EFFECTS OF CONCENTRIC AND ECCENTRIC CONTRACTIONS OF THE KNEE EXTENSORS ON MECHANICAL WORK, LACTATE CONCENTRATION, AND SURFACE EMG

by

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ABSTRACT

EFFECTS OF CONCENTRIC AND ECCENTRIC CONTRACTIONS OF THE KNEE EXTENSORS ON MECHANICAL WORK, LACTATE CONCENTRATION, AND SURFACE EMG

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The purpose of this study was to determine the effects of eccentric and concentric muscle contractions on the frequency and amplitude of EMG, torque, blood lactate, and the amount of work done. Ten college-aged males performed either four sets of twenty eccentric or concentric maximal contractions to induce muscle fatigue. Pre- and post-fatigues measurements of torque, EMG, blood lactate and work done were recorded. A 2 x 2 repeated measures ANOVA was used to test for differences in condition (concentric, eccentric) and time (pre, post) for the following dependent variables: total work done, average torque, change in lactate concentrations VL EMG, RF EMG and VM EMG. Significant pre – post differences were found for torque,

blood lactate and EMG median frequency. There was a significant interaction between time and condition for VL EMG amplitude. In the concentric condition VL EMG amplitude decreased due to fatigue, and increased due to fatigue in the eccentric condition. For work done the third and fourth sets were significantly lower than the first set for both the eccentric and concentric conditions.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The energy source for short-term, high-intensity exercise primarily comes from glycolysis and the phosphagen systems. When ATP is broken down to ADP and $P_{i,}$ a H^+ is released. During anaerobic metabolism, ATP is broken down in the cytosol and results in the accumulation of H^+ and eventually results on acidosis (27). Under these metabolic conditions lactate production delays the onset of muscle fatigue. While lactate does not causes acidosis, it is an indirect marker of the metabolic conditions that lead to acidosis. As an indirect marker of fatigue, lactate accumulation occurs when the rate of appearance is greater then the rate of disappearance. At rest blood lactate is typically in the range of 1-2mmol/L and following short-term, high-intensity exercise it can reach values over 20 mmol/L (27).

When the amount of work done is kept constant, concentric contractions will have a higher blood lactate concentration then eccentric contractions (4, 14, 19). Horstmann et al. (14) reported that one minute of concentric isokinetic contractions resulted in 5 mmol/L of blood lactate with a total work done of 6240 J. In comparison, one minute of eccentric isokinetic contractions resulted in 1 mmol/L blood lactate with of total work done of 6528 J. In addition to theses differences in blood lactate between

eccentric and concentric contractions, eccentric contractions will produce higher torque and lower EMG amplitudes (19, 29).

Enoka (10) has suggested that eccentric contractions may require a unique neural control. Furthermore, there is limited evidence that fast twitch motor units are selectively recruited during eccentric contractions (22, 28). Muscle biopsies following eccentric exercise have shown that predominately fast twitch fibers are damaged due to the high strains imposed by eccentric exercise (12, 20). Horstmann et al. (14) compared eccentric and concentric contractions while keeping the work done constant, but EMG data were not collected. None of the studies presented above have compared the changes in isometric EMG due to fatigue following eccentric and concentric exercise.

The purpose of this study is determine the effects of eccentric and concentric muscle contractions on the frequency and amplitude of EMG, torque generation, blood lactate, and the amount of work done.

1.2 Hypothesis

The null hypotheses for this study are: 1) no differences the changes in torque between eccentric and concentric contractions; 2) no differences in the changes in blood lactate between eccentric and concentric contractions; 3) no differences in work done between eccentric and concentric contractions; 4) no differences in EMG frequency and amplitude between eccentric and concentric contractions.

1.3 Definition of Terms

Eccentric Contractions- is a type of muscle contraction in which the resistance (such as a weight carried in the hand) is greater than the force applied by the muscle so that the muscle lengthens as it contracts.

Concentric Contractions- is a type of muscle contraction in which the muscles generates enough force to overcome the resistance to joint movement so it shortens as it contracts.

Surface Electromyography (EMG) - recording of electrical and neural activity in contracting muscles through the placement of electrodes on the surface of the skin.

Lactate- An indirect marker of fatigue. Lactate is a byproduct of anaerobic metabolism and it delays the onset of fatigue.

Fatigue- The decreased capacity or complete inability of an organism, an organ, or a part to function normally because of excessive stimulation or prolonged exertion.

1.4 Delimitations

The delimitations of the study were 1) males between the ages of 18 and 35 from the University of Texas at Arlington, 2) males without lower leg injuries within the past 2 years, 3) males that performed lower leg workout twice a week for at least the last month, and 4) males that were able to complete the 4 set of 20 eccentric and concentric contractions.

1.5 Assumptions

The following assumptions were made during the study: 1) the subjects filled out the health questionnaire accurately, 2) the subjects were well leg trained, 3) the subjects did not experience any muscle soreness on the day of testing, and 4) the subjects were able to finish the two different protocols fully.

1.6 Limitations

The limitations in my study included not being able to tell if the subject gave maximum effort; not knowing if the subject was actually leg trained; not knowing if the subject was still experiences soreness in the quadriceps; learning effect; subject selections; willingness of the subject; placement of the electrodes.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Introductory Statement

Literature relative to fatigue following eccentric and concentric contractions will be presented in the following sections: Fatigue and Lactate, Fatigue in Constant Force Isometric Contractions, Fatigue in Intermittent Force Isometric Contractions, Fatigue in Ramp Isometric Contractions, Fatigue in Eccentric Contractions, and Fatigue in Concentric Contractions.

2.2 Fatigue and Lactate

Fatigue is the major limiting factor in sports and physical activity around the world. Fatigue causes the body to not be able to produce the amount of force and energy needed to functional properly at high levels. Fatigue has been defined as a decrease in force production o an inability to regenerate the original force in the presence of an increased perception of effort. (18). The exact cause or mechanism for fatigue is still being explored for voluntary contractions. When one becomes fatigued or tired, the person's form starts to deteriorate. When one's form starts to go bad, then injury occurs when the person's body starts to overcompensate using various methods from different body parts. This deficiency has been contributed to a wide range of

factors that include activations from the central nervous system to muscles fibers themselves to myofilament interaction to the muscle not being able to perform the contraction (11).

There are two different theories on fatigue: central nervous and peripheral fatigue. Central fatigue can be described as a decrease in the neural drive or component of the motor unit that commands the muscles that decrease in force after contractions (17). Noakes suggested that this central fatigue could be a safety mechanism for the prevention of an organ failure at high intensities for long duration of times (24). Noakes believed that oxygen sensitive organs would send a signal to the "central governor" of the brain. This "central governor" would limit the muscle fiber recruitment in both submaximal and maximal exercise, so that anaerobiosis and ischemia would not occur at the organ and tissue level. Noakes also stated that there is a reduction in muscle recruitment, muscle glycolysis, O_2 consumption, and cardiovascular function but there is no evidence of change in myocardial function during maximal exercise (25).

The exact mechanism for central fatigue is unknown, but it has been speculated that serotonergic pathways are heavily involved in central fatigue (7, 23). Failure of a muscle to respond to an increase in neural stimulation indicates that the fatigue is not central rather the fatigue in peripheral. Peripheral fatigue is defined as when there is a decrease in the force generating ability of a muscle that is the result of action potential failure, impairment of cross-bridge formation, or excitation contraction coupling failure

when the neural drive has increased or is unchanged. The muscle will have lost its ability to perform the action (18).

A way to measure the neural drive for central fatigue is to use surface electromyography (EMG). Through the use of EMG, one can look at the firing of the muscle fibers before an exercise and after an exercise to determine the fatigue by examining the muscle fibers at the pre test at an isometric contraction and the post test EMG reading at a specific isometric contraction. Fatigue can be determined by measuring the EMG readings at a specific force at an isometric contraction before and after the compare the two (3). In previous studies, EMG readings have been used to show the electrical aspects of a muscle during a contraction. Also EMG have been used to determine if a specific muscle has undergone muscle fatigue be taking a pre EMG readings and a post EMG recording readings. EMG amplitude gives information that tells the motor unit firing rate and recruitment of the motor units. The EMG frequency gives the conduction velocity of the motor unit and the frequency in which the motor units are firing. As the muscle exhibits more fatigue, the amplitude in the EMG reading should go up (6). The increase in amplitude shows that they firing rate of the motor units have increased, along with the increase in motor unit recruitment. This proves the point that more motor units were used when the muscle was fatigue (3). Also root mean squared is the unit of measurement for the EMG reading. Immediately following the maximal eccentric contractions, the EMG power spectrum has been shown to be lower when comparing it to the pre exercise EMG readings. Lieber and Friden showed that since fast twitch muscle fibers and the main fiber type that is used during eccentric

contractions, there will be more selectively damage to theses type of fibers this damage should be reflected in the median frequency spectrum(12).

Lactate is a by product of anaerobic glycolysis when oxygen is not present. Lactate ion is formed when a proton or hydrogen is removed from carboxylic acid group of lactic acid when placed a solution. There are two isomers or types of lactate that exist in nature, l-lactate and s-lactate, with l-lactate being the predominately more important form in humans and mammals. Pyruvate is converted to lactate by the enzyme lactate dehydrogenase during the last step of glycolysis when oxygen is not readily available (27).

Resting lactate levels usually appear in the range of 1-2mmol/L in the blood and can reach to values of over 20mmol/L in extreme exercise conditions (27). Lactate is regularly maintained in the body and its concentration is not increased until the rate of production exceeds the rate of clearance in the body. This occurrence usually starts to happen during intense exercise when energy is needed immediately (27). The free floating lactate is then converted to energy in a variety of different ways. Lactate is shuttle to the liver and converted back to pyruvate by the enzyme lactate dehydrogenase. Pyruvate is then turned into glucose through the process of gluconeogensis and the glucose is cycled through the blood and use as energy for the muscle cells. This whole process is called the Cori cycle (27).

2.3 Isometric Fatigue

The body fatigues in different ways depending on the type of muscle action or motor unit activation that is needed in order to perform the task. The different muscle actions will have different torque, RMS, and median frequency reading in the muscle. In a study done by Babault et al (1), the researchers examined maximal concentric and isometric contractions. Neuromuscular activity has been measure by using isometric contractions. The different types of fatigue are dependent on the different types of muscular contractions. Isometric fatigue will be affected by the type of isometric contraction (constant force, intermittent contraction, non constant force), the length of time the contraction is held, and the level of muscular activation.

2.4 Fatigue in Constant Force Isometric Contractions

Iguchi (15) et al examined the effects of low frequency fatigue in the human quadriceps. The muscles that were examined were the vastus medialis (VM) and the rectus femoris (RF). Iguchi et al. had the subjects perform two fatigue tasks at 35% and 65% of a maximal voluntary contraction (MVC). For the 35% MVC fatiguing task, the subjects held the contraction for at 35% MVC for as long as possible. When the subject could not maintain the level, the subjects were required to produce a force greater than 55% MVC, then bring the force back to 35% MVC and hold the contraction for as long they can. If the force was not maintained for at least 3 seconds, then the test was terminated. For the 65% MVC, the subject had to hold the isometric contraction at the 65% target line until the force dropped below the line. When the force dropped below

45% MVC for 3 seconds, the task was terminated. The RMS amplitude for both muscles (VM and RF) increased progressively. The VM had a greater progression then the RF. This showed that VM and RF have different functions in fatiguing isometric contractions. For the MPF variable, there was not a significant difference between the two muscles. The torque changes for the 35% and 65% were 37.2 ± 73.5 Nm and 29.5 ± 62.8 Nm, respectively. The changes in EMG amplitude for the VM and RF at 35% MVC were 22 ± 6.2 %MVC and 16.8 ± 5.9 %MVC, respectively. The changes in EMG amplitude for the VM and RF at 65% MVC were 29.5± 13.9 %MVC and 15.4± 15.5 %MVC, respectively.

Mathur et al. (21) examined the reliability of surface EMG during sustained contractions of the quadriceps. The muscles that were examined were the rectus femoris (RF), vastus lateralis (VL), and the vastus medialis (VM). The subject performed a fatiguing task of 80% MVC on their dominant leg and 20% MVC on the other leg. The subject was told to hold the contraction as long as possible and when the contraction was not maintained at 20% of the target level, the test was then terminated. Mathur et al. reported MDF values for the 80% fatiguing task demonstrated for the RF, VL and VM were normalized values 0.78 ± 0.009 Hz, 0.86 ± 0.009 Hz, and 0.87 ± 0.11 Hz, respectively. In the 80% MVC fatigue task the change in EMG amplitudes for RF, VL, and VM were -8.6 μV, 23.8 μV, and 33.9 μV, respectively. Mathur et al. reported MDF values for the 20% fatiguing task demonstrated for the RF, VL and VM were normalized values 0.9 ± 0.13 Hz, 0.86 ± 0.12 Hz, and 0.92 ± 0.0088 Hz, respectively. Also, Mathur et al reported that EMG amplitudes for RF, VL, and VM of the 20%

fatiguing task to be 49.1 ± 57.3 μV, 64 ± 55.1 μV, and 33.9 ± 80.3 μV respectively. Mathur et al. found no significant difference among the different muscle for either the EMG amplitude or the MDF. They also suggested that the RF fatigued greater then the other two muscle groups during the 80% MVC. There was no significant difference in the rate of fatigue for the 20% MVC. Mathur et al. concluded that not all muscle groups recruited fiber the same way during knee extensions exercise. The also reported that RF had lower normalized MDF when compared to the two vasti muscle groups.

2.5 Fatigue in Intermittent Force Isometric Contractions

Babault et al.(1) investigated neuromuscular fatigue during maximum concentric and isometric contractions in the knee extensors. The vastus lateralis (VL) was examined during the study. In the concentric condition the subjects' were required to perform two sets of 3 concentric contractions at 60º/sec with two minutes rest in between sets. For the isometric portion (ISO), the subjects' performed three five second isometric MVCs with a minute rest in between the MVCs. Afterwards the subjects performed the two fatiguing protocols. For the CON protocol, the subject performed three sets of 30 maximal contractions (S1, S2, and S3). The last three contractions of each series were analyzed. During the ISO protocol (S1, S2, S3), the subject performed three MVCs. The MVCs were held until the torque reduction equal the same reduction that took place in the CON fatigue protocol. The decreases in torque after the ISO fatiguing protocol was 37.8 ± 11.5%, 46.4 ± 9.2%, and 57.9 ± 8.6 for S1, S2 and S3. The decreases in torque for the CON protocol were 35.9 ± 12.1%, 51.5 ± 8.6%, and

59.0 ± 8.1% for S1, S2, and S3. The activation levels for the ISO protocol was significantly greater reduction when compared to the CON protocol. Those values for CON were 11.2 ± 3.3, 15.2 ± 7.0, and 27.0 ± 6.0% for S1, S2, and S3, while the ISO values were 27.5 ± 6.6, 33.6 ± 6.4, and 36.3 ± 11.3% for S1, S2, and S3. The RMS of the VL after CON (5.9 ± 14.7. -5.8 ± 13.3, and -3.9 ± 7.9% for S1, S2, S3), were not significantly different from the pre fatigue values but for the ISO (-24.9 ± 14.9, -24.7 ± 24.8, -23.3 ± 24.1% for S1, S2, and S3), the RMS was significantly reduced ($P<0.01$). However, there were not any significantly differences between the series. Both protocol produced a significant difference in the MF when compared to the pre fatiguing readings (-20 ± 10%; $P<0.001$). The authors concluded that with the different protocols, the fatigue origin will be different. For the ISO protocol, central fatigue occurs first followed by peripheral, while with the CON protocol peripheral fatigue is first then central fatigue happens.

Beck et al.(2) examined the mechanomyographic amplitude and mean power frequency versus relationships during isokinetic and isometric muscles actions of the biceps brachii. The muscle that was observed was biceps brachii. There were two parts of the testing: isokinetic and isometric. The isometric portions consisted of two maximum 6 seconds isometric contractions done at 115 º joint angle to determine the MVC. Following the MVC determination, the subjects performed maximal muscle contractions in the range of 10% to 90% MVC in 10% increments in random order. A two minutes rest was given in between each contraction. After the contractions, two more MVC was measured to determine if there was a decrease in MVC. The isokinetic

phase consisted of subject laying supine and performing 2 maximum concentric contractions at 30º/sec, with the highest reading being the pre testing level. Afterwards, the subject performed submaximal contractions in 10% increments from the range of 10% to 90% PT in random order. Following the submaximal contractions, two more maximal efforts were performed to see if the PT was affected. There was no significant difference between the mean PT and MVC prior to or after the submaximal contractions. Also there were not any significant differences between the pre and post MVC and PT for each fatigue protocol.

Debrosses et al.(8) investigated the neural activation after maximal isometric contractions at different muscle lengths. The muscle groups that were examined were the vastus lateralis, rectus femoris, and the biceps femoris. The subjects were required to do a fatigue session at 40º knee flexion (FS) and a fatigue session at 100º knee flexion (FL). The pre and post MVC consisted of the subject holding the isometric MVC for five seconds and then the procedure was repeated. There were for post fatigue conditions that were measured: FS that was performed at both the short length (40º) and long length (100º) and FL that was performed at the two lengths too. During the fatiguing phase, the subject had to hold a MVC until there was 20% reduction in the predetermined MVC. The second contraction was held until there was a 40% decrease in MVC and the contraction were held until there was a 60% decrease in the MVC. Each subject completed both fatiguing protocol at the different lengths. There was a one minute rest in between each of the three contractions. The MVC torque levels were significantly different from the pre fatigue reading to the post fatigue reading but there

was no significant difference in between the conditions. The average torque reduction was 20.8% ± 7.6. The post MVC torque values were 176.7 ± 42.4 and 145.1 ± 27.2 Nm at the S and L lengths respectively after the FS condition. For the FL condition, the torque levels were 162.5 ± 25.4 and 148.9 ± 34.9 Nm at S and L respectively. The neural activation showed that there was a significantly decline in the S and L length of the FS (79 ± 13.1% and 87.1 ± 10.6%) condition but there was no significant difference in the FL (84.9 ± 9.9% and 93.4 ± 4.9%). For the RMS, there was no significant difference in the FL (0.055 ± 0.032 and 0.073 ± 0.037 at S and L respectively). However, there is a significantly decline in RMS values from pre to post fatigue in the FS condition (0.046 ± 0.023 and 0.061 ± 0.015). The authors concluded that different muscle length will produce different types of muscular fatigue. The short muscle length will typically produce more central fatigue while the longer muscle length will normally produce more peripheral fatigue.

2.6 Fatigue in Ramp Isometric Contractions

Mean frequency and signal amplitude of the surface EMG of the quadriceps increased with increasing torque were investigated by Karlsson et al(16). The muscles groups that were involved in the study were vastus lateralis, vastus medialis and the rectus femoris. The subjects were instructed to perform a gradually increased static knee extension at 90º knee flexed in approximately 10 seconds. The subjects performed three 10 s ramp contractions and the most linear contraction was used for data analysis. The data were processed using continuous wavelet transformation. The researchers

examine the relationship between EMG and force. The authors found that there was a positive correlation between the short-time MNF and force in the three muscle groups (mean R^2=0.25-0.37). For the RMS there was a positive and linear relationship between RMS and force (R=0.93, R=0.93, and R=0.91 for VL, RF, and VM respectively). The authors concluded that there was a strong relationship between RMS and force. The authors proposed mechanism behind this could be that with an increased in force cold be simultaneous recruitment of new motor units and an increased in firing rate.

2.7 Fatigue in Eccentric Contractions

Kay et al(18) compared neuromuscular recruitment patterns of the rectus femoris during eccentric, concentric and isometric contractions. The isometric (ISO) contractions consisted of subject's knee being position at 60º and then the subjects were instructed to maintain a maximal contraction for 100 seconds. The eccentric (ECC) and concentric (CON) consisted of the subject contracting their muscle at a speed of 60º/sec for a range of motion of 6º to 84º. In both the eccentric and concentric conditions the subjects performed 100 seconds of knee extension exercise. There were not any significant differences between the MVC of the three contractions (177.2 ± 61.1 Nm, 169.2 ± 41.1 Nm, and 211 ± 63.1 Nm for ISO, CON and ECC respectively). Also there was no significant difference between maximal IEMG during the MVC (287.0 ± 143.2 mV, 305.0 ± 146.3 mV, and 280.1 ± 143.5 mV). For the normalized torque after the endurance protocol, there was a significant difference for time in the ISO and CON groups with the final values being a decrease of 30.5 ± 12.7% for the ISO group and

57.7 ± 15.3% for the CON. The ECC group in comparison actually increased within the 100 seconds to a value of 108.65 ± 3.9%. For the IEMG values, the ISO condition had the greatest reduction with a decrease of 37.7 ± 12.9% of its initial value. The other conditions maintained the same IEMG reading throughout the endurance protocol. The ISO condition was significantly less then both the ECC and CON. The mean power frequency spectrum (MPFS) was compressed in all the conditions, but the shift was distinct in the CON (69.2 ± 9.6%) when compared to both the ISO (72.6 ± 9.4%) and ECC (92.6 ± 5.5%), with the ECC being significantly higher then the other two conditions. The eccentric protocol showed that the muscle groups had a greater resistance to fatigue. The isometric protocol showed that with the reduction in torque along with the reduction in IEMG and compression of the MPFS, that the fatigue that was present was more central and that the neural drive was suppressed. Lastly for the concentric protocol the authors suggested that since the IEMG either stayed the same or increased that but the force decreased, this showed that the neural input was still going to the muscles and that this protocol showed a peripheral fatigue.

Horita et al. (13) examined the relationship between muscle lactate accumulation and surface EMG of the vastus lateralis during isokinetic contractions. The subjects performed maximal voluntary knee extensions for either 30 seconds (25 contractions) or 60 seconds (50 contractions) on separate days. There was a 59% decrease in peak torque for the subjects after the fatiguing exercise. The muscle lactate concentration increased by 6.1 ± 2.1mmol/kg wet weight for the 30 second and 11.4 ± 3.2mmol/kg wet weight for the 60 second protocol. The median frequency decrease by

32.2 ± 5.9 Hz for the entire protocol. There was a significant difference in the lactate accumulation between the two exercise protocols. The authors also suggested that changes in the median frequency correlated with the muscle lactate in the identical muscle. Lastly the authors concluded that the decrease in electrical activity suggested that the muscle exhibited peripheral fatigue.

2.8 Fatigue in Concentric Contractions

Ebersole et al. (9) investigated the mechanomyographic and electromyographic response to repeated concentric muscle action of the quadriceps femoris. The muscles groups that were analyzed were vastus lateralis (VL), rectus femoris (RF), and the vastus medialis (VL). This testing consisted of coming to the lab on three different occasions. The first day was a familiarization day of getting the subjects comfortable with the Biodex System dynamometer. The last two visits the subjects 50 consecutive maximal concentric contraction with there dominant leg at either 60º/sec or at 300º/sec. Overall there was a decrease in torque across the 50 contractions for both the 60º/sec and 300º/sec (59 ± 24% and 53 ± 11%). The EMG amplitude showed a cubic increased after the 50 contraction for both speeds. The EMG MPF showed a quadratic decrease for each of the muscle group at 60º/sec and a quadratic decrease for the RF or a cubic decrease VL, VM. Ebersole et al. suggests that a decrease in torque could suggest a change from Type II fiber to Type I fibers being primarily used to complete the protocol. The authors suggested that the increased in EMG amplitude could be due to an alteration in the activation of muscle fibers in the VL, RF, and VM. Also the

increase in EMG amplitude did in fact get fatigue. Lastly the authors suggested that the decreased in EMG MPF is associated with the slowing of muscle fiber conduction velocity. Also the authors' stated that the morphological structures of the muscles could also be an explanation for the decrease in EMG MPF. The accepted theory is that the fatigue force velocity curve is influence by the percent of Type II fibers. The greater the percent of Type II fibers, the faster the rate of decline will be. The RF has the greater number of Type II fibers followed by the VL and the VM. Therefore in the study, the RF had the greatest decline in decline in MPF, while the VM had the least decline in MPF.

Perry-Rana et al. (26) examined MMG and EMG responses during fatiguing isokinetic muscle contraction at different velocities. The muscles groups that were analyze were vastus lateralis (VL), rectus femoris (RF) and vastus medialis. The participants visited the lab on four different days. The first day was the familiarization day. On the next three visits the subjects performed 50 consecutive maximal leg extensions contractions on 60º/sec, 180º/sec or 300º/sec. on the Cybex isokinetic dynamometer. The data showed a decreased in the normalized torque across the 50 contractions for the three different speeds. The percent decline in torque was 44 ± 14%, 65 ± 14%, and 63 ± 8% at 60º/sec, 180º/sec and 300º/sec, respectively. For EMG amplitude, for all the muscles groups and at the three different speeds, a cubic model regression equation was fitted through the data points. The peak torque decreased at a slower rate at the 60º/sec speed then at the two other speeds. Also at the 60º/sec, the torque leveled off during the last 20 repetitions, but for the 180º/sec and 300º/sec, the

torque leveled off during the last 10 repetitions. This trend in data shows the contribution of both Type I and Type II fibers to torque production at slower velocities and then the shift to predominately Type II fibers at the faster velocities. Also the fatigue resistant nature of Type I help weaken the decrease in torque during the test. Whereas for the higher velocities, the percent decline in torque was greater due to the higher recruitment of Type II fibers to perform the contractions. The EMG amplitude data showed a cubic model in that during the first 10 repetitions, there was a rapid increase in the EMG amplitude. EMG amplitude decrease slightly during the middle portion of the test and then another increase in the last 10 repetitions. The authors suggested that the initial rise in EMG amplitude could be do to the subjects not giving maximal effort at the beginning due to the torque values not reaching the maximal potential. Also the decreases in the middle and rise at the end could be related to the subjects were not motivated in the middle and motivations level was raised at the end when the subjects know that the test was almost over. The VM had the highest level of activation at the end of the test. This change was attributed to the fact that the VM having a higher percentage of Type I fibers and that the fiber type distribution in the muscle could account for different activation levels throughout exercises. Finally the EMG amplitude also showed that there was a greater decrease in the muscle that had a greater percentage of Type II fiber (60.3 ± 3.0%) then the muscles who had a lower percentage of Type II fibers (41.2 ± 3.2%).

CHAPTER 3

METHODS

3.1 Instrumentation

A Biodex isokinetic exercise machine (Biodex Medical Systems, Shirley NY) was used to fatigue the knee extensor muscles using either eccentric (lengthening) or concentric (shortening) exercises. Vastus lateralis and vastus medialis muscle surface EMG signals were recorded using a Biopac MP-150 amplifier (Biopac Systems Inc., Goleta Ca.). Blood lactate was be analyzed using an YSI 1500 Lactate Analyzer (Yellow Springs, OH). A disposable safety razor was used to remove excessive hair prior to attaching EMG electrodes to the vastus lateralis and vastus medialis muscles. Noraxon surface electrodes (Noraxon U.S.A. Inc., Scottsdale AZ) were placed over the vastus lateralis and vastus medialis muscles.

3.2 General Procedures

Subjects reported to the laboratory on 3 separate occasions. The first session lasted for approximately 20 minutes and the second and third session lasted approximately 30 minutes. On the first visit to the lab, all subjects read and signed an informed consent. The subjects were screened for a health history, history of thigh, lower leg and ankle injures. Subjects were included in the study if they recorded no

history of health risks. Subjects then practiced the concentric and eccentric exercise conditions on the Biodex exercise machine. For each repetition the subject were instructed to exert maximal knee extension force against the Biodex machine. Real time feedback was provided to the subject to teach them how to exert maximal knee extension force on repetition. Once the subject was acclimated to the Biodex machine, he was asked to complete one set of 20 repetitions of both eccentric (i.e. subject kicked out at a high speed of 180 d/s and when the subjects pulled their leg back toward them the Biodex applied a slight resistant to the movement at 60 d/s) and concentric exercise (i.e. subject kicked out forcefully at 180 d/s and their leg was gently returned to starting position at 60 d/s). The subject then rescheduled his next visit to the laboratory for ether the concentric or eccentric fatigue protocol. The subject was randomly assigned to begin with either the eccentric or concentric exercise condition. The exercise condition was counterbalanced with 10 subjects beginning with eccentric and 10 subjects beginning with concentric exercise.

3.3 Fatigue Protocol

The fatigue protocol consisted of performing 4 sets of 20 repetitions of either concentric or eccentric knee extension exercises on a Biodex. For the eccentric part of the fatigue protocol the extension phase (kicking out of the leg) of the exercise was performed at 180 d/s and the flexion phase (bending of the knee) of the exercise was performed at 60 d/s. For the concentric part of the fatigue protocol, the extension and

flexion phase were both performed at 180 d/s. The rest time in between each set is 30 seconds.

3.4 EMG Analysis

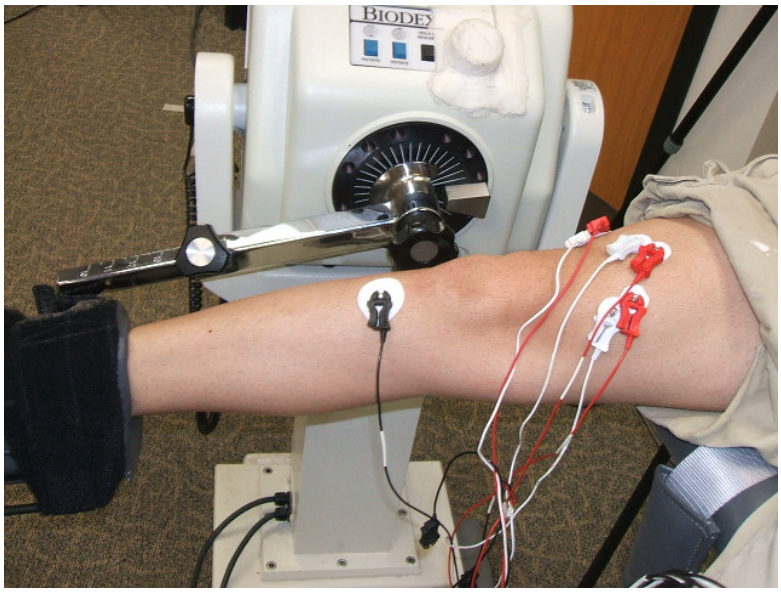

Figure 3.1 EMG Electrodes Placement

Upon entering the lab the subject was prepped for electrode placement by shaving the electrode sites over the vastus lateralis and vastus medialis and rectus femoris muscles and the ground electrode site over the medial anterior shin. After shaving the electrode locations, the electrode sites were cleaned by wiping the skin with an alcohol pad and a gauze pad. Then the surface electrodes were placed over each muscle (vastus lateralis, vastus medialis, and rectus femoris) and the ground electrode was placed over the anterior medial shin. The electrodes were placed in the direction of the fibers to ensure maximal conduction readings. The Biopac MP-150 electrode cables

then attached to the electrodes and the quality of the surface EMG signals were verified by having the subject perform a light contraction. If any of the muscle signals showed signs of poor connections, the electrodes were replaced and subsequently the signal fidelity was again be verified. The EMG readings were amplified 1000 times and filtered with a bandwidth of 10-500 Hz. EMG and Biodex torque, position, velocity signals were sampled at 1000 Hz using a 16 bit analog-digital card. The EMG electrode were Noraxon dual pre-gelled (product #272) electrodes with a diameter of 1 cm and an inter electrode distance of 2 cm.

3.5 Blood Sampling Procedures

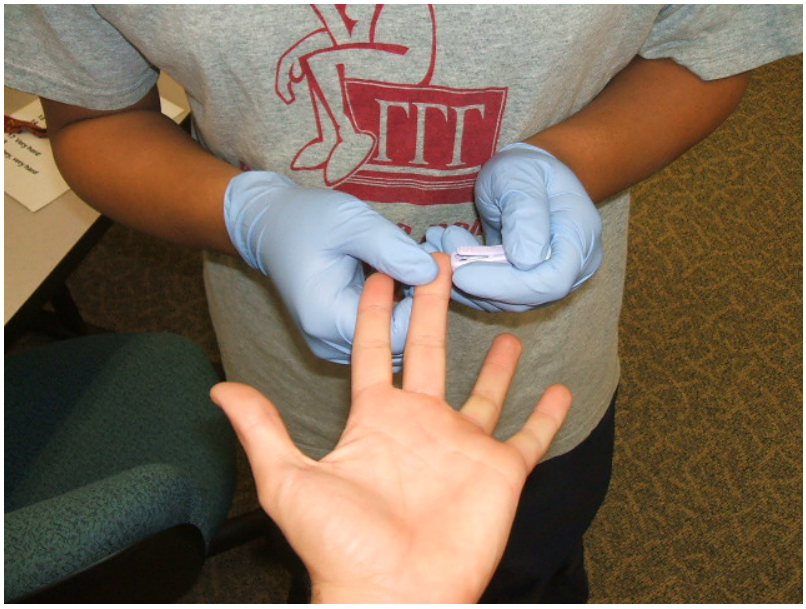

Figure 3.2 Blood Lactate Sampling

Blood samples were taken before and 2 min after the completion of the exercise protocol. Using latex gloves, the examiner washed the subject's finger with soap and

water and dry with a clean, low-lint towel. The finger was punctured and cleaned with alcohol followed by a puncture with a sterile lancet. The first drop of blood was wiped off and then the blood was collected with a 25-μL glass capillary tube. Gauze was used to wipe any excess blood and then a small sterile bandage was placed over the puncture site. Blood lactate was analyzed within 30 min of the completion of the test using a YSI 1500 Lactate Analyzer. The YSI 1500 Lactate Analyzer worked by injecting the blood filled capillary tube into the analyzer and the blood lactate levels are analyzed. Within two minutes the concentration of blood lactate was displayed on the screen.

3.6 Exercise Protocol

After the pre fatigue blood sample was collected from the subject, the subject sat on the Biodex exercise machine with his knee joint center aligned with the axis of rotation of the Biodex arm. Then the subject's right leg and torso was stabilized by fastening Velcro straps over the leg and torso to prevent excessive body movement during the exercise. The subject then performed 4 sets of 20 maximal knee extensions of either the eccentric contraction (i.e. subject kicked out at a high speed of 180 d/s and the subject pulled their leg back toward them the Biodex will applied a slight resistant to the movement at 60 d/s) or concentric contraction (i.e. subject kicked out forcefully at 180 d/s and their leg gently returned to starting position at 60 d/s) with 1 minute of rest between each set of 20 repetitions. A post exercise blood sample was taken 2 minutes after the last set. The subject then was rescheduled to complete his remaining condition no sooner than 3 days and no less than 10 days after performing his first condition.

3.7 Data Analysis

From the Pre and Post Isometric readings, the RMS and average torque were computed by averaging the one second sample.

3.8 Statistical Analysis

A 2 x 2 repeated measures ANOVA was used to test for differences in condition (concentric, eccentric) and time (pre, post) for the following dependent variables: total work done, average torque, change in lactate concentrations VL EMG, RF EMG and VM EMG. Both condition and time were within subjects factors. Post hoc test were performed using Tukey. Alpha was set at 0.05 for all comparisons.

CHAPTER 4

RESULTS

4.1 Maximal Voluntary Contractions

For the isometric maximal voluntary contractions (MVC) there was no significant effect on condition ($F(1, 9) = 1.66$ $p=.0.23$) or a significant interaction between the time and condition ($F(1, 9) = 0.45$ $p=0.52$), but there was a significant time effect ($F(1, 9) = 26.19$ $p= 0.000630$). Pre isometric torque, 153.0 ± 52.9 Nm, was significantly greater than post isometric torque 124.4 ± 40.5Nm. Isometric torque is shown Figure 4.1 by contraction condition and time.

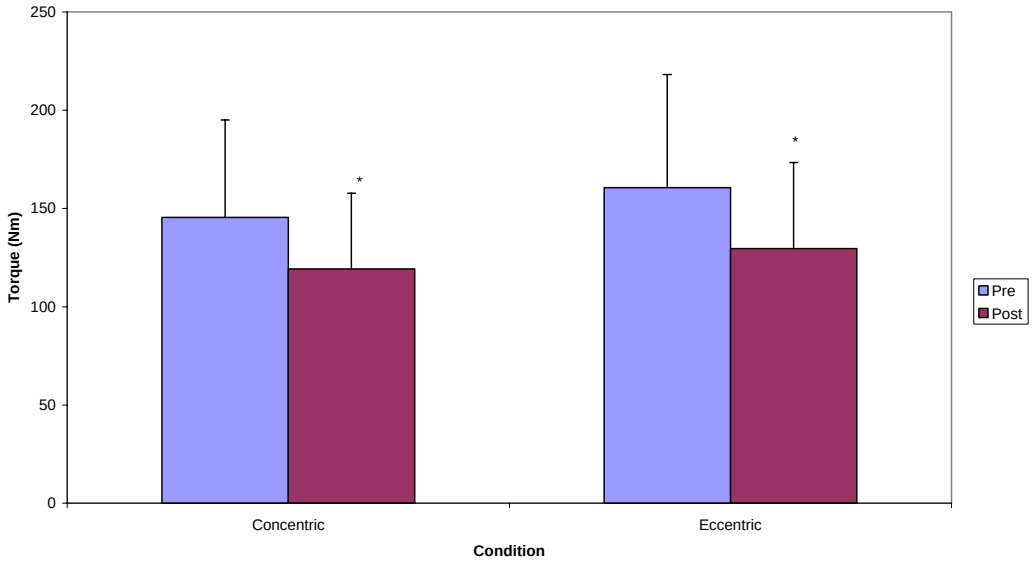

Figure 4.1. Torque During pre and post MVC: There a signifcant difference between time.

4.2 EMG Amplitude and Median Frequency of the Vastus Lateralis

For the amplitude of the vastus lateralis, there was not a significant effect on time ($F(1, 9) = 0.59$ $p=0.46$) or a significant effect on the condition ($F(1, 9) = 0.38$ $p= 0.55$), but there was an interaction between the time and condition ($F(1, 9) = 6.60$ $p= 0.003$), see Figure 4.2. The only comparison that was significantly different for VL amplitude was that post eccentric EMG amplitude 270.1 ± 116.2 mV was significantly greater than the post concentric EMG amplitude 206.6 ± 129.3 mV. For the frequency of the vastus lateralis, there was not a significant effect on the condition ($F(1, 9) = 4.25$ $p=0.06$) or no significant interaction between the condition and the time ($F(1, 9) = 1.56$ $p=0.24$) but there was a significant between the time ($F(1, 9) = 20.61$ $p=.0014$. Pre median frequency, 116.7± 32.1 Hz, was significantly greater than post isometric torque 97.2 ±24.4 Hz. Isometric torque is shown Figure 4.3 by contraction condition and time.

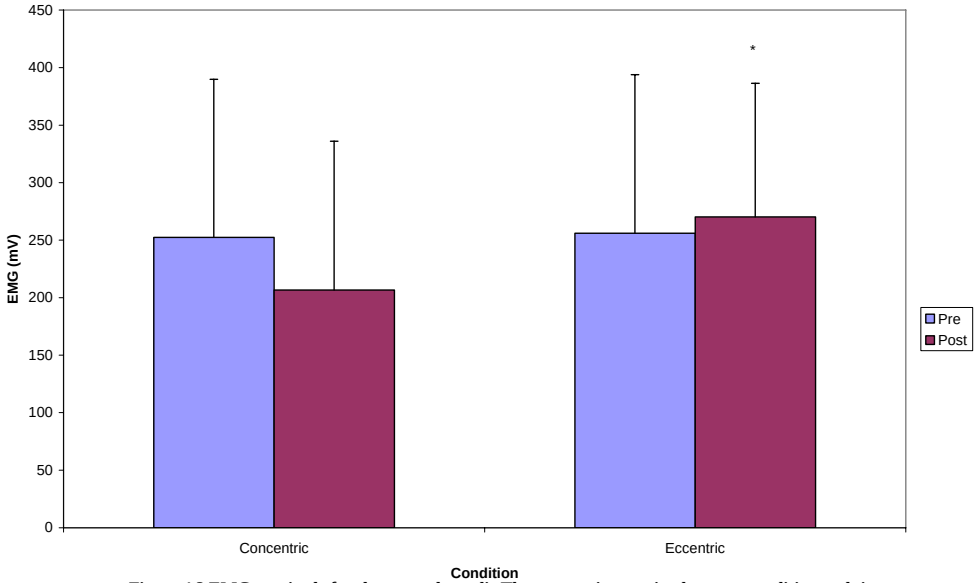

Figure 4.2 EMG ampitude for the vastus lateralis There was a interaction between condition and time for the eccentric protocol.

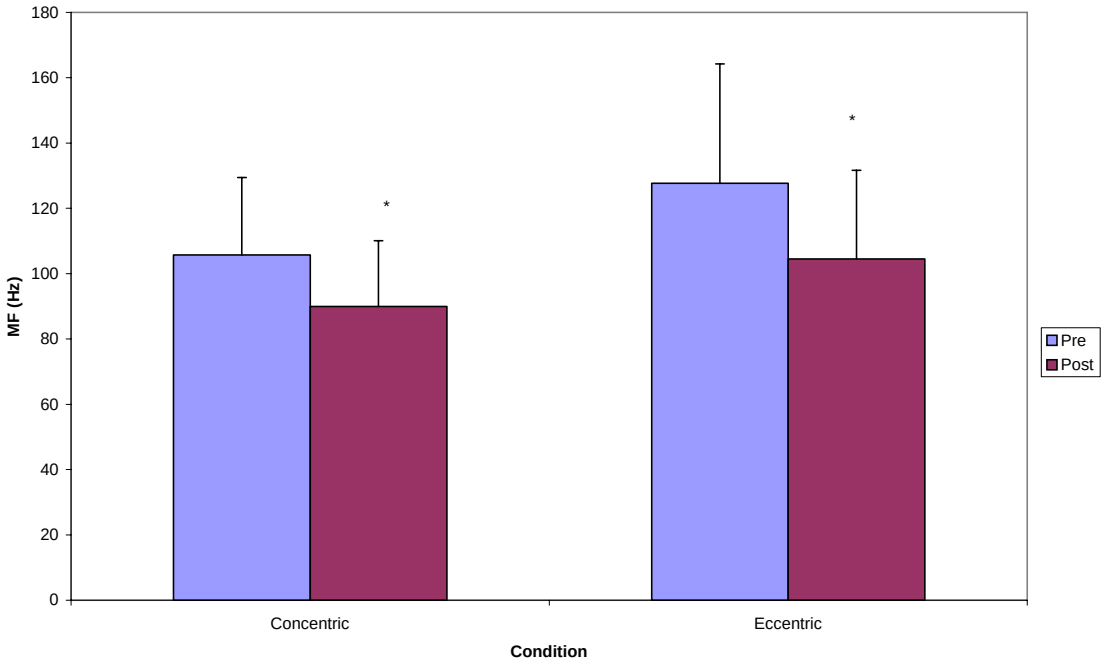

Figure 4.3. Median Freqeuncy for the Vastus Lateralis: There was a significant effect on time.

4.3 EMG Amplitude and Median Frequency of the Vastus Medialis

For the amplitude of vastus medialis there was no significant interaction between the time ($F(1, 9) = 1.11$ $p=0.31$), no significant interaction between the conditions ($F(1, 9) = 0.39$ $p=0.55$), or no significant interaction between time and condition ($F(1, 9) = 1.70$ $p= 0.22$), see Figure 4.4. For frequency of the vastus medialis, there was no significant interaction between the conditions ($F(1, 9) = 2.53$ $p=0.15$) no significant difference between the time and conditions ($F(1, 9) = 0.28$ $p=0.61$) but there was a significant effect on time ($F(1, 9) = 24.86$ $p=0.000753$). Pre median frequency, 98.6± 22.7 Hz, was significantly greater than post median frequency

82.3 ±14.6 Hz. Median frequency is shown Figure 4.5 by contraction condition and time.

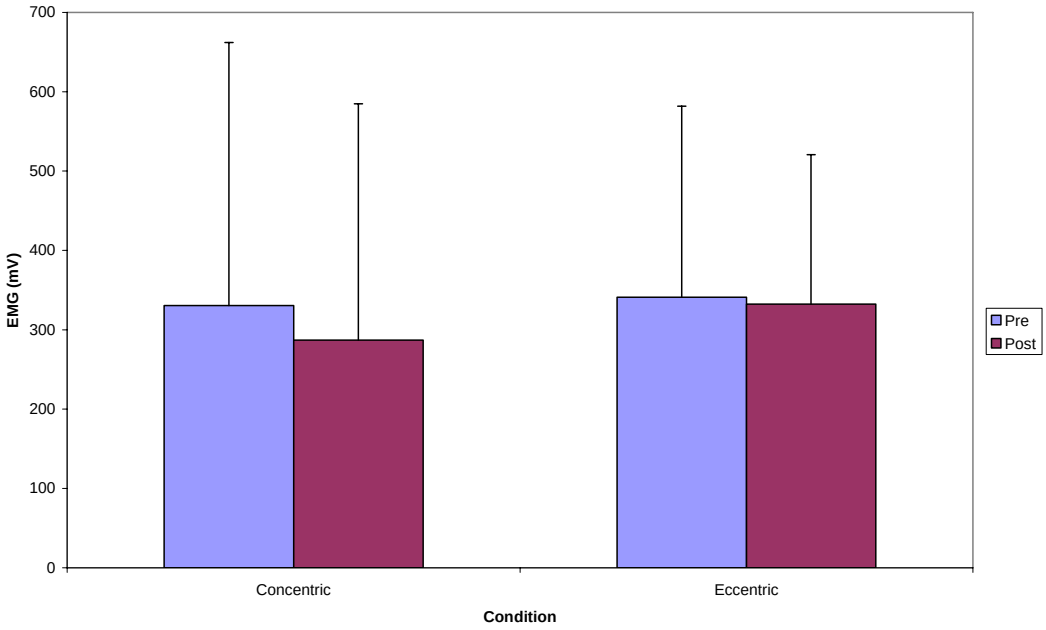

Figure 4.4 EMG Amplitude of the Vastus Medialis.

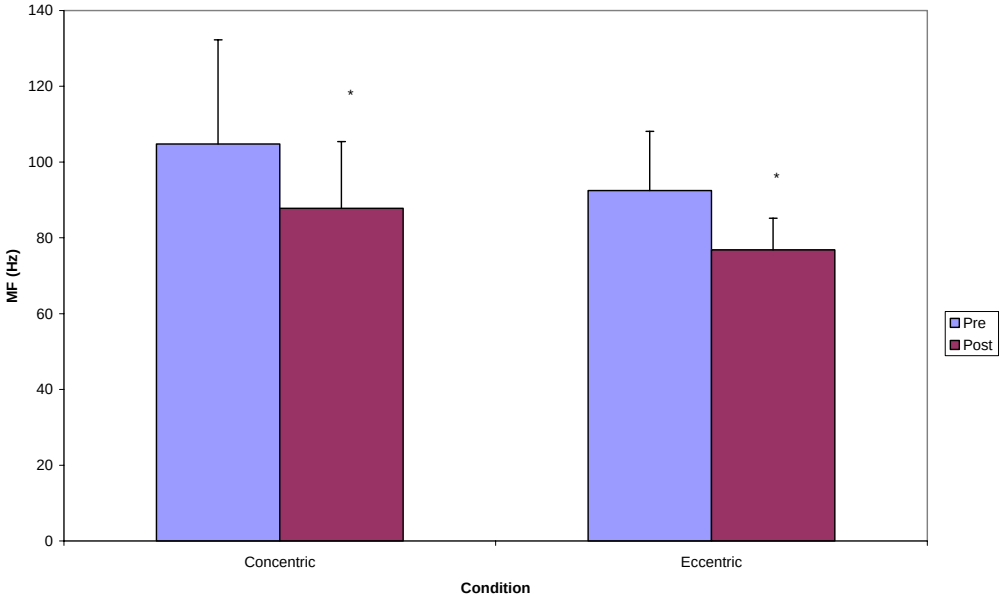

Figure 4.5 Median Frequency of the Vastus Medialis: There was a time effect on both conditions.

4.4 EMG Amplitude and Median Frequency of the Rectus Femoris

For the amplitude of rectus femoris there was no significant interaction between the time (F (1, 9) = 0.00 p=0.97), no significant interaction between the conditions (F (1, 9) = 1.49 p=0.25), or no significant interaction between time and condition (F (1, 9) = 1.19 p= 0.30) see Figure 4.6. For frequency of the rectus femoris, there was no significant interaction between the conditions (F (1, 9) = 0.11 p=0.75) no significant difference between the time and conditions (F (1, 9) = 0.28 p=0.60) but there was a significant effect on time (F (1, 9) = 59.31 p=0.000030). Pre median frequency, 104.6± 15.1Hz, was significantly greater than post median frequency 81.9± 9.7 Hz. Median frequency is shown Figure 4.7 by contraction condition and time.

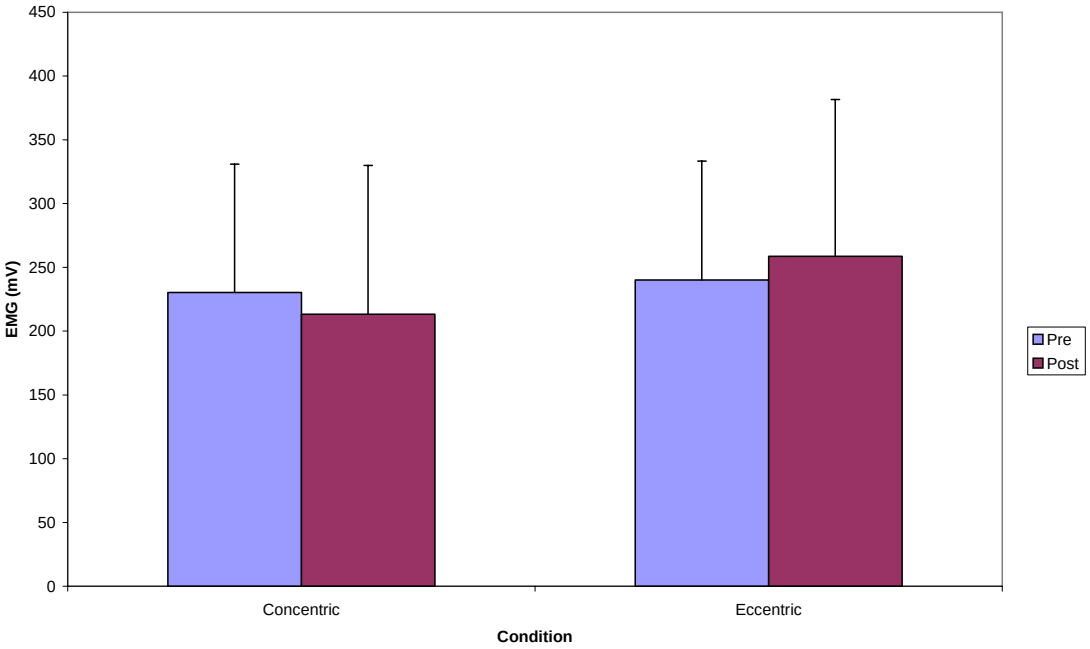

Figure 4.6 EMG Amplitude on the Rectus Femoris.

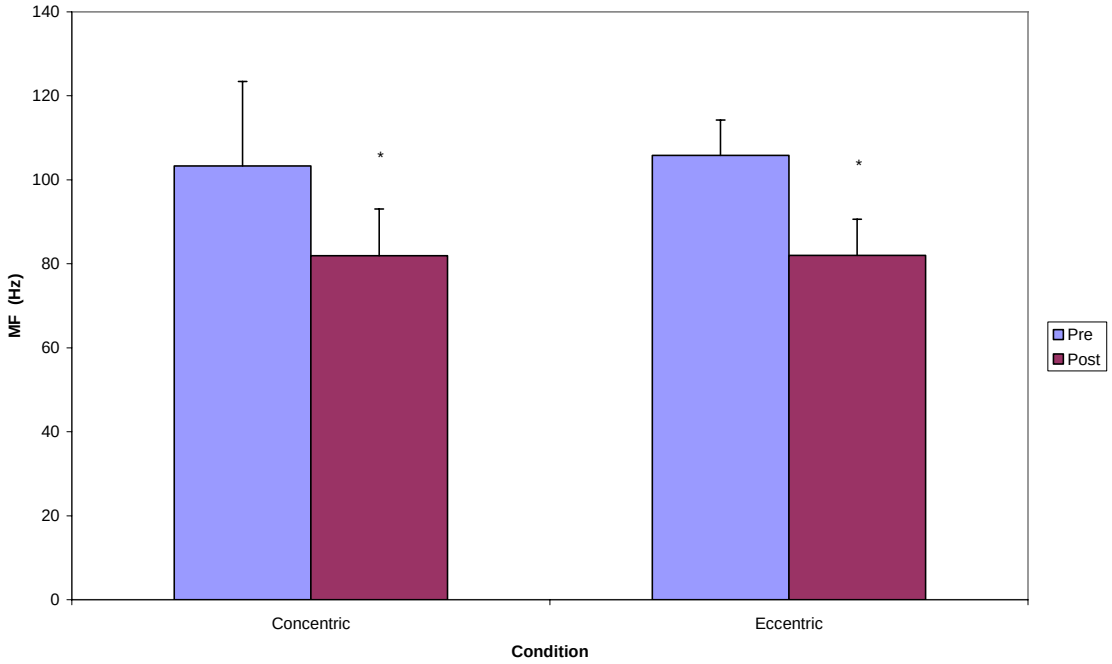

Figure 4.7 Median Frequency of the Rectus Femoris: There was a time effect for both conditions.

4.5 Pre and Post Lactate Measurement

For the lactate measurements, there was no significant effect between conditions ($F(1, 9) = 0.12$ $p=0.74$), there was no significant interaction between time and conditions ($F(1, 9) = 0.53$ $p=0.49$) but there was a significant effect between on time ($F(1, 9) = 150.83$ $p=0.000001$). Pre median frequency, 2.4 ± 0.5 mmol/L, was significantly greater than post median frequency 5.1 ± 0.9 mmol/L. Median frequency is shown Figure 4.8 by contraction condition and time.

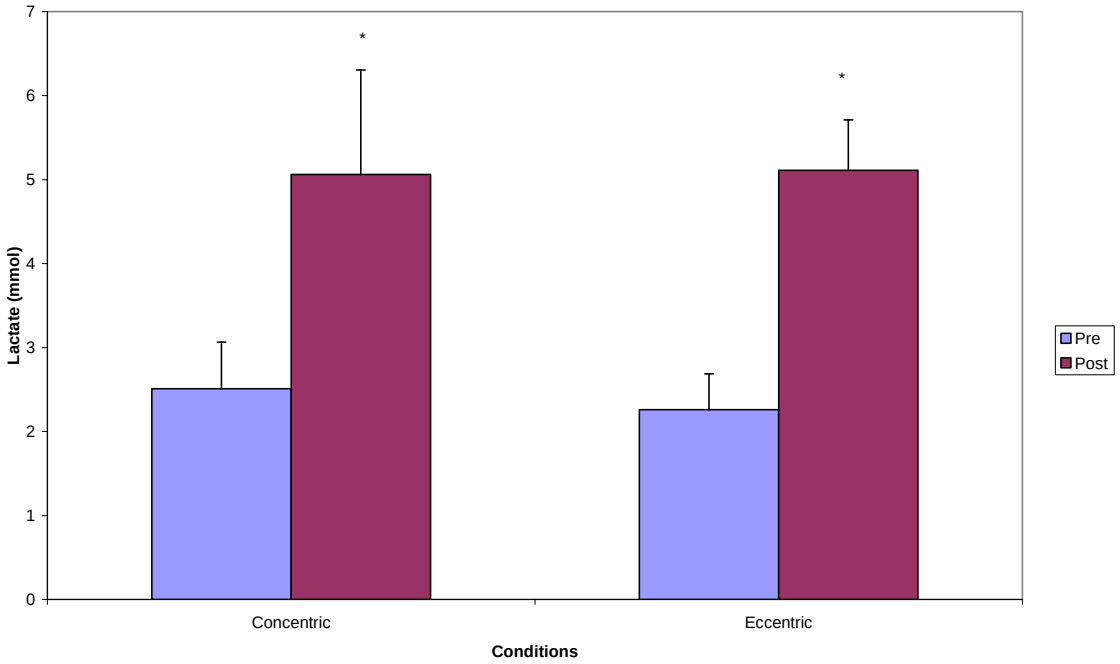

Figure 4.8 Pre and Post Lactate Measurements: There was an effect of time on both conditions.

4.6 Work Done for the Eccentric and Concentric Contractions

For the total work done between the eccentric and concentric contractions, there was a significant difference between the conditions ($F(1, 30) = 36.5$, $p = .0001$), see Figure 4.9. In the eccentric contractions, (3756.9 ± 1364.2 J) the subjects did significantly more work than the concentric contractions (1839.4 ± 634.5 J). Also there was a significant difference between the sets ($F(3, 30) = 5.0$, p .006), see Figure 4.10. Set 1 3185.2 ±1886.8 J was significantly different from: Set 3 2543.2 ± 1215.8 J and Set 4 2422.5 ± 1055.0 J.

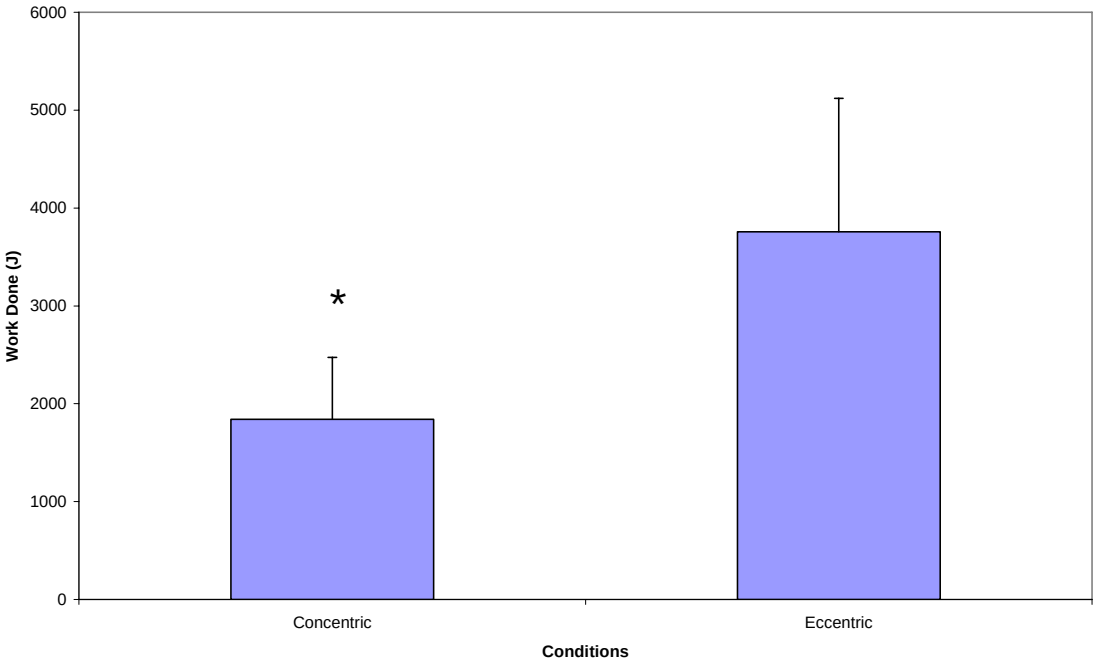

Figure 4.9 Work done between Eccentric and Concentric: There was an effect between conditions.

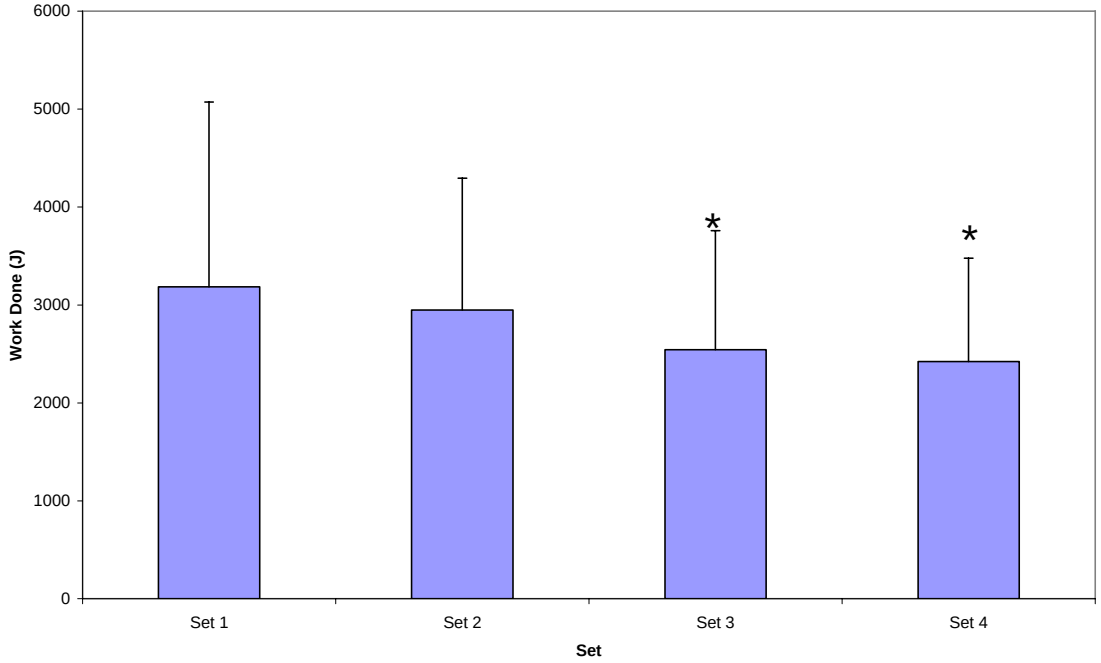

Figure 4.10 Work done during the different sets: Sets 3 and 4 were significantly different from 1.

CHAPTER 5

DISCUSSION

The purpose of this study was to compare isometric torque, EMG, blood lactate, and work done before and after fatigue induced by four sets of twenty eccentric and concentric contractions. There were no differences in the effects of fatigue between the eccentric and concentric contractions for isometric torque, median frequency and blood lactate. However, following the fatigue fatigue, isometric torque and median frequency for all three muscles decreased and blood lactate increased. Theses are normal responses to fatigue and they have been observed in other papers (15).

In the present study, four sets of twenty isokinetic contractions resulted in a mean decrease in isometric torque of 28.6 ± 12.4 Nm and a mean increase in blood lactate of 2.7 ± 0.4 mmol/L. In comparison, Horstmann et al. (14) reported that one minute of concentric isokinetic contractions resulted in 5 mmol/L of blood lactate with a total work done of 6240 J and one minute of eccentric isokinetic contractions resulted in 1 mmol/L blood lactate with of total work done of 6528 J. Horstmann et al. (14) concluded that amount of work was equal but the concentric exercises resulted in an accumulation of more blood lactate. In the present study, our subjects performed the same number of eccentric and concentric contractions but they performed 1917.5 ±

999.4 J more work in eccentric contractions because of the nature of the experiment. We believe that our contrary findings of no differences in blood lactate between eccentric and concentric contraction conditions can be attributed to the additional work that was done in the eccentric contraction condition.

While blood lactate does not cause acidosis, it is an indirect marker of the aerobic conditions that lead to acidosis or lower pH (27). Accumulation of H^+ reduces the pH and the results in slower propagation of the muscle fiber action potential. The median frequency of the EMG is directly related to the conduction velocity of the action potential (5). In the present study four sets of twenty isokinetic contractions caused the median frequency of the VL decrease by 19.7 ± 6.5 Hz, the VM to decrease by 16.3 ± 9.6 Hz, and the RF to decrease by 22.6 ± 4.4 Hz. In fatigue studies using both isometric and isokinetic exercise, similar decreases in median frequency have been observed (1, 8, 17, 20, 24). Therefore, our study supports previous literature that indicates that as the muscle fatigues fast twitch fibers fall out of recruitment and the lower pH causes a slowing of nerve conduction velocity.

We expected to see a greater rate of fatigue in the eccentric contractions due to the high neural drive to the muscle (10) and limited evidence that fast twitch motor units are selectively recruited during eccentric contractions (22, 28). Muscle biopsies following eccentric exercise have shown that predominately fast twitch fibers are damaged due to the high strains imposed by eccentric exercise (12, 20). In the present study similar rates of fatigue between eccentric and concentric contractions were observed for torque, blood lactate, and median frequency, while there was a trend for

increased neural drive in the eccentric condition (Figures 4.2, 4.4, 4.6). For example, even though mild fatigue was exhibited by a decrease in torque in both exercise conditions there was slightly higher EMG amplitude in all quadriceps muscles in the post eccentric exercise condition, which might indicate that the eccentric isokinetic condition required a higher neural drive.

In conclusion, despite doing more work in the eccentric condition we observed similar effects of fatigue for torque, blood lactate, and median frequency. Therefore, future studies should continue to investigate the potential differences between these modes of exercise.

APPENDIX A

HUMAN SUBJECT APPROVAL FORM

UNIVERSITY OF TEXAS AT ARLINGTON

OFFICE OF RESEARCH COMPLIANCE

IRB FORM #1
INITIAL SUBMISSION OF A RESEARCH PROTOCOL TO

THE INSTITUTIONAL REVIEW BOARD FOR THE PROTECTION OF HUMAN SUBJECTS

Faculty, staff, students, or employees who propose to engage in any research, demonstration, development, or other activity involving the use of human subjects must have review and approval of that activity by the Institutional Review Board, prior to initiation of that project. The Board is responsible for safeguarding the rights and welfare of subjects who participate in the activity.

If you require further assistance in completing this form or need additional information, please contact the Office of Research Compliance at extension 3723.

SECTION A: GENERAL INFORMATION

1. **Project Title:**
2. Effects of concentric and eccentric contractions of the knee extensors on mechanical work, lactate concentration and surface EMG

3. **Principal Investigator:**
   - **Name**:Jeremiah Campbell
   - **Title:** Graduate Assistant
   - **Department:** Kinesiology **Mail Box**: 19259
   - **Telephone**:817-272-7017
     Email:campbelj@uta.edu

4. **Co-Investigator:**
   - **Name**:Cynthia Trowbridge
   - **Title**:Assistant Professor
   - **Department:** Kinesiology **Mail Box**: 19259
   - **Telephone**:817-272-3134

     Email:ctrowbridge@uta.edu

5. **For a student submitting a protocol, please identify the faculty member responsible for conducting the research:**
   - **Name:**Mark Ricard
   - **Title:** Associate Professor
   - **Department:**Kinesiology **Mail Box:**19259
   - **Telephone:** 817-272-0764 **Email:**ricard@uta.edu

6. **Expected Start Date:** 2-1/2007 *(You are not authorized to start any research on human subjects until the IRB has approved the research protocol.)*

7. **Expected Completion Date:** 10/2007 **(The IRB can only approve a research protocol for a maximum period of 3 years. If you require a longer period of approval for your research, you will have to submit a new protocol to the IRB on the 3-year anniversary date.)**

SECTION B: FUNDING If this research is not supported by funding, please skip to section C.

If you have or are seeking funding for your research, please specify the source.

7. **Source:** ☐ **FEDERAL (Specify Agency:)**

☐ **INDUSTRY SPONSORED (Specify Agency:)**

☐ **Local Departmental** ☐ **State** ☐

Other:

FUNDED GRANT / CONTRACT NUMBER:

☐ **Check here if grant is pending. Date of Grant Submission:**

8. Do you plan to do the research if you do not receive funding? Yes

SECTION C: SUMMARY OF THE RESEARCH PROTOCOL

Please answer the following in simple, non-technical / non-exculpatory language.

9. List primary research questions.
1. How does the type of knee muscle contraction (eccentric, concentric) affect mechanical work, lactate concentration and EMG ? EMG is an abbreviation for electromyography. Electromyography is the study of the electrical activity associated with muscular contraction. In this study we will record EMG activity by placing surface electrodes over the muscles of interest.

10. Describe the research design. A 2 x 2 factorial repeated measures design will be used for data collection. The factors are time (pre fatigue, post fatigue) and knee muscle contraction type (eccentric i.e. lengthening of muscle fibers, concentric i.e. shortening of muscle fibers). The dependent variables are lactate concentration, mechanical work and EMG of the vastus lateralis and vastus medialis muscles. Each subject will complete 4 sets of 20 eccentric or concentric knee muscle contractions. The order of muscle contraction type (eccentric, concentric) will be counterbalanced with at least 3 days between conditions. Two factor repeated measures ANOVAs will be used to test for differences between contraction type (eccentric, concentric), time (pre fatigue, post fatigue) and time by contraction interactions for the following dependent variables: lactate concentration, mechanical work and EMG of the vastus lateralis, vastus medialis and rectus femoris muscles. A finger stick will be used to obtain the blood needed to determine blood lactate levels before and after each contraction type is performed.

11. List potential benefits that may accrue to the study subjects as a result of their participation. This research has no benefit to the subjects. This

research will provide information for practitioners on the effects of fatigue upon EMG and mechanical work.

12. **List potential benefits that may accrue to society as a result of this study.** Human motion typically is the result of both eccentric and concentric contractions. Eccentric contractions are known to be mechanically more efficient at the expense of greater trauma to the muscle tissue.

13. **What are you and your research team's relevant qualifications to perform this research? If applicable, include information about relevant licenses / medical privileges.** I have an undergraduate degree in Biochemistry. Dr. Ricard has a PhD in Biomechanics and twenty years of experience in EMG force-fatigue relationships. Dr. Blevins has a PhD in Clinical Exercise Physiology and Dr. Trowbridge has a PhD in Physical Medicine and Rehabilitation.

14. CHECK <u>ALL</u> RESEARCH PROCEDURES INVOLVING HUMAN SUBJECTS:

Any materials presented to the research subject (oral or written) may not ask of the subject to provide information about another human being who has not undergone the informed consent process (this includes the immediate family of the subject).

☒ **Collection of Blood** ***State below the methods of collection (i.e. venipuncture, arterial puncture, etc.) Attach IRB Form #5 if a Tissue Repository is needed.***

☐ **Collection of Other Bodily Materials** ***State below the methods of collection. Please attach IRB Form #5 if a Tissue Repository is needed.***

☐ **Analysis of Existing Data**

☐ **Cognitive or Perceptual Experiment**

☐ **Evaluation of a Program or Services** ***State below whether it is Federal, State, Local, or 'Other'.***

☐ **Interview** ***State below whether it is oral or written and attach a finalized copy.***

☒ **Questionnaire or Survey** ***Attach a finalized copy***

☐ Induction of Mental or Physical Stress

☐ **Use of Private Health Information** ***State below the method for obtaining this data***

☐ Audio/Video recording of subjects

☐ **Use of Genomic DNA or cDNA**

☐ **Use of Infectious or Carcinogenic Materials**

☐ **Educational Test or Educational Materials (curriculum, books, etc.)** ***Attach copies or describe in detail***

☐ Observation of Public Behavior with PI Participation

☐ **Observation of Public Behavior without PI Participation**

☐ **Analysis of Existing Biological Specimens** ***State below where the samples were obtained from, where they will be kept and for how long, and who will have access to them.***

☐ **Deception** ***State below the debriefing procedures used***

☐ Taste Test

☒ **Medical Procedures** ***(e.g. drug, device, radiation, surgery, non-surgical manipulation, non-invasive physical measurements, etc.)***

☐ Materials Commonly Regarded as Socially Unacceptable

☐ **Use of Identified Data/Specimens**

☐ **Use of Coded Data/Specimens**

☐ **Use of Recombinant DNA** ***Attach a copy of the IBC application for rDNA along with this submission to the IRB***

☐ Use of Biohazardous Materials

☐ **Psychological Test** ***Attach Applicable copies or describe in detail***

14a. Please describe, in sufficient detail, the procedures for any checked items above. If you need more space, you may attach a separate sheet of paper. INSTRUMENTS: A Biodex isokinetic exercise machine will be used to fatigue the knee extensor muscles using either eccentric (lengthening) or concentric (shortening) exercises. Vastus lateralis and vastus medialis muscle surface EMG signals will be recorded using a Biopac MP-150 amplifier. Blood lactate will be analyzed using a YSI 1500 Lactate Analyzer. A disposable safety razor will be used to remove excessive hair prior to attaching EMG electrodes to the vastus lateralis and vastus medialis muscles. Noraxon surface electrodes will be placed over the vastus lateralis and vastus medialis muscles.

PROCEDURES: Subjects will report to the Biomechanics Laboratory (ACT 150) on 3 separate occasions. The first session will last for approximately 20 minutes and the second and third session will last approximately 30 minutes. On the first visit to the lab, all subjects will read and sign an informed consent. Then subjects will be screened for a health history, history of thigh, lower leg and ankle injures. Subjects will be included in the study if they record no history of health risks. Subjects will then practice the concentric and eccentric exercise conditions on the Biodex exercise machine. For each repetition the subject will be instructed to exert maximal knee extension force against the Biodex machine. Real time feedback will be provided to the subject to teach them how to exert maximal knee extension force on repetition. Once the subject is acclimated to the Biodex machine, he will be asked to complete one set of 20 repetitions of both eccentric(i.e. subject will kick out at a high speed

of 180 d/s and when the subjects pulls their leg back toward them the Biodex will apply a slight resistant to the movement at 60 d/s) and concentric exercise (i.e subject kick out forcefully at 180 d/s and let leg gentle returned to starting position at 60 d/s). The subject will then reschedule his next visit to the laboratory for ether the concentric or eccentric fatigue protocol. The subject will be randomly assigned to begin with either the eccentric or concentric exercise condition. The exercise condition will be counterbalanced with 10 subjects beginning with eccentric and 10 subjects beginning with concentric exercise.

The fatigue protocol will consist of performing 4 sets of 20 repetitions of either concentric or eccentric knee extension exercises on a Biodex. The extension phase (kicking out of the leg) of the exercise will be performed at 180 d/s and the flexion phase (bending of the knee) of the exercise will be performed at 60 d/s. Upon entering the lab the subject will be prepped for electrode placement by shaving the electrode sites over the vastus lateralis and vastus medialis and rectus femoris muscles and the ground electrode site over the medial anterior shin. After shaving the electrode locations, the electrode sites will be cleaned by wiping the skin with an alcohol pad and a gauze pad. Then the surface electrodes will be placed over each muscle (vastus lateralis, vastus medialis, rectus femoris) and the ground electrode will be placed over the anterior medial shin. The Biopac MP-150 electrode cables will then be attached to the electrodes and the quality of the surface EMG signals will be verified by having the subject perform a light contraction. If any of the muscle signals show signs of poor connections, the electrodes will be replaced and subsequently the signal fidelity will be again be verified. Prior to and 2 minutes after the fatigue protocol blood will be drawn from a finger of the non dominant hand using a finger prick induced by a sterile lancet, USING STERILE TECHNIQUE AND UNIVERSAL PRECAUTIONS.

Blood Sample Procedures

Blood samples will be taken before and 2 min after the completion of the exercise protocol. Using latex gloves, the examiner will wash the subject's finger with soap and water and dry with a clean, low-lint towel. The finger to be punctured will then be cleaned with alcohol followed by a puncture with a sterile lancet. The first drop of blood will be wiped off and then the collection free-flow of blood will be made with a 25-µL glass capillary tube. Gauze will be used to wipe any excess blood and then a small sterile bandage will be placed over the puncture site. Blood lactate will be analyzed within 30 min of the completion of the test using a YSI 1500 Lactate Analyzer. The YSI 1500 Lactate Analyzer works by injecting the blood filled capillary tube into the

analyzer and the blood lactate levels are analyzed. Within two minutes the concentration of blood lactate is displayed on the screen.

Fatigue Exercise Protocol

After taking the pre fatigue blood sample the subject will be seated on the Biodex exercise machine with his knee joint center aligned with the axis of rotation of the Biodex arm. Then the subject's right leg and torso will be stabilized by fastening Velcro straps over the leg and torso to prevent excessive body movement during the exercise. The subject will then perform 4 sets of 20 maximal knee extensions of either the eccentric contraction (i.e. subject will kick out at a high speed of 180 d/s and when the subjects pulls their leg back toward them the Biodex will apply a slight resistant to the movement at 60 d/s) or concentric contraction (i.e subject kick out forcefully at 180 d/s and let leg gentle returned to starting position at 60 d/s) with 1 minute of rest between each set of 20 repetitions. A post exercise blood sample will be taken 2 minutes after the last set. The subject will then be rescheduled to complete his remaining condition no sooner than 3 days and no less than 10 days after performing his first condition.

14b. If the proposed research <u>is limited to</u> the use of discarded materials or retrospective chart review and there are no identifiers associating the specimens or chart information with the donors, skip sections D through G. However, if the donors can be identified, fill out section D and then skip to section H.

SECTION D: STUDY POPULATION

15. Please indicate which, if any, of the following are involved:

☒ **UTA Staff**

☒ **UTA Faculty**

☒ **UTA Students**

☐ **Non-English Speaking People** ***Attach the consent form and all applicable materials in the native language(s) of the subjects in the research***

☒ **Adults competent to consent for themselves (non-UTA)**

☐ **Mentally Incapacitated** ***Attach IRB Form #2A***

☐ **Children** ***(Ages 0-17 years) Attach IRB Form #2D***

☐ **Pregnant Women, Fetuses, or In Vitro Fertilization** ***Attach IRB Form#2C***

☐ **Prisoners** ***Attach IRB Form #2C***

16. Total number of subjects 20 healthy male subjects.

17. Subject recruitment. Please summarize your explanation of how you will recruit subjects. Include location of recruitment and enrollment. ***Please attach a copy of all recruitment flyers and ads.***

Examples of subject recruitment:
☒ **Direct person- to person solicitation per consent form.**
☐ **Telephone (attach oral presentation)**
☐ **Letter (attach finalized copy)**
☒ **Notices (attach finalized copy)**
☐ **Internet (attach finalized copy)**
☐ **Subject pool**
☐ **Other (explain and / or attach finalized copy if applicable)**

17a. List all criteria for including subjects. Male UTA staff, faculty, students, and community members who are between the ages 18-36 years old who do pass the health status questionnaire.
Reasons for males only: Surface Electromyography (sEMG) is used to measure muscle activity. This is a very reliable way to assess muscle function at a level of muscle firing and recruitment; however, subcutaneous adipose fat (skinfold thickness) serves as a low pass filter to the sEMG signals and it can dilute the signal. Unfortunately, females tend to have more subcutaneous adipose tissue on their thighs than males; therefore, we typically use males because of their low subcutaneous adipose tissue. We get better sEMG signals in this population and better data. The subjects must be actively participating in either weight training or running at least 2 times per week for a period of at least one month at the time of the study.

17b. List all criteria for excluding subjects. Any females (see reason above). Males who are younger than 18 years of age or older than 36 years old and males who do not pass the health status questionnaire.

18. **What rewards, remuneration, or other incentives, if any, will be used to recruit subjects?** none

19. **If the subject is a student who is undergoing this research for a course credit, how will you ensure that the subject was not coerced into participating?**
20. **Will you allow alternatives to the participation in the research without negative consequences?**

SECTION E: CONFIDENTIALITY – PRIVACY – COERCION

21. **Does this activity utilize data collected for other purposes? (e.g. student record, student assessments, patient records, etc.) (If this is for a data repository, please complete and attach an IRB Form #5 as well as a Consent Form for Data Repositories)**

☐ **YES** ☒ **NO**

a. **If yes, please specify the source of data to be utilized and how the data will be retrieved and reviewed.** n/a

b. **Could any of the recorded data contain personal or sensitive information? If yes, how do you propose to code and where will you maintain confidentiality of the data?** n/a

(Any subject data (including documents, audio, and videotapes) developed for or used by a human subject investigation protocol are potentially sensitive and must be maintained with confidentiality. All identifiable data are to be kept in a designated locked file. Sharing of identifiable data with other institutions, agencies, or companies must be identified prospectively to both the IRB and the subjects of the study.)

22. Could any part of this activity result in the potential identification of child abuse, elderly abuse, communicable diseases, or criminal activities that would / could not have been otherwise identified? If yes, estimate the likelihood of disclosure and describe the plan of action that you will take if this occurs. *In rare circumstances when research reveals these issues, confidentiality should be maintained to the extent that the law allows.*

☐ **YES** ☒ **NO**

23. Does any part of this activity have the potential for coercion of the subject? If yes, explain and describe proposed safeguards.

☐ **YES** ☒ **NO**

24. Please explain how you plan to maintain confidentiality. Include where your signed consent forms and identifiable data, if applicable, will be kept (under lock and key) and who will have access. All information will be kept in Activities Building Room 220. Only principal and co-investigators, and research collaborators will have access.

SECTION F: RISKS - PSYCHOLOGICAL RISKS

25. Aside from possible loss of confidentiality, is there a possibility of psychological injury resulting from participating in the research?

☐ **YES** ☒ **NO**

26. If you answered yes, how do you plan to minimize and control the risks?

27. Could the desired information be obtained from animals or other laboratory models? Explain.

☐ **YES** ☒ **NO**

In the event of an adverse event, you must fill out the IRB Form #8 to report the event to the Institutional Review Board for the protection of human subjects <u>immediately</u>.

SECTION G: RISKS - PHYSICAL RISKS

28. Is there a possibility of physical injury resulting from participation in the research?

☒**YES** ☐**NO**

29. If you answered yes, how do you plan to minimize and control the risks?

Eccentric exercise typically produces muscle soreness. If the subject exerperiences muscle soreness following the eccentric exercise protocol he will be instructed to rest (not participate in strenuous physical activity) until the soreness is no longer present and then the subject will be reschedule.The measure of soreness will be self reported. The finger prick sites may become infected. The subject will be instructed to look for signs of redness or pain related to the finger prick and report to the UTA Health Center if he believes his finger is infected.

30. Could the desired information be obtained from animals or other laboratory models? Explain.

☐**YES** ☒ **NO**

In the event of an adverse event, you must fill out the IRB Form #8 to report the event to the Institutional Review Board for the protection of human subjects <u>immediately</u>.

SECTION H: COST OF RESEARCH

31. Will the subjects incur any additional expenses for experimental (or otherwise unnecessary diagnostic) tests or procedures? If yes, explain

☐**YES** ☒**NO**

32. Is there any charge to the participant for participation? If yes, explain.

☐**YES** ☒**NO**

SECTION I: INFORMED CONSENT

33. Written, informed consent from the subject or from a legally responsible representative of the subject is normally required from the human research participants. The finalized consent form in all applicable languages should be included with the materials submitted to the IRB. You must keep all signed consent forms under lock and key during the study and for a period of 3 years after termination of the research on UTA Campus. These consent forms are subject to inspection by the Research Compliance Officer, the IRB and / or DHHS.

If you do not plan to obtain consent or written documentation of consent, please attach a completed IRB Form # 3.

a. If appropriate, describe your rationale for obtaining oral consent or assent instead of written consent. Attach a copy of the information to be read and given to the subjects.

b. Do you plan to make consent forms available in the native language for all subjects involved in the research? Please explain your procedures in determining the primary language spoken by the subjects and how you plan to deliver the informed consent process to subjects who do not speak English.

☐ **YES** ☒ **NO**

SECTION J: COOPERATIVE AGREEMENTS WITH OTHER INSTITUTIONS

34. If any part of this study will be conducted in an institution or location administratively separate from UTA, please indicate at which institution (attach an approval letter).

a. Does this activity utilize recorded data to be sent to cooperating institutions, or agencies not under your control?

☐ **YES** ☒ **NO**

b. If yes, could the data contain personal or sensitive information or put the participant in any type of legal risk?

c. If yes, how do you propose to maintain the confidentiality of the data?

SECTION K: CONSULTATION AND COLLABORATION

35. Subject recruitment and management:

If approval is required from other professionals for the recruitment and management of the subjects, please identify and obtain signature(s) from the individual(s) responsible for the subjects. If unobtainable, please explain or attach a signed agreement or letter.

Name of Professional	**Department**	**Signature**	**Date**
1. _____	_____	_____	____
2. _____	_____	_____	____
3. _____	_____	_____	____

36. Research collaboration:

Research collaborators are other researchers whose participation enhances the scientific merit of a research project. Have all collaborators indicate by signing this document that they have read the research protocol and agree to participate. If unobtainable, please explain or attach a signed agreement or letter.

Name of Collaborator	**Department**	**Signature**	**Date**
1. Jennifer Blevins _____	_____	_____	
2. Cynthia Trowbridge _____	_____		

3. _____ _____ _____

SECTION L: CONFLICT OF INTEREST DISCLOSURE

37. **Have you submitted a financial disclosure statement to your department chair listing all of your significant financial interests in accordance with The University of Texas at Arlington conflict of interest policy?**

☒**YES** ☐**NO**

38. **Did your department chair find that there was a potential conflict of interest and did he/she forward the statement to the Dean and / or the Vice President for Research and Information Technology?**

☐**YES** ☒**NO**

39. **If yes, please explain the conditions and restrictions imposed. If the conflict of interest is still pending review, please indicate here.**

☐**YES** ☐ **NO**

40. **Did your department chair forward the original statement to the Office of Research Compliance?**

☒**YES** ☐**NO**

SECTION M: SIGNATURES

I understand that I am responsible for the accuracy of the statements made in this protocol and for the conduct of research.

I understand that I am to submit annual reviews to the Institutional Review Board for the Protection of Human Subjects. If the annual report (IRB FORM # 6) has

not been received by the IRB Chair (or designee) by the anniversary date of the approval, this protocol's approval is terminated.

I understand that I am to file a final report upon conclusion of the research with the Institutional Review Board for the Protection of Human Subjects (IRB FORM # 7).

I understand that if my research is under a sponsored research agreement, additional standards may apply.

I am aware that upon approval of this protocol, the Research Compliance Officer may request to be present during at least one of my informed consent procedures on my Human Subjects.

I am aware that the signed consent forms need to be filed under lock and key during the research and for a period of 3 years upon termination of the research (if unfunded). For funded research, the consent forms will be kept for the length established under the terms and conditions of the award. These consent forms will be available for inspection by the Research Compliance Officer, the UTA IRB, or agents from Federal Agencies.

I understand that I, as well as all Human Subject Investigators involved in this study, must have documented Human Subject training in the Office of Research Compliance before performing any Human Subject research.

_____ _____

Principal Investigator **Date**

I have examined this completed form and I am satisfied with the adequacy of the proposed research design and the measures proposed for the protection of Human Subjects. I will take responsibility for informing the student of the need for safekeeping of all raw data (e.g. test protocols, tapes, questionnaires, interview notes, etc.) in a university office or computer file. I will be responsible to see that all consent documents are stored on UTA campus in a locked file during the research and 3 years after the conclusion of the research. I will be responsible to see that all Annual and Final Reports (IRB Form #7) are submitted to the IRB by the anniversary date(s) of the approval and upon conclusion of the research (conclusion of data analysis.)

_____ _____

Faculty Sponsor (If not the Principal Investigator) **Date**

I have read this completed form and endorse this research to be conducted.

Department Chairman or Dean or Director	**Date**

APPENDIX B

INFORMED CONSENT

This Informed Consent will explain about being a research subject in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer.

PURPOSE:

The purpose of this study is to investigate the effects of eccentric (lengthening) and concentric (shortening) contractions of the knee muscles on muscular fatigue. Muscular fatigue will be assessed through blood lactate samples and data collected during knee contraction. During this study I will be required to complete a knee muscle fatigue protocol consisting of 4 sets of 20 maximal knee extensions on the Biodex exercise machine on two separate days.

The specific purposes of this research study are as follows:

1. Do the knee extensor muscles show a greater decline in mechanical work when performing lengthening contractions than when performing shortening contractions?
2. Is the concentration of blood lactate greater when performing lengthening contractions than when performing shortening contractions?
3. Is there a difference in the change in muscle activation when performing lengthening contractions than when performing shortening contractions?

DURATION

In this study I will be scheduled for three appointments. The first session will last for approximately 20 minutes and the second and third sessions will last approximately 30 minutes. The first appointment will consist of a health history, and a practice session in which I will practice the lengthening and shortening knee exercise on the Biodex exercise machine. During the second and third sessions I will be required to perform a fatiguing exercise protocol on the Biodex exercise machine.

The total number of subjects participating is 20.

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PROCEDURES

The procedures, which will involve you as a research subject, include:

1. To be included in this study, you will report to the Biomechanics Laboratory (Room 150) in the Activities Building and fill out a health history questionnaire. If you have not been running or lifting weights at least 2 times/week for the last month you will

be excluded. If you are selected to participate in this study, you will be scheduled for two (2 data collections) appointments.

2. At the first appointment (familiarization) I will be required to complete a health history questionnaire. I will practice the lengthening and shortening knee exercise on the Biodex exercise machine. I will be given an explanation of how to perform each exercise. Following my first session, I will be scheduled for my second appointment.
3. For my second appointment, after reporting to the Biomechanics Laboratory (ACT 150), I will be asked to change into shorts. Three locations on the front of my thigh and one on the front of my shin will be prepped for electrode placement by shaving about a 2 inch circular area to remove excessive hair. After shaving these locations, the shaved areas will be cleaned by wiping the skin with an alcohol pad and a gauze pad. Then the surface electrodes will be placed over each location. Then electrode cables will then be attached to the electrodes and the quality of the muscle signals will be verified by having me perform light contractions. If any of the muscle signals show signs of poor connections, the electrodes will be replaced and the signal quality will be checked again. Next, a finger on my non dominant hand will be cleaned with an alcohol pad. After cleaning, the index finger will be pricked with a sterile lancet and sample of my blood will be collected. After the blood sample is taken a sterile band aid will be placed over my finger and I will then be seated on the Biodex exercise machine. My right leg and torso will then be secured to the exercise machine using Velcro straps. I will then be allowed to lightly practice the exercise condition for the test session, either a lengthening contraction or a shortening contraction. After this brief practice period I will be instructed to perform the fatiguing protocol consisting of 4 sets of 20 contractions with one minute of rest between each set of 20 contractions. Two minutes after the last set my middle finger will be pricked with a lancet and a small sample of my blood will be taken. Once again a band aid will be placed over the skin prick location. Upon completion of session 2, I will be scheduled for session 3. In session 3, I will be required to repeat the procedures outlined in session 2 by performing the remaining condition, either the lengthening or shortening exercise condition.
4. For my third appointment, I will repeat the same protocol as I did in my second appointment but this time I will do the other exercise protocol.

POSSIBLE RISKS/DISCOMFORTS

The possible risks and/or discomforts of your involvement are include:

1. Delayed onset muscle soreness- soreness that occurs 24 hours after exercise. Soreness could be felt when walking up the stairs and when the muscle is pressed firmly. The soreness could last for 72 hours.
2. Kneecap pain as a result of tendon fatigue.
3. Red skin under skin electrode.
4. Finger soreness, prick mark, and/or slight discoloration
5. Wound infection at site of prick

Throughout the tests you will be monitored by laboratory personnel trained in CPR and First Aid. Emergency (911) will be called for any emergency situations.

POSSIBLE BENEFITS

The possible benefits of your participation are:

1. Improved understanding of the effects of lengthening and shortening exercises on fatigue.

ALTERNATIVE PROCEDURES / TREATMENTS

There are no alternative procedures or courses of treatment. **However, you can elect not to participate in the study at any time with no negative consequences.**

CONFIDENTIALITY

Every attempt will be made to see that your study results are kept confidential. A copy of the records from this study will be stored in (Office of Dr. Mark Ricard, ACT 220) for at least three (3) years after the end of this research. The results of this study may be published and/or presented at meetings without naming you as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the UTA IRB, and personnel particular to this research (Mark Ricard, Kinesiology Department) have access to the study records. Your records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

FINANCIAL COSTS

The possible financial costs to you as a participant in this research study are:

1. There should be no financial costs to you as a participant unless you incur medical treatment outside the UTA covered costs.

CONTACT FOR QUESTIONS

If you have any questions, problems or research-related medical problems at any time, you may call Jeremiah Campbell at 817-272-7017 (**campbelj@uta.edu**) or Dr. Mark Ricard at 817-272-0764 (ricard@uta.edu) or at the Biomechanics Laboratory 817-272-7146.

You may call the Chairman of the Institutional Review Board at 817/272-1235 for any questions you may have about your rights as a research subject.

VOLUNTARY PARTICIPATION

Participation in this research experiment is voluntary. You may refuse to participate or quit at any time. You may quit by calling Jeremiah Campbell (**campbelj@uta.edu**),

whose phone number is 817-272-7017. You will be told immediately if any of the results of the study should reasonably be expected to make you change your mind about staying in the study.

By signing below, you confirm that you have read or had this document read to you. You will be given a signed copy of this informed consent document. You have been and will continue to be given the chance to ask questions and to discuss your participation with the investigator.

You freely and voluntarily choose to be in this research project.

PRINCIPAL INVESTIGATOR: _____

DATE

_____

SIGNATURE OF VOLUNTEER DAT

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BIOGRAPHICAL INFORMATION

Jeremiah Cedric Campbell was born on February 3, 1983 to Janice and Buttie Campbell in El Paso Texas. He is the youngest of two children (Nakila Turley). On May 18, 2005 Jeremiah graduate from the School of the Talented and Gifted Magnet High School at the Yvonne A. Ewell Townview Center. He received his Bachelors of Arts in Biochemistry for Austin College located in Sherman Texas on May 15, 2005. He will receive his Masters of Science in Exercise Physiology in August 2007 from the University of Texas at Arlington. Jeremiah's future plan is to pursue a doctoral degree in Exercise Physiology with emphasis in metabolism. His likes include basketball, science, and a good book.