced from the 105-91 degree arc to the 30-16 degree arc of motions, the middle range of the contraction. Conversely, the isokinetic movement of the biceps and triceps demonstrated constant increases and did not show peak increases and decreases in muscular activity. The authors attributed this to the isokinetic equipment, which was designed to maintain constant resistance throughout the range of motion. As mentioned earlier, Morrissey et

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al., (1995) described isokinetic training as the most efficient strength training method, but as suggested, these devices are only practical in laboratory and therapeutic settings. This research helps highlight the similarities and differences between these different types of contractions. It also reveals some of the limitations of the EMG analysis of an isotonic contraction, considering the peak amplitudes during specific angles of movement. One limitation to the study by Vailas et al. is that research involving fatigue and its corresponding measurements were not considered. The following experiments address the effect fatigue has on EMG analysis, as well as, the muscular activity found in the contractions.

In a study by Morlock, Bonin, Muller, and Schneider (1997), EMG signals were compared during a trunk flexion, iso-inertial test. This experiment used an isokinetic device as the modality for the exercise and resistance was set at 40% maximal voluntary contraction. The device maintained constant speed and resistance throughout a set of trunk flexion repetitions until exhaustion. Under these conditions, the contractions are similar to isotonic movements and EMG measurements can be expected to follow a stereotypical pattern. The EMG measurements used in this study were change in signal amplitudes and spectral density. Signal amplitudes measure the muscular activity while the median frequency is a measure of fatigue (Basmajian and DeLuca, 1986; Enoka, 1988). The researchers found that with increasing amplitudes there was a decrease in median frequency indicating an increase in fatigue with increased duration of exercise.

Fatigue related effects in EMG analysis consider duration and intensity of the exercise performed (Hagberg, 1981). Increased intensity corresponds to increased muscular activity and increased fatigue (Enoka, 1988). These conditions will change the

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measurements recorded (Hagberg, 1981). Hagberg measured the root mean square amplitude of the muscular activity and mean power frequency (MPF) in the investigation of dynamic contractions to fatigue. The exercise performed was isokinetic contractions of the elbow joint maintaining constant speed for the duration of the repetitions. The results of this research show similar increases in amplitude and decreases in frequency to the experiment conducted by Morlock et al. Hagberg found significant increases in signal amplitude during isokinetic exercise comparable to isometric recordings. The dynamic contractions consistently produced an increase in muscular activity (signal amplitude) for the duration of the contraction. MPF decreased as the contraction continued with a significant shift at 79.8% of the contraction. These similar findings provide evidence for the increasing muscular activity during dynamic contractions, as well as, evidence supporting a decrease in MPF as muscles begin to fatigue.

In a similar study, EMG measurements were obtained during submaximal, fatiguing, isotonic contractions of the quadriceps (Arendt-Nielsen and Mills, 1988). The researchers obtained integrated EMG (iEMG) measurements preceeding and following a shift in MPF. This experiment focused on the EMG analysis at different levels of the percent of a maximal voluntary contraction on a controlled isokinetic apparatus, but the results provide useful information having the same increases in amplitude and decreases in frequency for all of the different levels of the protocol.

Great attention has been placed on the specific methods of EMG measurement. The reason for the specifications extends from the scientific basis of EMG analysis. The U. S. Department of Health and Human Services published Selected Topics in Surface Electromyography for the Use in the Occupational Setting: Expert Perspectives in 1992.

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Within the publication, a perspective on basic measurement methods and techniques is given for all types of situations. Focusing on dynamic contractions leads to many problems with EMG measurements. The EMG force relationship present during isometric contractions is not applicable to isokinetic and isotonic movements because of the length-tension/force-velocity, or muscle lengthening during movement. This leads to a significant limitation of analysis. The experts suggest that measurements of dynamic contractions be limited to the general muscular activity, which is an amplitude measurement and a measurement of frequency for fatigue related exercise (LeVeau and Andersson, 1992). The amplitude and frequency are derived from the raw EMG signal and researchers suggest the raw signal be used for all EMG investigations. Interpretation of the signal varies and no standards currently exist. Therefore, comparing a participant to themselves in a pre/post situation is the most reliable method for using EMG signals (LeVeau and Andersson, 1992).

The previous research experiments demonstrate how EMG measurements relate to dynamically based contractions. The researchers used specialized isokinetic equipment, but the protocols have not been focused on the velocity of the contractions. A study directly measuring the effect of contraction speed on EMG activity by Rosentswieg, Hinson, and Ridgway (1975) used a modified bench press as the exercise modality. In this study, subjects performed sets of three different contraction speeds. Researchers measured EMG for the anterior deltoid, pectoralis major, biceps brachii, and triceps. Findings indicated more muscular activity at the slower speeds. The researchers suggest that the increased muscular activity may be a reason why slower speeds appear to develop strength faster.

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Research involving muscular activity during isotonic contractions is scarce. One study involving surface EMG (sEMG) analysis during fatiguing dynamic (isotonic) contractions addresses this issue (Potvin, 1997). The study was specifically designed to determine the feasibility and limitations of using sEMG to monitor muscle activity during isotonic contractions. In this study, Potvin measured average EMG (aEMG) amplitude, mean power frequency (MPF), and angular velocity (AV), comparing the measurements from a rested to a fatigue related state. An increased aEMG was found from the rested condition to the fatigue related condition. MPF data were pooled with a progressive decrease in frequency when the fatigue related state was analyzed, followed by the AV showing no effect on aEMG during the eccentric phase and producing some increase in aEMG during the concentric phase of the contraction.

EMG measurements during isotonic activities have limitations. Isotonic movements allow for different variations in muscular activity and the limitations must be noted. Muscular activity can be accurately measured, however, increased activity does not indicate strength gains. Force measurements cannot be accurately detected during isotonic movements due to the variation in resistance (LeVeau and Andersson, 1992). Another limitation involving muscular activity is effectiveness of training. Theoretically, increased muscular activity leads to increased efficiency, however, no conclusive evidence exists measuring the effectiveness of high intensity versus traditional training methods. Limitations in measurement of muscular activity are force related and theoretical on the basis of effectiveness, but measurement of muscular activity has been reliably collected by researchers. The limitations involved with fatigue and frequency data are more operational. Power frequency data has been found to be an indicator of

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fatigue in isometric contractions, however the effects of movement may alter the display (Basmajian, 1986). Spectral shift indicates the onset of fatigue (Enoka, 1988; Basmajian and DeLuca, 1986) and the information collected from EMG measurements can be interpreted as an effect of fatigue, but significant spectral shift in MPF data may be difficult to determine during isotonic contractions (Potvin, 1997). These limitations may account for criticism of the current research, however, the theoretical and practical basis allows for interpretation and further discussion of the topic.

The research conducted by Rosentswieg, Hinson, and Ridgeway and Potvin demonstrates the importance of repetition speed and isotonic exercise. The experiments involve similar EMG measurements, but the failure to compare repetition speed during isotonic contractions limits the use for an average individual. Isotonic contractions are most often used when the general population exercises. The purpose of the current research will address these issues and discover muscular differences between training protocols.

Summary

Investigations involving different weight-training methods have given fitness professionals the opportunity to select from a wide variety of resistance training protocols. The protocols function to increase muscular strength and muscular endurance. There is, however, debate over which protocols work most efficiently and most effectively. The debate has lead to many different investigations of the training methods. These experiments have not produced significant results concerning the most efficient or effective method of training.

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One of the most highly debated concepts is the speed of contraction. Some professionals believe that training at a faster speed will increase effectiveness. These professionals promote a fast contraction speed. Other professionals promote a slow contraction speed and believe slower training increases effectiveness and promotes a safer exercise program. Concerns regarding safety in weight training have been expressed, but it seems that both methods produce favorable results. The purpose of the current study is to determine the difference between fast and slow repetitions.

One useful tool developed to measure muscular activity is electromyography. Electromyography (EMG) allows researchers to measure muscular activity during the actual performance of a contraction. The EMG activity can be used to compare a participant performing any variety of training protocols, including fast or slow contractions.

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CHAPTER 3

METHODS

The purpose of this study was to determine if differences in EMG activity exist between fast and slow contraction speeds during isolated, one-armed biceps curls to muscle failure. Specifically, the study used electromyography (EMG) to determine differences in muscular activity, percent change in mean frequency, and time to muscular failure at different contraction speeds for the elbow flexors.

This chapter provides a description of the methods used in the present study. Initially, participant selection is addressed, followed by a description of the experimental protocol utilized in the study. Finally, the chapter discusses the instrumentation and procedures used to collect and analyze the data.

Participants

Participants were recruited from the University of Nevada, Las Vegas student population. The population was selected to represent normal, healthy male participants between the ages of 21 and 35 years. A subject data sheet was distributed to each participant asking name, age, height, weight, and dominant arm (See Appendix I). The throwing arm of each participant was as the dominant arm in this study. Each participant

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read and signed an informed consent form detailing the benefits and possible risks associated with participation in this study (See Appendix I).

Experimental Protocol

Twenty-six healthy male participants volunteered for the study. One participant was lost due to data collection error. Participants had an average age of 24.4, ranging from 21 years to 35 years. Average height was 69.7 inches. Average weight was 178.3 lbs. Descriptive statistics for individual participants can be found in Table 3.1. Each participant was required to report to the sports injury research center on three different days. Day 1 was participant orientation and determination of one repetition maximum (1RM). Days 2 and 3 were actual data collection.

During the orientation day, each participant was asked to complete the data sheet and sign the informed consent form (See Appendix I). In addition, each participant performed a series of single biceps curls to determine one repetition maximum (1RM). Afterwards, 75% of 1RM was calculated and each participant was scheduled for testing. At least two days recovery time was given to each participant following 1RM testing and data collection. On data collection days (2 and 3), the participant performed biceps curls to muscular failure on a preacher curl apparatus allowing for stability and isolation of the elbow flexors. For each test, the participant was seated in the preacher curl apparatus. A demonstration of the contraction speed was given and the participant was asked to simulate the motion involved in the test. Cadence for each contraction speed was maintained using a metronome and verbal assistance was given by the examiner during

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Table 3.1

Individual descriptive statistics

Participant	Age	Height	Weight	Dominant Arm	1RM
1	21	69	185	R	45.0
2	23	69	178	L	35.0
3	23	68	185	R	35.0
4	23	72	185	R	35.0
5	30	67	165	R	40.0
6	35	73	168	R	25.0
7	24	74	185	R	27.5
8	27	70	160	L	27.5
9	21	73	250	L	40.0
10	23	76	180	R	25.0
11	23	68	165	R	47.5
12	23	67	185	R	27.5
13	22	70	185	R	35.0
14	21	66	130	R	27.5
15	27	69	215	R	32.5
16	26	69	165	R	45.0
17	23	69	175	R	35.0
18	23	73	192	R	40.0
19	25	66	135	R	20.0
20	25	72	160	L	22.5
21	28	59	184	R	37.5
22	21	74	170	R	35.0
23	25	68	155	R	32.5
24	26	73	260	R	42.5
25	25	70	150	R	27.5
26	21	68	168	L	35.0
mean	24.38	69.69	178.27	---	---
sd	3.14	3.41	28.22	---	---

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each trial. Prior to the beginning of each test condition, the participant was given a set of instructions. Instructions involving positioning on the preacher curl apparatus included having the participant's feet remain flat on the floor, the upper arm remained flat on the bench, the non-dominant hand remained on the participant's hip and the wrist of the dominant arm was to remain straight. The instructions given involving the performance included completing the set to muscular failure, executing the most strenuous effort, completing each repetition through a full range of motion, and to perform the movement as smooth as possible. The set of instructions was given before each test condition. After the participant was ready, the EMG recording was started and the resistance was handed to the participant for testing. Muscular failure was achieved when the participant could no longer continue or proper cadence could no longer be maintained.

On the first test day, the participant either performed the fast or slow contraction speed based on participant counterbalancing. Scheduling for the second test was confirmed and two days rest was given for adequate muscle recovery. On the second test day, the participant performed the alternate speed. Prior to the second test, the participant was questioned about muscle soreness. If the participant was experiencing muscle soreness, an extra day of recovery was given. The training speeds used during each trial included a fast contraction speed and a slow contraction speed. The fast contraction speed had a one second concentric phase and a one second eccentric phase. The slow contraction speed consisted of a two second concentric phase and a four second eccentric phase (Brzycki, 1995). A metronome was set at 60 beats per minute and the participant was asked to follow the cadence for the fast contractions while a verbal cadence, assisted by the same metronome, was used for the slow contraction speed.

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Data Collection

Surface EMG (sEMG) signals were recorded from the biceps brachii of each participant's dominant arm. The skin was abraded, cleaned, and bipolar electrodes were attached over the belly of the muscle with a center-to-center distance of 1.5 cm. Measurements were taken across the muscle belly providing accurate placement, within one millimeter, of the electrodes between the testing days. A ground electrode was placed on the acromium process of the scapula. For each set of repetitions, the sEMG signals were recorded and saved. Dependent variables measured for each condition included integrated EMG (iEMG), percent change in mean frequency and time to muscular failure. The two levels of the independent variable were fast and slow contraction speeds. To ensure accurate electrode placement on the second test, a skin marker was used to outline the electrodes. On the second test day, the skin was again abraded and cleaned, and new electrodes were placed inside the marks.

Instrumentation and Data Acquisition

Electromyography measurements were recorded using the Noraxon Myosystem 2000. The Noraxon system was designed with breakthrough technology, allowing researchers to accurately measure EMG signals during dynamic movements. The system's signal processing allows clear, consistent measurement of muscular activity without commonly used filters that alter the frequency band of the amplifier. The Noraxon technology screens artifacts normally seen with dynamic movements.

EMG electrode cables were connected to the signal processor. When the signal was recorded, the EMG activity was converted from analog to digital and relayed to a

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personal computer. Integrated EMG is measured using the rectified signal. Rectification allows the EMG activity to be analyzed as a positive measurement throughout the recorded trial. The muscular activity (iEMG) was calculated as the area under the curve (Winter, Rau, Kadefors, Broman, and DeLuca, 1980). Mean frequency measurements are processed through the analysis of the frequency band. The raw EMG signal is mathematically separated into bandwidth using a Fast Fourier Transformation (FFT). The FFT identifies the power spectrum. Analysis of the power spectrum allows researchers to check signal quality and frequency distribution for the measurement. The combination of the frequency for each bandwidth produces mean frequency (LeVeau and Anderson, 1992). Measurement over time and comparison from a rested to a fatigued condition provides the change in frequency measurement that is generally related to fatigue. The measurements in this study were collected at 1000Hz, processed by the EMG software and recorded.

Data Analysis

The total iEMG, percent change in mean frequency (MF), and time to muscular failure were calculated for each set of contractions. Mean difference in iEMG between the conditions was analyzed using a dependent t-test. Percent change in MF was determined over time. Each set of contractions was marked and divided into individual contractions. Mean frequency for each individual contraction was calculated by the EMG software. The frequency data for each contraction changed during testing. The measurement of change in the frequency data, increase or decrease, was completed by comparing MF of the first and last contraction. The percent of increase or decrease in

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MF was the dependent variable. The percent change, increase or decrease, in MF was recorded for each condition and compared using a dependent t-test. Time to muscular failure was also recorded. The time in seconds was measured from the beginning of each contraction to muscular failure. Time to muscular failure (duration) was compared between each test condition using a dependent t-test. Alpha level was set at .05 using the Bonferroni technique (.05/3 = .167) to adjust for multiple t-tests. In addition to the direct comparison of the dependent variables, a Pearson's product moment correlation was used to determine the relationship between the variables. Correlation was used to analyze the relationship between iEMG and time to muscular failure, iEMG and change in MF, and time to muscular failure and change in MF. Each of the statistical analyses was completed on Microsoft Excel.

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CHAPTER 4

RESULTS

This study investigated differences in EMG activity between fast and slow contraction speeds. Isolated, one-armed biceps curls were performed to muscle failure at fast and slow contraction speeds and electromyography (EMG) was used to determine muscular activity for the two conditions. Integrated EMG, an indicator of muscular activity over time, was measured and compared for each test condition. Percent change in mean frequency was also measured by EMG and compared. The change in mean frequency has been related to fatiguing muscles, however problems associated with frequency data and isotonic contractions may inhibit a direct relationship to fatigue. Time to muscular failure was recorded and compared for each condition. The linear relationship between all pairs of the variables was also investigated in the study.

iEMG

Integrated EMG measurements indicate muscular activity over time. Increased muscular activity has been related to more effective strength gains (Rosentwieg et al., 1975). The iEMG was calculated for each test condition and compared using a dependent t-test. Typical iEMG recordings can be viewed in Figure 4.1. The fast contraction condition mean was 13456.40 ± 6213.86 μv (microvolts) while the slow

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contraction condition had a mean of 17799.10 ± 8403.99 μv. A graphical representation of the means is illustrated in Figure 4.2. Dependent t-test results reveal significant differences between fast and slow contraction speeds, ($t = 4.76$, $p < .001$).

Percent Change in Mean Frequency

Change in mean frequency has been related to the onset of fatigue during muscular contractions. Typical patterns in frequency data have generally shown decreases in frequency over time during fatiguing contractions (Hagberg, 1981; Potvin, 1997). Dynamic contractions inhibit accurate measurement of the onset of fatigue, however the change in mean frequency from beginning to end reveals consistency with previous research (Hagberg, 1981). The current data revealed decreasing frequency over time for each condition. A representative graph of frequency data demonstrates typical change over time for the two different trials (Figure 4.3). The mean decrease in percent change in MF for the fast contractions was 27.5 ± 9.8%. The slow contractions demonstrated less percent change in MF with an average of 22.8 ± 9.2%, however the mean comparison of change failed to reach significance, ($t = 2.46$, $p = .021$).

Time to Muscular Failure

Time to muscular failure was compared for each condition. The fast contraction condition had a mean of 38.9 ± 6.2 seconds to muscular failure while the slow contraction condition had a mean of 68.6 ± 34.1 seconds. Figure 4.4 reveals a graphical representation of the mean comparison. The dependent t-test revealed a significant difference between conditions, ($t = 5.23$, $p < .001$).

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Correlations

A Pearson's product moment correlation was used to determine the relationship between, (1) iEMG and time to muscular failure, (2) iEMG and percent change in MF, and (3) time to muscular failure and percent change in MF. The relationship between iEMG and time to muscular failure was significant ($r = .514$, $p < .05$). A significant relationship was detected with 26.5% of the variability shared between the variables. Examination of iEMG and percent change in MF revealed no significant relationship between the variables ($r = .046$, $p > .05$). A non-significant relationship was also determined between time to muscular failure and percent change in MF ($r = .11$, $p > .05$). Observed and critical values are presented in Table 4.1.

Table 4.1

Correlation Matrix

	iEMG	Change in MF	Duration
iEMG	--- ---	r = 0.046 p = 0.753	r = 0.514 p = 0.001
Change in MF		--- ---	r = 0.110 p = 0.449
Duration			--- ---

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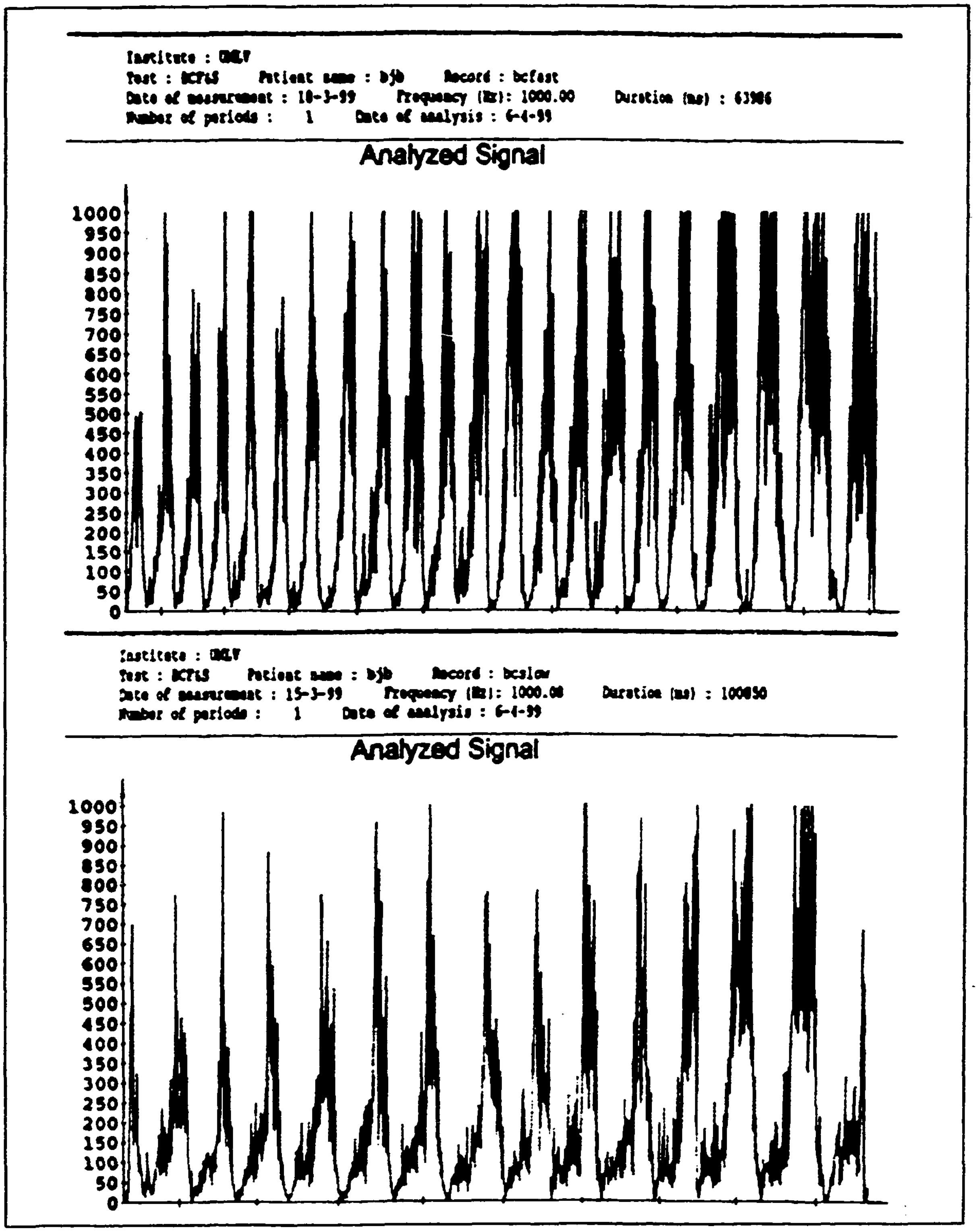

Institute : UNLV
Test : BCT&S Patient name : bjb Record : bcfast
Date of measurement : 18-3-99 Frequency (Hz): 1000.00 Duration (ms) : 63986
Number of periods : 1 Date of analysis : 6-4-99

Institute : UNLV
Test : BCT&S Patient name : bjb Record : bcslow
Date of measurement : 15-3-99 Frequency (Hz): 1000.00 Duration (ms) : 100050
Number of periods : 1 Date of analysis : 6-4-99

Figure 4.1 Typical representations of integrated EMG data. Fast contraction speed (top) from rested state to muscular failure. Slow contraction speed (bottom) from rested state to muscular failure.

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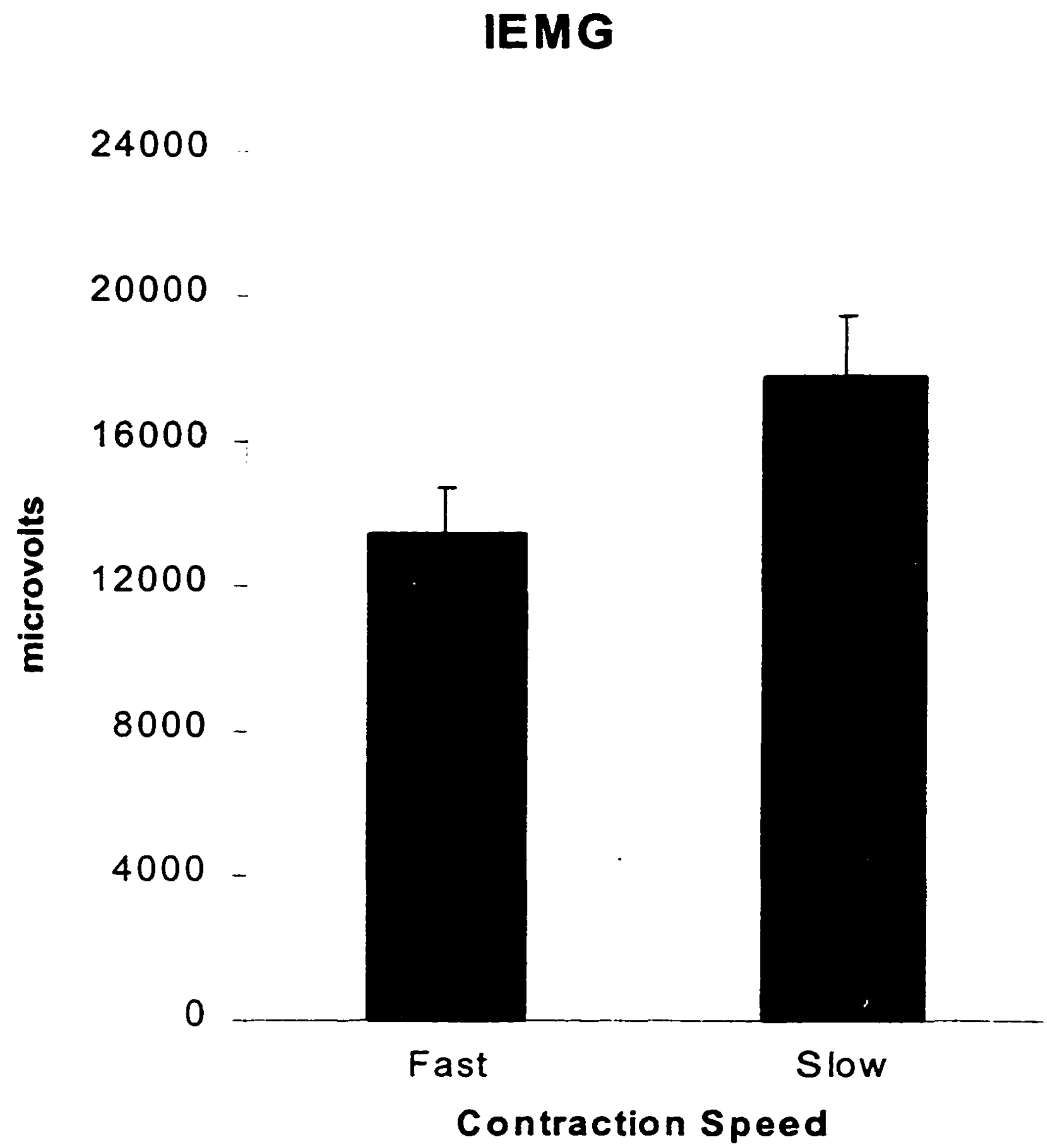

Figure 4.2 Comparison of fast and slow contraction speeds. Slow contraction speed reveals significantly greater iEMG from rested state to muscular failure.

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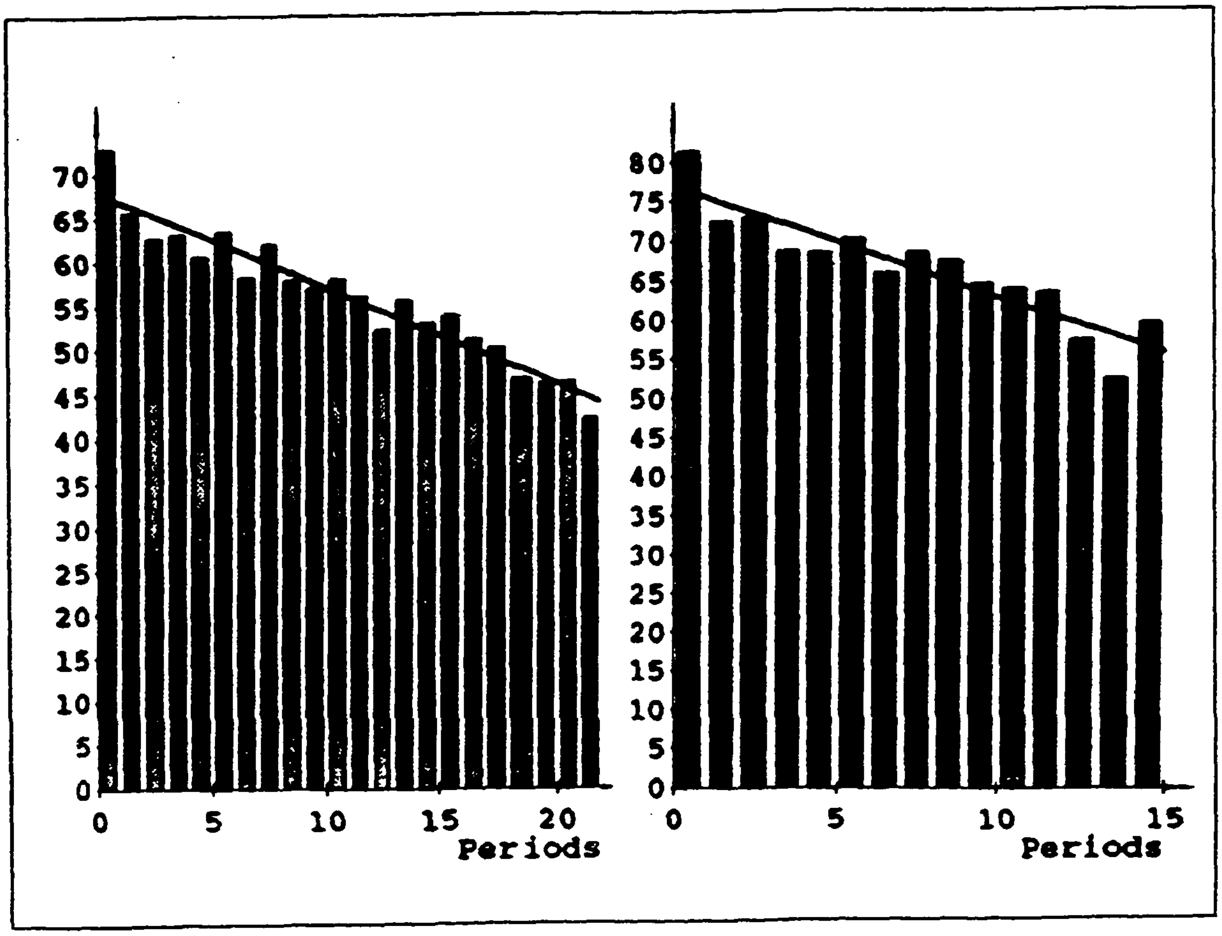

Figure 4.3 Typical frequency data for fast (left) and slow (right) contraction speeds. Measurements taken for each contraction (period) from rested state to muscular failure.

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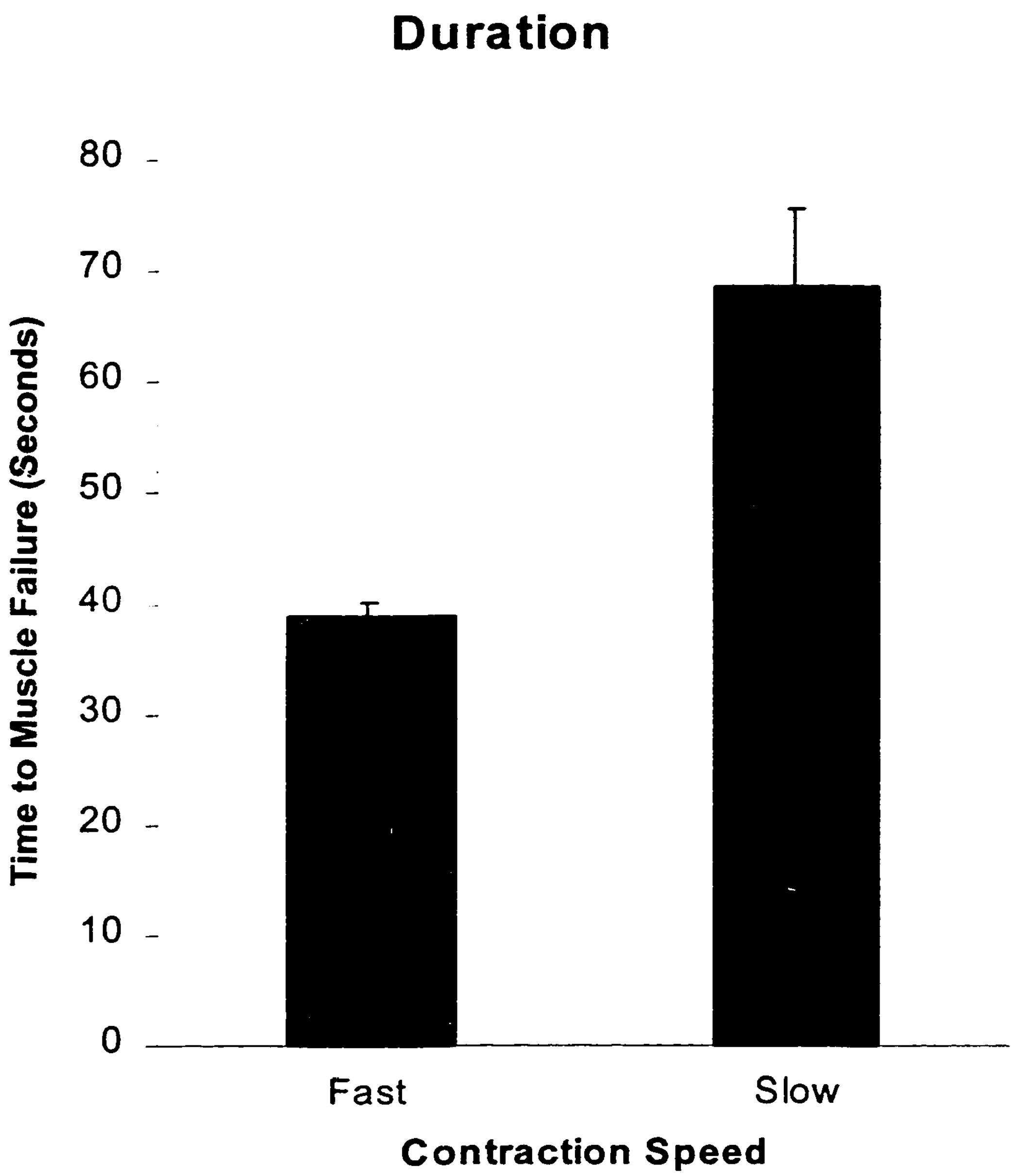

Figure 4.4 Mean comparison of time to muscular failure for fast and slow contraction speeds.

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CHAPTER 5

DISCUSSION

The purpose of this study was to determine if differences in EMG activity exist between fast and slow contraction speeds during isolated, one-armed biceps curls to muscle failure. Significant differences were seen between fast and slow contraction speeds for both integrated EMG (iEMG) and time to muscular failure. The linear relationship between time to muscular failure and iEMG was also significant. A moderate relationship (r = .514) was determined, however other variables, including intensity of contraction, may contribute to the correlation. This chapter includes possible explanations for the differences found in each of the analyzed measurements, the possible relationship to efficiency of strength training, and a conclusion.

Integrated EMG

Integrated EMG measurements record muscular activity over time. The measurements have been shown to progressively increase during fatiguing muscle contractions (Potvin, 1997; Hagberg, 1981). These findings are similar to previous EMG research that tested differences between contraction speeds (Hagberg, 1981; Arendt-Nielsen and Mills, 1988). In a comparison of contraction speeds, Rosentswieg et al. (1975) found significantly higher EMG activity for slower contraction speeds. The

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findings of this study revealed similar results. Significant differences were found when comparing muscular activity between contraction speeds. The slow test condition produced more muscular activity than the fast test condition. More muscular activity during the slow contractions may have resulted from more muscular work. When muscle contractions are slow and deliberate, the muscle is forced to overcome the resistance without momentum. Momentum may lessen the resistance following the initial movement and may elicit less muscular response. Another possible explanation for the differences in iEMG may be the length of the set of contractions. The iEMG for the slow contractions was significantly higher than the fast contractions, however, time to muscular failure was also greater during the slow contractions.

Time to Muscle Failure

Time to muscular failure was measured and analyzed. Measurement of muscular failure was subjective, however, each participant was urged to complete the two test conditions with the same effort. Time to muscle failure was used because muscular failure is regarded as the point where muscles will begin to adapt during weight training (Selye, 1956). Muscular failure was reached when the participants could no longer move the resistance or the proper cadence could not be maintained. Significant differences were found between fast and slow contraction speeds. Time to muscle failure was significantly longer during the slow contraction speed. An explanation for this finding could be that the muscles fatigued more quickly during the fast contractions. Overcoming the same resistance at a faster pace may have increased the speed of the muscles' recruitment of the fast twitch fibers. If the muscle recruitment was increased,

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the fast twitch fibers may have been needed sooner and the muscle may have fatigued faster. This evidence could suggest that weight training should be performed at a faster pace because the fast twitch fibers may have been recruited faster, however, the fast twitch fibers are also recruited during the slow contractions. The benefits of increased muscle activity (iEMG) may outweigh the benefits of achieving muscle failure in less time.

Change in Mean Frequency

Mean frequency (MF), an EMG measurement used to gain an understanding of muscle fatigue, was measured for the two test conditions. MF was calculated for each separate contraction. The change in MF, from start to finish, was recorded. The change in mean frequency was converted to a percentage and was compared for the two test conditions. Frequency data measurements were similar to findings in previous research, but the comparison of change between conditions revealed no significant differences. Measurement of muscle fatigue using EMG has previously been studied. However, Potvin suggested that mean frequency may be altered during isotonic movements. The current evidence provides support to findings that report decreasing frequency data over time (Hagberg, 1981, Potvin, 1997), but the lack of a significant difference in change between contraction speeds fails to provide evidence supporting different levels of fatigue for the two test conditions. The data demonstrated a higher percent change in MF for the fast contractions, but significance was not achieved. A possible explanation for the increased change may be the shortened duration for the fast contraction trial.

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Correlations

The linear relationship between iEMG and time to muscle failure may explain why slow contractions elicit more muscular activity than fast contractions. The findings indicate a moderate relationship (r = .514) explaining 26.5% of the variability within the data. A possible explanation for the relationship between iEMG and time to muscular failure could be the intensity of the contractions. In this case, the intensity of the contractions can be defined as increased muscle activation (Enoka, 1988). Fast contraction speeds introduce momentum during performance (Brzycki, 1995). When momentum becomes involved during weight training, an initial burst of energy accelerates the resistance. Once the resistance is in motion the muscle must maintain control, but increasing activation is not required (Allman, 1979; Pollack et al., 1993). Performing slow contractions reduces the involvement of momentum when free weight training, increasing the intensity of the training.

The relationship between iEMG and change in mean frequency was also analyzed. The relationship between the variables was non-significant (r = .046). This finding suggests that no relationship exists between muscular activity and fatigue-related changes seen in EMG measurements. The finding also provides evidence suggesting increased muscular activity (iEMG) does not lead to greater decreases in frequency data. Previous research has indicated that as muscular activity increases the mean frequency decreases, however the previous research failed to compare contraction speed and its effect on mean frequency. The current evidence may have limitations. If a weak relationship exists between the change in mean frequency and fatigue, during isotonic movements, the findings may be flawed.

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Finally, the relationship between time to muscular failure and change in mean frequency was examined. This relationship was also found to be non-significant (r = .110). Therefore, time to muscular failure is independent of change in mean frequency. Change in mean frequency has been related to muscle fatigue, however the findings of this study suggest that increased duration does not indicate increased fatigue. Contraction speed must therefore affect the relationship between duration and the onset of fatigue.

Efficiency of Strength Training

Some authors have reported less efficient strength training when performing fast contractions speeds (Pipes, 1979, Pollack et al., 1993, Brzycki, 1995). Muscular efficiency can be defined as the optimal muscular activation for the movement performed. A more efficient training protocol would produce greater strength increases and would maintain strength without wasted effort (Brzycki, 1995). Slow contraction speeds and the protocols promoting them appear to be more efficient for increasing muscular activation. Muscle fatigue has also been related to efficiency of strength training. Achieving muscular failure will fatigue muscle leading to adaptation (Brzycki, 1995; DeLorme, 1945; Pollack et al., 1993). Faster contraction speeds may achieve muscle failure in less time than slow contraction speeds, but recruitment of fast twitch fibers occurs during both protocols and slow contractions elicit more muscular activity than fast contractions.

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Conclusions

The findings of this study provide evidence that significant differences in EMG activity and time to muscle failure exist between fast and slow contraction speeds. Differences between fast and slow contraction speeds are clear and the evidence provided by this research may help to explain differences between the techniques promoting fast or slow contraction speeds. The findings do not provide an explanation of which training method achieves more strength gains, but the evidence may suggest differences in efficiency for fast and slow contraction speeds. The current findings demonstrate the feasibility of testing different training speeds using electromyography, but further research must be conducted to determine answers for the debate between the techniques that promote different contraction speeds in strength training. The relationship between iEMG and time to muscular failure indicates an explanation of increased iEMG while performing the slow contractions, however other variables contribute to the increased muscle activity. Finally, contraction speed may affect frequency data when determining a relationship with muscular activity.

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APPENDIX I

INSTITUTIONAL REVIEW BOARD APPROVAL

INFORMED CONSENT

DATA SHEET

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UNLV

DATE: November 5, 1998

TO: Philip J. Melhorn (KIN-3034)

FROM: Dr. John Young, Chair
Biomedical Sciences Committee

RE: Expedited Review of Human Subject Protocol:
"An Electromyographical Comparison of Slow and Fast Isotonic Contractions to Fatigue of the Biceps Brachii"
OSP #: 504s0998-106x

The protocol for the project referenced above has been reviewed and approved by an expedited review by the Institutional Review Board Biomedical Sciences Committee. This protocol is approved for a period of one year from the date of this notification and work on the project may proceed.

Should the use of human subjects described in this protocol continue beyond a year from the date of this notification, it will be necessary to request an extension.

If you have any questions or require any assistance, please contact Marsha Green, IRB Secretary, at 895-1357.

cc: M. Hoffman (KIN-3034)
CSP File

Office of Sponsored Programs
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Informed Consent

University of Nevada, Las Vegas - Department of Kinesiology

Sports Injury Research Center

1. The principal investigator for this study is Philip J. Melhorn, who is a graduate student in the Department of Kinesiology, UNLV.
2. You are invited to participate in a study analyzing the muscular activity of the elbow flexors completed at different training speeds.
3. The purpose of this study is to determine if there is a difference in muscular activity, change in mean frequency, and time to failure when performing biceps curls at different training speeds. On two separate occasions participants will complete one set of biceps curls to fatigue with identical resistance. Each participant will follow a cadence set by a metronome for specific training speeds. Electromyography (EMG) will be used to measure the muscular activity and provide a measurement associated with fatigue of the elbow flexors. The testing will last approximately 15-35 minutes including preparation time for each session.
4. Risks involved include possible muscular soreness of the elbow flexors lasting no more than 24 hours and possible light skin irritation from electrode placement. Participation in scientific research is the only apparent benefit.
5. Any personal information that is obtained in the course of this study will remain confidential. The results of this study may be published in scientific journals, but only statistical data will be published and no individual participant will be identified.
6. If you have any questions or concerns about this research, or if you wish information about the rights of research subjects, you may contact the Office of Sponsored Programs, UNLV, at 702-895-1357, Philip J. Melhorn, Department of Kinesiology, at 702-870-0829, or Dr. Mark Hoffman, Department of Kinesiology, at 702-895-3419.
7. Participation in this study is entirely voluntary, and you may withdraw from participation at any time. Your decision whether or not to participate or to withdraw will not prejudice your future relations with the University of Nevada, Las Vegas.

Your signature below indicates that you have read the above information, and that you are consenting to participate in this research study.

______________________	______________________
Printed Name	Date and Time
______________________	______________________
Signature	Participant Number

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A Comparison of EMG activity, change in mean frequency, and time to failure while performing fast and slow contraction speeds of the elbow flexors

Name: ____________________________________

Code: ___________

Date of Birth: _____/_____/_____ Age: __________

Height: _______________inches Weight: _________

Dominant arm (throwing arm)(circle one): RIGHT LEFT

Have you ever been diagnosed with or experienced any musculoskeletal disorder of the upper body? If yes, explain: ______________________________________

One repetition maximum (1RM): ________________

Adjusted resistance (75% of 1RM): ________________

Contraction speed:

	Fast	Slow
Trial date	_______	________
IEMG	_______	________
Change in MF	_______	________
Duration	_______	________

Comments: ____

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APPENDIX II

INDIVIDUAL PARTICIPANT DATA

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		Fast			Slow	
Participant	iEMG	Change in MF	Duration	iEMG	Change in MF	Duration
1	14474.06	-22.06	35.943	19564.29	-23.41	39.604
2	19042.93	-15.43	23.213	31555.46	-14.39	47.652
3	12390.22	-29.24	51.337	21329.34	-12.35	72.074
4	31424.89	-23.26	55.393	39006.81	-15.18	80.494
5	15973.31	-43.06	48.240	17590.77	-30.70	87.730
6	10096.10	-45.53	44.334	10809.46	-35.03	53.419
7	11631.95	-24.16	34.454	27.655.18	-12.89	127.821
8	11210.92	-38.86	56.036	17003.71	-28.89	145.687
9	4790.11	-13.46	32.458	6844.45	-18.42	39.714
10	22258.20	-36.79	54.378	24730.90	-18.30	145.524
11	18810.64	-20.67	48.824	24295.06	-18.00	64.136
12	5651.39	-16.64	44.344	6560.29	-26.32	66.350
13	7625.08	-23.78	33.619	6566.70	-8.87	34.814
14	18308.22	-41.89	58.433	19514.00	-26.69	93.766
15	8093.23	-13.92	20.776	9107.03	-17.24	29.657
16	12992.71	-22.23	18.341	20496.12	-16.31	41.099
17	23722.16	-39.77	37.179	24306.10	-49.16	69.953
18	13024.63	-30.29	53.407	10666.19	-15.27	47.272
19	8506.91	-33.01	30.826	11620.47	-20.60	39.387
20	13609.03	-39.27	48.390	26142.73	-35.07	121.077
21	15643.02	-20.72	38.467	21101.10	-33.44	65.108
22	8645.18	-20.37	17.350	13580.25	-24.89	39.560
23	12064.77	-22.97	41.890	11531.61	-22.72	61.412
24	8950.76	-24.34	32.013	11083.75	-29.00	57.835
25	7500.41	-20.01	19.802	12253.01	-16.12	44.839

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APPENDIX III

STATISTICAL DATA

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Integrated EMG

t-Test: Paired Two Sample for Means
iEMG (microvolts)

	Fast	*Slow*
Mean	13456.3932	17799.1112
Variance	38612114.7520	70627116.6105
Observations	25.0000	25.0000
Pearson Correlation	0.8472	
Hypothesized Mean Difference	0.0000	
df	24.0000	
t Stat	-4.7657	
P(T<=t) one-tail	0.0000	
t Critical one-tail	1.7109	
P(T<=t) two-tail	0.0001	
t Critical two-tail	2.0639	

Change in Mean Frequency

t-Test: Paired Two Sample for Means
Change in MF (%)

	Fast	*Slow*
Mean	-27.2692	-22.7632
Variance	95.587816	85.52693933
Observations	25	25
Pearson Correlation	0.538705781	
Hypothesized Mean Difference	0	
df	24	
t Stat	-2.462657765	
P(T<=t) one-tail	0.010676214	
t Critical one-tail	1.710882316	
P(T<=t) two-tail	0.021352427	
t Critical two-tail	2.063898137	

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Time to Muscle Failure

t-Test: Paired Two Sample for Means
Time to Muscle Failure (seconds)

	Fast	*Slow*
Mean	38.85788	68.63736
Variance	160.3308936	1164.74298
Observations	25	25
Pearson Correlation	0.598208058	
Hypothesized Mean Difference	0	
df	24	
t Stat	-5.238012107	
P(T<=t) one-tail	1.13863E-05	
t Critical one-tail	1.710882316	
P(T<=t) two-tail	2.27725E-05	
t Critical two-tail	2.063898137	

iEMG and Duration

SUMMARY OUTPUT
Correlation (iEMG and Duration)

Regression Statistics	
Multiple R	0.514834626
R Square	0.265054692
Adjusted R Square	0.249743331
Standard Error	6614.524197
Observations	50

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iEMG and Change in Mean Frequency

SUMMARY OUTPUT
Correlation (iEMG and Change in MF)

Regression Statistics	
Multiple R	0.045659
R Square	0.002085
Adjusted R Square	-0.01871
Standard Error	9.77983
Observations	50

Duration and Change in Mean Frequency

SUMMARY OUTPUT
Correlation (Duration and Change in MF)

Regression Statistics	
Multiple R	0.109399
R Square	0.011968
Adjusted R Square	-0.00862
Standard Error	9.73128
Observations	50

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