



An analysis of the Yoyo Strength Ergometer
by Dean Randal Mercado

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in
Health and Human Development
Montana State University
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Abstract:

The purpose of this study was to observe and quantify the effect selected anthropometric measurements may have on electromyographic (EMG) and kinematic data of a subject performing on the Yoyo Strength Ergometer (YSE). Fourteen subjects took part in the study. EMG and kinematic data were collected while the subject performed on the YSE. Kinematic data were automatically digitized and smoothed using Ariel Performance Analysis System (APAS) software. EMG data were analyzed using Excel and custom programs written on Lab View Version 5.0 software. Four independent variables (IV) were identified for this study 1. Height (HT) 2. Leg length (LL) 3. Upper leg length (ULL) 4. Lower leg length (LLL) Several dependent variables (DV) were identified for this study 1. ROM 2. Average angular velocity (AAV) 3. Peak Angular Velocity (PAV) 4. Joint angle at peak muscle activity (JAPMA) 5. Percentage of maximum isometric contraction (PMIC) Linear regression was performed comparing each IV with every DV. Statistically significant correlations were found and included 1. HT and AAV at knee 2. LL and AAV at knee 3. LL and PAV at hip - eccentric 4. LL and PAV at knee 5. LL and PAV at knee - eccentric 6. ULL and PAV at hip 7. ULL and PAV at knee - eccentric 8. LLL and AAV at hip 9. LLL and PAV at hip 10. LLL and AAV at hip - eccentric 11. LLL and AAV at knee 12. LLL and AAV at knee - eccentric 13. LLL and PAV at knee 14. LLL and PAV at knee - eccentric Taller subjects or subjects with longer legs, upper legs, or lower legs had greater concentric angular velocities and lower eccentric angular velocities. Possible explanations could be that the taller individuals pushed harder or may have had a mechanical advantage. Neither were substantiated because of the lack of performance data available from the YSE. There were no statistically significant correlations between the IV and the EMG DV. The data also provided the basis for the argument that the YSE could be an effective resistance training device, as the data compares well with other resistance training devices.

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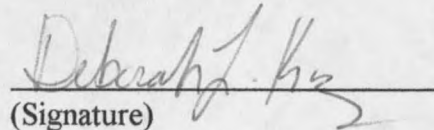
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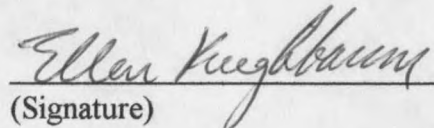
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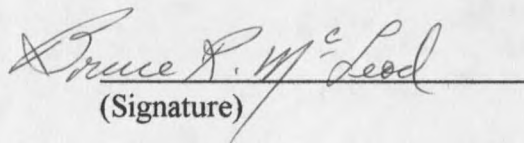
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ABSTRACT

The purpose of this study was to observe and quantify the effect selected anthropometric measurements may have on electromyographic (EMG) and kinematic data of a subject performing on the Yoyo Strength Ergometer (YSE). Fourteen subjects took part in the study. EMG and kinematic data were collected while the subject performed on the YSE. Kinematic data were automatically digitized and smoothed using Ariel Performance Analysis System (APAS) software. EMG data were analyzed using Excel and custom programs written on Lab View Version 5.0 software. Four independent variables (IV) were identified for this study

1. Height (HT)
2. Leg length (LL)
3. Upper leg length (ULL)
4. Lower leg length (LLL)

Several dependent variables (DV) were identified for this study

1. ROM
2. Average angular velocity (AAV)
3. Peak Angular Velocity (PAV)
4. Joint angle at peak muscle activity (JAPMA)
5. Percentage of maximum isometric contraction (PMIC)

Linear regression was performed comparing each IV with every DV. Statistically significant correlations were found and included

1. HT and AAV at knee
2. LL and AAV at knee
3. LL and PAV at hip - eccentric
4. LL and PAV at knee
5. LL and PAV at knee - eccentric
6. ULL and PAV at hip
7. ULL and PAV at knee - eccentric
8. LLL and AAV at hip
9. LLL and PAV at hip
10. LLL and AAV at hip - eccentric
11. LLL and AAV at knee
12. LLL and AAV at knee - eccentric
13. LLL and PAV at knee
14. LLL and PAV at knee - eccentric

Taller subjects or subjects with longer legs, upper legs, or lower legs had greater concentric angular velocities and lower eccentric angular velocities. Possible explanations could be that the taller individuals pushed harder or may have had a mechanical advantage. Neither were substantiated because of the lack of performance data available from the YSE. There were no statistically significant correlations between the IV and the EMG DV. The data also provided the basis for the argument that the YSE could be an effective resistance training device, as the data compares well with other resistance training devices.

CHAPTER 1

INTRODUCTION

Today there seems to be a renewed interest, by the general public, in space exploration. With the recent success of the Mars Pathfinder missions, there seems to be a rekindled interest in space exploration similar to that of the Apollo missions to the moon during the late 1960's and early 1970's. However unlike the Apollo missions which lasted an average of 9.1 days, a manned, round trip journey to Mars could take in excess of one year. This length of time necessary to make the round trip journey to Mars raises the subject of how the human body will react to extended periods of time in microgravity. In an attempt to study this phenomenon, researchers are studying astronauts as they prepare for, perform, and return from their missions, as well as studying individuals in various situations which are meant to simulate a microgravity environment. The findings of the researchers present a problem to the ultimate goal of a manned mission to Mars or any lengthy mission. When exposed to microgravity or simulated microgravity, the body goes through various physiological adaptations. These physiological adaptations are generally negative and can limit an astronaut's ability to perform certain tasks, such as extra-vehicular activities and emergency egress - emergency evacuation procedures. Physiological adaptations the body may experience, when exposed to microgravity or simulated microgravity, include decreases in stroke volume, cardiac output, aerobic power or VO_2 max (Convertino, 1996, Greenleaf et al. 1989, and Levine et al. 1996), aerobic pathway enzymes, oxygen delivery, oxygen

utilization, anaerobic threshold (Convertino 1996), bone mineral content or density, muscle cross sectional area, muscle function (Convertino, 1996, Greenleaf et al. 1989), and body weight (McArdle 1996). Researchers have found that most of these adaptations can occur in as little as nine days of exposure to microgravity or simulated microgravity (Levine et al. 1996).

One method used in an attempt to counteract these physiological adaptations is to perform physical exercise during the exposure to microgravity or simulated microgravity (Convertino 1996, Greenleaf et al. 1989, Levine et al 1996, Greenleaf et al. 1982). In a normal gravitational environment, such as on earth, exercise can cause beneficial adaptations to the cardiovascular and musculoskeletal systems, including increased bone mineral content or density, increased muscle cross sectional area, improved muscle function, and improvements in many cardiovascular functions (McArdle et al 1996, Robergs et al. 1997, Williams 1994).

Several forms of exercise have been performed and studied in a microgravity or simulated microgravity environment including cycle ergometers, treadmills, and resistance training devices (Convertino 1996). There have been mixed results concerning the effectiveness of these exercises as countermeasure to the adaptations that occurs as the result of microgravity or simulated microgravity. While aerobic forms of exercise, such as a cycle ergometer or treadmill, can counteract some of the negative adaptations that occur to the cardiovascular system, they have little if any effect on the decreases seen in the musculoskeletal system (Convertino 1996, Greenleaf et al. 1989).

Traditional resistance training, on the other hand, has been shown to positively affect

the musculoskeletal system. The problem arises in that many of the present forms of traditional resistance training are simply moving objects against the pull of gravity. Obviously without gravity, as in a microgravity environment like space, these traditional exercises are useless. Other forms of resistance training which have been studied include isokinetic resistance devices, spring loaded devices, and elastic based resistance training devices. These devices have proved to have limited success in attenuating the musculoskeletal losses experienced during exposure to microgravity. As a result, there has been a recommendation to develop a resistance training device and/or programs which will utilize an optimal combination of eccentric and concentric contractions that could induce the neuromuscular and musculoskeletal adaptations to attenuate the effects of a microgravity environment (Baldwin et al 1996).

Hans Berg and Per Tesch developed the Yoyo Strength Ergometer in an attempt to fulfill the need for a resistance training device to be used in a microgravity environment. The Yoyo Strength Ergometer is a mechanical, gravity-independent ergometer that requires no external power source and provides a resistance exercise similar to that of a traditional leg press device. The Yoyo Strength Ergometer utilizes the inertial properties of two weights for resistance. While observing unpublished research by Caruso and colleagues using the Yoyo Strength Ergometer, some promising results as well as a possible limitation surfaced. Certain subjects seemed to have a limited range of motion while exercising on the Yoyo Strength Ergometer.

The National Aeronautics and Space Administration (NASA) has set up some physical standards in their selection process of potential astronaut candidates, in particular a range of

heights from a minimum of 58.5 inches to a maximum of 76 inches (J.S.C. form 465). The Yoyo Strength Ergometer, in its present form, may be limited in its effectiveness as a resistance training device for a population ranging in height similar to that of potential astronaut candidates.

Statement Of Purpose

The purpose of this study was to observe and quantify the effect selected anthropometric measurements, height, leg length, upper leg length, and lower leg length may have on selected electromyographic (EMG) and kinematic data of subjects performing on the Yoyo Strength Ergometer.

Hypothesis

It was hypothesized that subjects with a height at the upper extreme of the range for astronauts or a height at the lower extreme of the range for astronauts, would demonstrate alterations in technique while performing on the Yoyo Strength Ergometer. Two examples of different technique include either a decreased range of motion (ROM) or an alteration in the levels of muscle activity in selected lower extremity muscles.

Limitations

There were several limitations to the study, most associated with the EMG analysis. These limitations, which are common when using surface electrodes, were: the potential for cross talk, being limited to the more superficial muscle fibers, and analyzing a limited number of muscles on one limb of a biaxial movement. Other limitations included the relatively low

number of individuals serving as subjects, and the lack of any performance data from the Yoyo Strength Ergometer.

Delimitations

There were certain delimitations in this study. The study was delimited by the number of repetitions performed on the Yoyo Strength Ergometer by the subjects, the amount of exposure to or practice on the Yoyo Strength Ergometer, and a certain range of height, between 58.5 inches and 76.5 inches, chosen for analysis.

Definitions

Before proceeding, several key terms should be defined.

Electromyography (EMG) is a technique used to identify the relative levels of activation of parts of muscles, a muscle, or a muscle group (10).

Maximal isometric contraction is the maximum contraction of a muscle or muscle group that produces no obvious or measurable change in muscle length or joint position.

Isokinetic is the muscle contraction that accompanies constant angular velocity of a limb.

Concentric is a muscle contraction that shortens sufficiently to cause movement at the articulation that it crosses.

Eccentric is a muscle contractions that occurs while the muscle is lengthening.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Physiological Adaptations To Microgravity or Simulated Microgravity

Although it is apparent that humans can survive and function in a microgravity environment, much remains to be learned concerning the adaptive processes of the human body (Tipton et al 1996). Exposure to a microgravity environment can result in structural and functional deficits to the musculoskeletal system (Baldwin et al. 1996). Long term changes include decreased muscular strength, muscle mass, bone mass, decreased VO₂ max, dehydration, decreased plasma volume, decreased stroke volume, increased resting heart rate, increased systolic blood pressure, elevated body temperature, increased oxygen uptake at rest, decreased oxygen uptake during exercise, and an increase in energy expenditure for a given level of work (Convertino 1996). A major adaptation to microgravity or simulated microgravity is the decrease in the cross sectional area of postural muscles, such as the calf and thigh muscles. Convertino et al. (1989a,b) found significant decreases in calf and thigh muscle cross sectional area and volume. Convertino (1990) reported a loss in the strength of postural muscles in exposure to weightlessness in as little as two to five days. Dudley et al. (1989) studied in vivo torque-velocity muscles following 30 days exposure to simulated microgravity. The researchers found that changes in strength were not affected by the type or speed of muscle action. An additional finding by the researchers was that the strength of the extensor muscles decreased more than the flexor muscle group following the exposure to

simulated microgravity.

Several other studies were performed concerning the musculoskeletal system and the effects of immobilization. Appell (1986) reviewed material concerning skeletal muscle atrophy during immobilization. He found studies which stated that it could take from four to fourteen months for a person to regain losses in strength resulting from immobilization. Gogia et al. (1988) studied the effect of bed rest on extremity muscle torque in healthy males. Significant decreases in muscle torque following 35 days of bed rest in six of seven muscles tested, including postural muscles tested were found. Duchataeu and Hainaut (1987) studied the changes in muscles that occur as a result of immobilization and found decreases in muscle strength as great as 55%.

Exercise As A Countermeasure To Unweighting

There has been an attempt by the scientists at NASA to counteract the physiological losses observed as a result of microgravity with exercise countermeasures. During the early history of NASA, little or no exercise took place during space flights. Exercises that were used might have included isometric exercises or bungee cords. Later with the advent of larger space crafts, there was more exercise being performed in space, possibly due to the added space available in the space crafts. Exercise equipment currently used in spaceflight includes the cycle ergometer, treadmill, and several strength training devices (Convertino 1996). However most of the exercise being performed was of the aerobic type including bicycle ergometers, tethered treadmills, and rowing machines. The cycle ergometer and treadmill both proved to be beneficial in attenuating the deficits dealing with aerobic or cardiovascular

power. However the aerobic types of exercise had little or no success on deterring losses observed in muscle strength, muscle mass, and bone mass (Convertino 1996). Tethered and Lower Body Negative Pressure treadmills had been favored in spaceflight in an attempt to simulate ground based walking. The main troubles with these devices were the large size of the equipment and the low mechanical efficiency of the treadmill exercise in spaceflight (Convertino 1996).

The next obvious approach to exercise countermeasures was resistance training. However, traditional resistance devices are load dependent. That is, they rely on the pull of gravity on the object to provide the resistance. Isokinetic dynamometers have been used as an alternative. An isokinetic dynamometer is velocity dependent and can provide both concentric and eccentric contractions. The trouble with isokinetic devices is that they generally require an external power source, are extremely heavy and cumbersome, and are generally limited in the movements available, all characteristics which are deemed undesirable by NASA. There are a wide variety of resistance training devices being used in space with a broad range of success and equally broad range of limitations. Rope and pulley devices, chest expanders, rope and capstan, and spring-resistance devices have been used among others. Devices such as these are advantageous because of their small size and light weight however they become unpleasant to use at the level necessary to induce sufficient beneficial results. Another drawback is the lack of quantification of forces applied.

Much of the research on the effects of exercise as a counter measure to exposure to microgravity closely mirrors the types of exercises utilized, predominantly aerobic. However, some research does exist concerning resistance training programs and equipment as well as

ways to combat the negative adaptations that result from microgravity or simulated microgravity.

Loaded eccentric contractions that occur during normal daily activity, such as standing and walking, are absent during weightlessness. Kirby et al. 1992 hypothesized that eccentric resistance training could prevent soleus muscle atrophy during non-weight bearing. Electrically stimulated maximal eccentric contractions, four sets of six repetitions, were performed on adult female rats at 48 hour intervals during a ten day experiment. Non-weight bearing significantly reduced soleus muscle wet weight (7%), while eccentric exercise training during non-weight bearing resulted in higher soleus muscle wet weight than non-exercising non-weight bearing controls (30%).

Greenleaf et al. (1989) studied the result of isokinetic and isotonic exercise performed during a 30-day bed rest study. Interestingly enough, the subjects who performed the isotonic exercise did not see the dramatic decreases in aerobic power and plasma volume when compared with the control or no exercise group and the isokinetic exercise group. Greenleaf et al. (1989) found near-peak, variable intensity, isotonic leg exercise maintained peak VO_2 during 30 days of simulated microgravity.

Duvoisin et al. (1989) studied the affect of electromyostimulation (EMS) on the size and function of muscle during 30 days of simulated microgravity. Subjects receiving the EMS saw smaller decreases in torque and cross sectional area in several lower extremity muscles when compared with the control group.

Convertino (1990) reported the results of using a cycle ergometer during the 28-day Skylab mission. Even with daily usage of the cycle ergometer, post flight exercise tests reveal

a decreased cardiac output, increased heart rate, and a decrease in arm and leg strength. On the next Skylab mission, a isokinetic resistance device was used to exercise the arms and legs in addition to the cycle ergometer. Although arm strength was preserved during post flight exercise test, leg strength and cardiovascular responses both decreased. On a later Skylab mission, a Tethered Treadmill was added to the exercise arsenal. Although some cardiovascular functions saw smaller deficits compared to earlier missions, there still existed some deficits in other cardiovascular functions as well as a loss of muscle strength.

Greenleaf et al. (1983) reported, as part of his review of related literature, that other researchers found isotonic and isokinetic exercises performed during simulated microgravity experiments to have various results on strength changes of different muscles of the body. He reports a range from small increases in muscle strength to decreases in muscle strength of up to 11%. However, when compared to control, or non-exercising, subjects who saw losses in muscle strength up to 57% in anterior leg muscle strength, exercise seems beneficial.

One possible drawback to isokinetic and isometric exercise is the specificity of adaptations that occur. Increases in force production are specific to the angle of training in isometric exercises, (Kitai et al 1989, Weir et al. 1995), while increases in force production are also specific to the angular velocity in isokinetic exercises (Behm et al. 1993, Timm et al. 1993). Knapik et al. (1983) studied angular specificity and test mode, isometric or isokinetic contractions, specificity and found no significant differences between isometric and isokinetic groups when tested isometrically. However, there was a significant difference between the two groups when tested isokinetically; the isokinetic group demonstrated more improvement. According to these results, the adaptations that occur as the result of isokinetic exercise does

transfer to isometric strength.

Since exercise protocols of endurance type are insufficient for maintaining musculoskeletal system, normal motor control, posture, muscle mass, and bone mass, NASA has solicited research to determine strategies for exercise, both independently and in conjunction with other therapeutic modalities that could prevent or minimize the deficits incurred in response to exposure to microgravity (Tipton et al. 1996). The exercise protocol should include aspects which focus on maintaining routine motor skills, heavy resistance paradigms, activities that generate high impact, and an element of aerobic activity (Tipton et al. 1996). The resistance portion of the exercise programs should include a combination of isometric, eccentric and concentric contractions. The resistance programs should elicit improvements in the muscular system as well as the neurological and skeletal systems. The equipment must be convenient to use and should be small and light weight for easy handling. The exercise should also result in a limited drain on the life-support materials (Convertino 1996) requiring little or no external power to operate.

Physiological Adaptations to Exercise

The progressive overload of a muscle through resistance training has been shown to increase the cross sectional area of muscles (Bandy et al. 1990), lean body mass and muscle mass (Tesch 1988). Traditionally, this increase in cross sectional area is attributed to an increase in the diameter of individual muscle size. However some researchers feel that an addition of new muscle fibers could provide some portion of the increase in cross sectional area (Bandy et al. 1990). Bandy et al. (1990) cites several sources indicating increased

muscle strength, increased motor unit activation, increased reflex response, and an increase in motor unit synchronization.

Kraemer et al (1990) studied various resistance training protocols. Although the protocols all resulted in different levels of physiological adaptations, all resistance training protocols tested resulted in an increase in human growth hormone and testosterone levels.

Garfinkel and Cafarelli (1992) studied relative changes in maximal force, EMG, and muscle cross sectional area after isometric training. They found that their eight week isometric training program increased both muscle cross sectional area and maximal force.

Narici et al. (1989) studied changes in force, cross sectional area and neural activation during strength training and detraining. They found that following a 60 day training program, muscle EMG activity, force, and cross sectional area all increased significantly.

Krotkiewski et al. (1979) studied the effect of isokinetic strength training on several physiological systems. Resistance training resulted in an increased muscle size in the sample population.

Curtetion et al. (1987) reported that although men experienced greater absolute increases in strength, the percentages gained did not differ significantly from men to women following a 16 weeks resistance training program. Additionally both men and women experienced significant increases in cross sectional area of certain muscles.

Dalsky, G. (1987) reported the results of a review of literature on the effects of exercise on bone mineral content. Most researchers agree that exercise helps maintain axial bone mineral content, increased lumbar bone mineral content, and helped maintain calcium levels. This was reaffirmed in a study by Raab et al. (1990) who found an improvement in

bone mechanical properties resulting from exercise, regardless of subject age.

Robertson et al. (1990) studied the relationship between EMG and torque during isokinetic knee flexion and extension exercise. They reported that EMG data collected from surface electrodes of certain knee flexor and extensor muscles was a good indicator of torque.

Klopfer and Greij (1988) examined quadriceps and hamstring performance during high velocity isokinetic exercise. No significant difference in quadriceps performance between dominant and non-dominant leg was found. A significant difference in performance of the hamstrings between dominant and non-dominant legs was found. However, there was no distinct pattern in hamstring performance differences. The results were attributed to the heterogeneous nature of the subjects as well as subject motivation and fatigue.

Osternig et al. (1984) studied electromyographic patterns of the knee flexor and extensor muscles during isokinetic exercise under varying speeds and conditions, finding that co-contraction of the antagonist muscles was not significant during either knee flexion or extension exercises. When compared to quadriceps EMG activity during knee flexion, hamstring EMG activity during knee extension was found to be greater. It was hypothesized that this might be because the quadriceps are generally a more powerful muscle group and could produce an equal amount of force with less EMG activity.

Denuccio et al (1991) compared quadriceps eccentric verses concentric data on an isokinetic dynamometer. At an angular velocity of 180 degrees per second, the average peak torque was significantly greater during eccentric contractions compared to concentric contractions. Regardless of the type of contraction, peak torque occurred at the same average angle of 66 degrees of knee flexion.

Cerny (1995) compared vastus medialis oblique/vastus lateralis muscle activity ratios for selected exercises. With the exception of terminal knee extension exercises with the hip rotated medial verses laterally, none of the other exercises resulted in significant differences in muscle activity. Zakaria et al. (1997) also show no preferential activation of the same muscles during various lower extremity exercises.

Wretenberg et al. (1993) studied joint moments of force and muscle activity during squatting exercises. Hip moments, knee moments, and muscle activity were found to increased significantly as the depth of the squat increased to a parallel squat.

Isear et al. (1997) studied lower extremity recruitment patters during an unloaded squat. All of the muscles demonstrated the greatest EMG activity between 60 to 90 degrees of knee flexion. The vastus medialis oblique, vastus lateralis, and the gastrocnemius all demonstrated a maximum EMG during the lowering portion of the activity, or eccentrically. The rectus femoris, hamstrings, and gluteus maximus all demonstrated a maximum EMG during the raising portion of the activity, or concentrically. When reported as a percentage of maximum voluntary isometric contraction, the vastus medialis oblique, vastus lateralis, and rectus femoris all demonstrated greater values then all other muscle groups tested between 0 to 90 degrees eccentrically and 90 to 60 degrees concentrically. From 60 to 30 degrees, the rectus femoris percentage greatly decreased, however the vastus medialis oblique and vastus lateralis values remained high. All quadiceps muscle activity greatly decreased during the final 30 degrees of the movement. And because the hamstring and rectus femoris muscles are both two joint muscles, the combination of the hip angle and knee angle during the exercise can greatly affect muscle activity.

Wilk et al. (1996) studied EMG activity during open and closed kinetic chain exercises, reporting results similar to Isear et al (1997). Peak EMG activity of the quadriceps muscles, vastus medialis, vastus lateralis, and rectus femoris, occurred between 88 to 102 degrees concentrically during the squat and leg press. The hamstrings muscles, biceps femoris, semimembranosus, and semitendinosus, demonstrated peak EMG activity at approximately 40 degrees concentrically in the squat and between 60 and 70 concentrically during the leg press. Additionally quadriceps muscle activity, when reported as a percentage of maximal isometric contraction, was greater than hamstring muscle activity.

Kellis and Baltzopoulos (1996) studied muscle moments and EMG during isokinetic exercise. Maximum knee extensor moments occurred between knee angles of 60 to 80 degrees while extensor EMG activity was greatest between 50 and 70 degrees. Maximum flexor moments and EMG activity occurred between 20 and 40 degrees. In addition exercise velocity had no effect on any of the results.

Summary

It is apparent that there is a need for countermeasures to the physiological adaptations that occur as a result of exposure to microgravity or unweighting. Although aerobic exercise can be of some benefit, there is still the need for resistance type exercises which have been shown to have beneficial results on the musculoskeletal system. The Yoyo Strength Ergometer was developed in an attempt to address the need for a resistance training device to be used as a countermeasure. However as a relatively new device, its effectiveness as a resistance training device must be researched.

CHAPTER 3

METHODOLOGY

Introduction

The purpose of this study was to determine the effect of certain anthropometric measurements on selected electromyographic and kinematic data of a subject performing on the Yoyo Strength Ergometer. Electromyography data of selected hip extensor, knee extensor, and ankle plantar flexor muscles were collected. Video data of motions in the sagittal plane were collected using a video camera. The methods and procedures used to collect and analyze the data are presented in this chapter.

Subjects

Twelve male and two female, apparently healthy students attending Montana State University were selected for the study. Subjects reported no illness, sickness, or injury in the two years prior to the study, according to questionnaires administered prior to testing. The subjects were selected to match certain characteristics, height and age, of astronauts employed by NASA. All subjects were at least 58.5 inches and at most 76 inches tall. All subjects were at least 18 years of age. Subjects were informed of the purpose and procedures of the study and signed an informed consent form.

Instrumentation

EMG data were collected with Preamplified Surface Electrodes (Motion Control, Salt Lake City, UT) . The EMG signals were processed via a BNC - 2090 A to D board (National Instruments, Austin, TX) and saved on a IBM compatible desktop computer (Virtual Computers Technology, Bozeman, MT). An AG-450 Camcorder (Panasonic Communications and Systems Co., Seattle, WA) operating at 60 Hz was used to videotape the testing sessions. The camera was placed approximately 24 feet away from the subject, perpendicular to the subject's sagittal plane, on their right side (see Fig. 3.1). The camera was equipped with a 8 to 80 mm 1:1.4 Panasonic TV Zoom Lens. Lighting was provided by one Pallite VIII light (Photographic Analysis Limited, Markham, Ontario) placed 26 feet away from the subject (see Fig. 3.1). A model 67070 goniometer (Country Technology Inc, Gay Mills, WI) was used for all Range of Motion measurements. A model 01290 Anthropometer (Lafayette Instrument Company, Lafayette, IN) was used for all anthropometric measurements, except height and weight which were measured on a Model 3P7044 balance scale (Detect, Web City MO).

Procedures

Testing consisted of one session lasting approximately 45 - 60 minutes. The visit consisted of a familiarization session aimed to introduce the subjects to the Yoyo Strength Ergometer followed by the collection of the anthropometric data, a warm up, application of the surface electrodes, and finally actual test session on the Yoyo Strength Ergometer. The session began with an explanation of the purpose of the study and having the subject read and sign the Human Subjects Consent Form. Once consent had been established, a brief

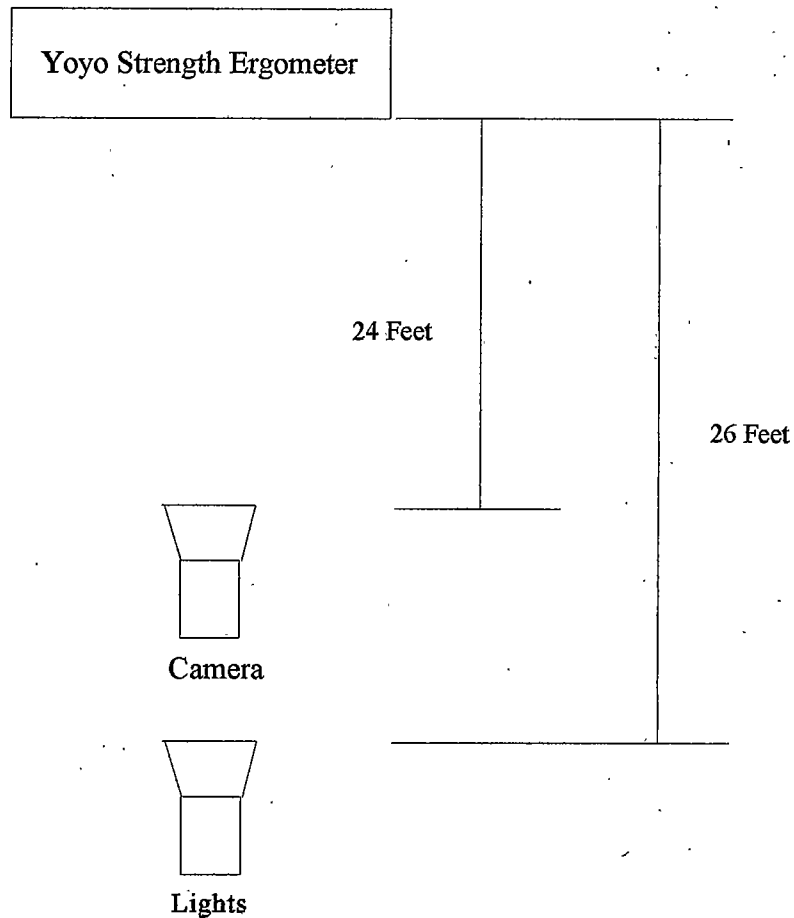


Figure 3.1 Camera and light setup (see Figure 3.5)

explanation of the operation of the Yoyo Strength Ergometer was given. With the subject standing erect, an ankle angular position was measured and assumed to be that subjects neutral ankle angular position. The subject was then placed on the Yoyo Strength Ergometer, with his or her knees fully extended, and the foot pedals were adjusted to as closely

approximate the neutral ankle position just established. The subject was then asked to perform several repetitions on the Yoyo Strength Ergometer to allow the subject to familiarize himself or herself with the machine. The starting, mid, and final positions of the motion were then identified to the subject.

One repetition was defined as one concentric and one eccentric phase. The concentric phase consisted of the portion of the movement from the starting position, the position with the strap completely wound up and the hip, knee, and ankle in maximum flexion, to the point where the strap is fully unwound and the hip, knee, and ankle were at a position of maximum extension allowed by the Yoyo. The eccentric phase consisted of the portion of the movement from position of maximum extension back to the starting position. The subject was encouraged to practice utilizing maximum effort during the concentric and eccentric phase while still performing through the full Range of Motion allowed by the Yoyo. The subject was also encouraged to practice initiating motion upon a verbal command from the tester. The verbal command consisted of a three second countdown followed with the command "Go."

Subject Preparation

Next selected anthropometric measurements of each subject, height, weight, seated height, total leg length, upper leg length, and lower leg length were measured as were the maximum active flexed position of the hip, knee, and ankle and then recorded. Standing height and weight were measured to the nearest quarter inch and quarter pound. Total leg length, upper, and lower leg length measurements followed, with all measurements being recorded with the subject in the standing position. Total leg length was the measure of the

distance from the ground to the greater trochanter of the femur. Upper leg length was determined by the distance between the greater trochanter and the lateral epicondyle of the right femur. Lower leg length was determined by the distance between the lateral epicondyle of the right femur and lateral malleolus of the right fibula. The subject was then asked to sit down and a sitting height measurement, defined as the distance from the surface of the chair to the top of the person head, was taken.

The active maximum hip flexion position was measured on the right side and began with the subject in the seated position and then asked to flex his or her right leg as much as possible allowing their knee to flex while minimizing all other motion. The active maximum knee flexion position was measured in a similar manner only flexing the right knee. Maximum plantar flexion and dorsiflexion positions were measured first with the right knee at approximately 90 degrees and then again with right knee straight.

Next the subjects performed a brief warm up consisting of cycling on a Monark 824 E cycle ergometer for five minutes. Upon completion of the warm up, the subject was then prepared for EMG surface electrode placement and the reflective markers positions were determined. Although the subjects were performing a bilateral motion of the lower extremity, data were collected from their right side only, making EMG surface electrode and reflective marker placement necessary only on the right.

The EMG surface electrodes were placed according to protocols established by Basmajian and Blumenstein (1989), to collect EMG data from the Gluteus Maximus, Biceps Femoris, Rectus Femoris, Vastus Medialis, the lateral head of the Gastrocnemius, (see Fig. 3.2 and Fig. 3.3). Each site was cleaned by rubbing vigorously with a sterile gauze pad and

rubbing alcohol. The five sites for the reflective markers were then determined for each subject. The sites consisted of the acromion process, greater trochanter, lateral epicondyle of the femur, lateral malleolus of the ankle, and on the lateral side of the head of the fifth

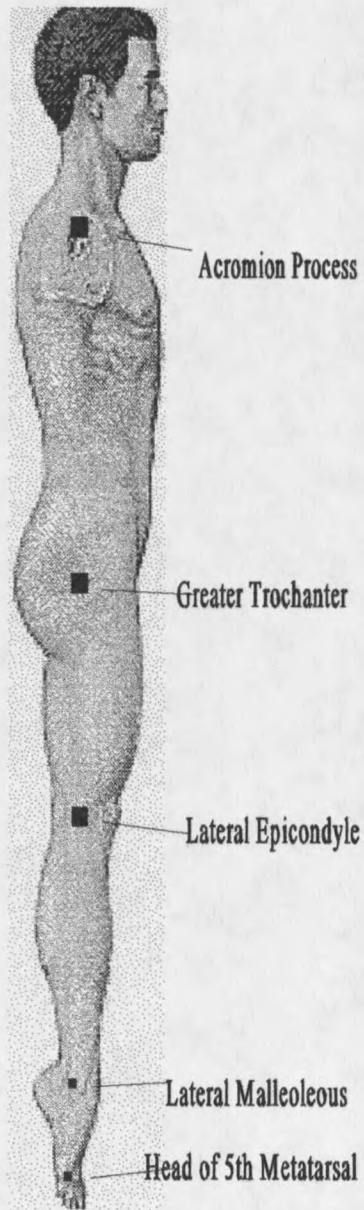


Figure 3.2 Placement of reflective markers (Adapted From ADAM Comprehensive 2.3; ADAM Software Inc., Atlanta, GA)

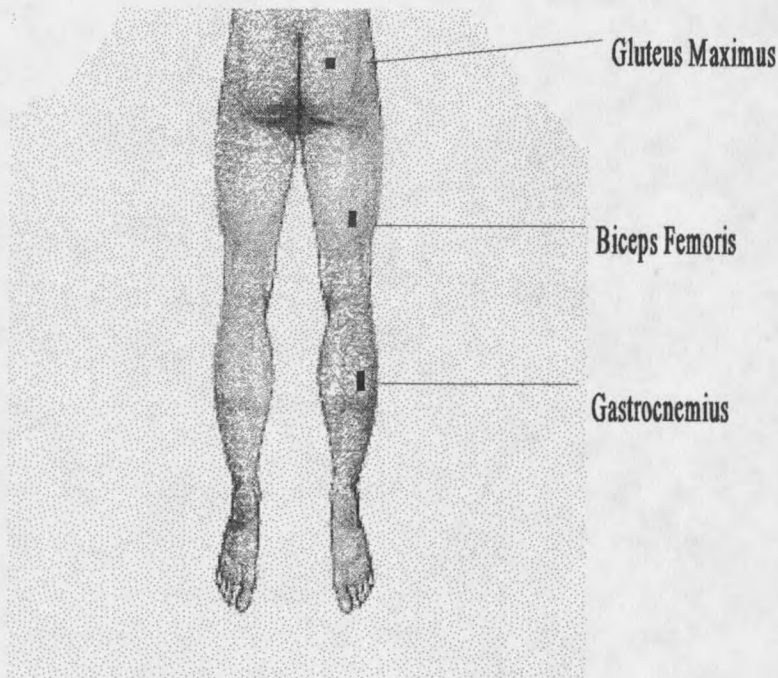


Figure 3.3 EMG electrode placement for posterior muscles (Adapted From ADAM Comprehensive 2.3; ADAM Software Inc., Atlanta, GA)

metatarsal. The positions were selected as points to represent the right shoulder, right hip, right knee, right ankle, and right foot respectively (see Fig. 3.4). Once the EMG Surface electrodes and reflective markers were in place, the subject was then placed on the Yoyo Strength Ergometer.

Testing

The testing protocol consisted of two steps. The first step was collecting EMG data while the subject was performing a maximum isometric contraction on the Yoyo Strength Ergometer. The subject was placed in a position of approximately 90 degrees of knee flexion and the Yoyo Strength Ergometer was then fixed at that position. EMG data were collected at this position for three seconds. The second step consisted of collecting EMG and

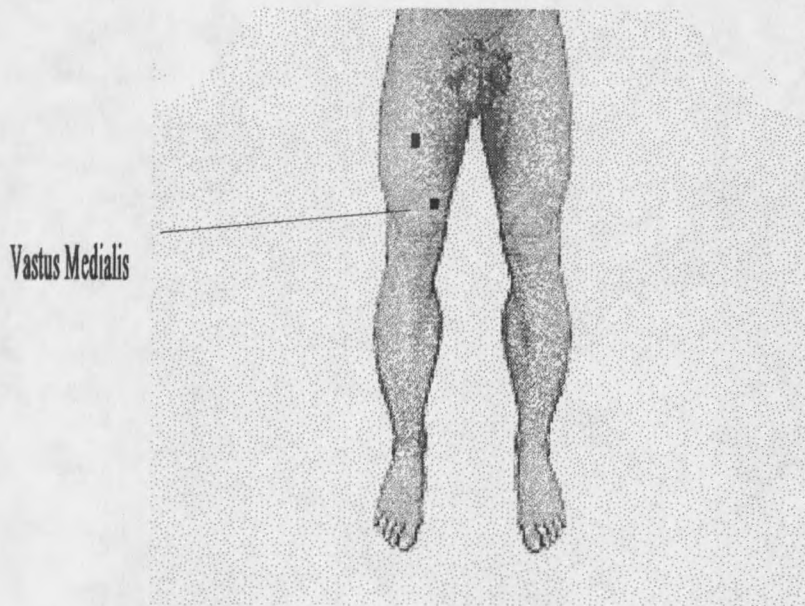


Figure 3.4 EMG electrode placement for anterior muscles (Adapted From ADAM Comprehensive 2.3; ADAM Software Inc., Atlanta, GA)

kinematic data while the subject was using the Yoyo Strength Ergometer. The subject performed one set of three repetitions with a maximum effort through the full ROM. With the video camera positioned and recording, the testing began. The subject was instructed to begin pushing on the foot pedals. Once full extension was achieved by the lower extremity joints, the subject was then encouraged to relax and allow the Yoyo Strength Ergometer strap to fully rewind. The set began with a verbal command by the tester at the point when the strap had completely rewound. It was also at this point that the tester began recording the EMG data. The subjects were verbally encouraged to push with maximal effort during the concentric portions of each repetitions and to resist as much as possible during the eccentric portion of each repetition short of stopping the pedals before full ROM had been accomplished. Testing concluded at the end of the third eccentric phase and the return of the

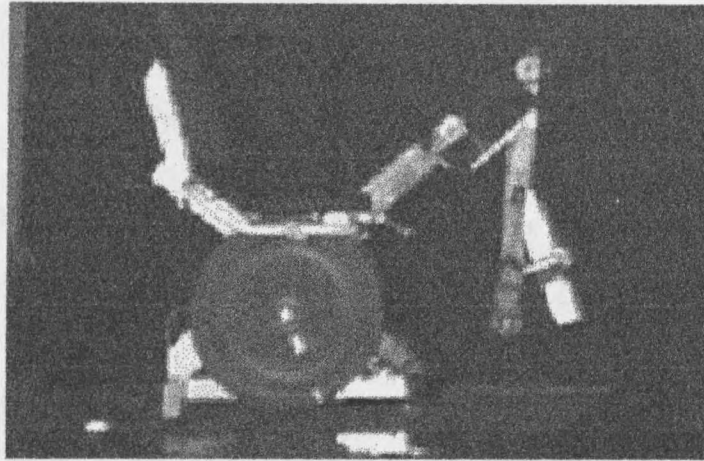


Figure 3.5 Yoyo Strength Ergometer

foot pedal to the starting position. Upon completion of the testing procedure, the surface electrodes and reflective markers were removed from the subjects and the subjects were allowed to cool down on the cycle ergometer.

Analysis

All video data were automatically digitized and automatically smoothed using a Cubic Spline, with smoothing values ranging from 0.05 to 0.2, on an Ariel Performance Analysis System (Ariel Dynamics, Trabuco Canyon, CA). Once digitized, angular displacement and angular velocity data were computed. Also the beginning and ending of each concentric and eccentric phase were established (see appendix for sample kinematic data).

All EMG data were collected with preamplified surface electrodes at a frequency of 2000 hertz. The digital EMG data were then filtered via a Recursive Second Order Butterworth Bandpass Filter at lower and upper cutoff frequencies of 50 Hertz and 850 Hertz respectively. A Root Mean Square (RMS) value was calculated for the maximum isometric

contraction signal and then normalized for time (see appendix for sample EMG data)

The filtered signals for the three repetitions were divided into concentric and eccentric portions for each repetition, concentric repetition one, eccentric repetition one, etc. A RMS value was then calculated for each respective portion of the signal for each respective muscle. The RMS values were then normalized for time and each value was then reported as a percentage of maximum isometric contraction. By using the percentage of maximum isometric contraction, there was an attempt to decrease error.

Additionally peak EMG signals were calculated and used to identify a joint angular position at peak EMG activity. The smoothed EMG signals were also rectified in an attempt to identify peak contractions. Peak contractions were identified by searching for the peak smoothed rectified EMG values during each contraction. All EMG data were analyzed using Excel Spreadsheets (Microsoft, Redland, WA) and custom software written on Lab View Version 5.0 (Graphical Programming for Instrumentation, Austin, TX).

Statistical Analysis

Four independent variables were identified for this study. The first independent variable was subject height, the second was total leg length, the third was upper leg length, and the fourth was lower leg length. The dependant variables were divided in to two categories, kinematic and EMG.

1. Kinematic Dependent Variables
 1. ROM
 1. Hip
 2. Knee
 3. Ankle
 2. Average Angular Velocity

1. Concentric
 1. Hip
 2. Knee
 3. Ankle
2. Eccentric
 1. Hip
 2. Knee
 3. Ankle
3. Peak Angular Velocity
 1. Concentric
 1. Hip
 2. Knee
 3. Ankle
 2. Eccentric
 1. Hip
 2. Knee
 3. Ankle
4. Joint Position at Peak Muscle Activity
 1. Gluteus Maximus
 1. Hip
 2. Vastus Medialis Oblique
 1. Knee
 3. Biceps Femoris
 1. Hip
 2. Knee
 4. Gastrocnemius
 1. Knee
 2. Ankle
2. EMG Dependent Variables
 1. Percentage of Maximum Isometric Contraction
 1. Concentric
 1. Gluteus Maximus
 2. Vastus Medialis
 3. Biceps Femoris
 4. Gastrocnemius
 2. Eccentric
 1. Gluteus Maximus
 2. Vastus Medialis
 3. Biceps Femoris
 4. Gastrocnemius

Regression analysis was performed using the four independent variables. When two independent variables are highly correlated, there is very little additional information provided by the second independent variable above and beyond that provided by the first independent variable. With the high correlations between the independent variables, multiple regression analysis was avoided (Glass et al. 1996).

The regressions performed included comparing each independent variable with each of the dependent variables. Subject height, total leg length, upper leg length, and lower leg length were compared with each of the dependent variables.

CHAPTER 4

RESULTS

Fourteen college students participated as subjects in this study. The anthropometric data collected are listed in Table 4.1. Included in this table are the four independent variables, subject height, total leg length, upper leg length, and lower leg length.

Table 4.1. Subject Data

Subject #	Age (years)	Height (inches)	Weight (pounds)	Seated Height (inches)	Total Leg Length (inches)	Upper Leg Length (inches)	Lower Leg Length (inches)
1	22	72.75	231.00	36.50	37.75	17.50	18.50
2	35	69.25	206.00	36.25	37.25	15.25	17.50
3	23	70.75	189.50	36.50	39.00	17.75	17.50
4	22	73.88	215.50	37.50	41.13	19.50	20.00
5	21	66.50	116.00	34.75	37.25	17.50	16.25
6	23	66.75	130.00	35.00	37.00	16.25	17.00
7	21	69.75	185.00	35.63	38.00	16.38	18.00
8	34	72.75	194.50	36.64	40.00	17.50	19.25
9	21	65.00	128.00	34.50	34.63	14.00	16.50
10	27	70.50	174.50	35.25	39.00	17.00	18.50
11	29	70.25	158.00	36.50	38.75	17.00	17.25
12	29	72.00	234.00	38.00	38.63	18.50	17.50
13	21	75.00	200.00	38.13	40.38	18.63	17.50
14	26	76.50	207.00	37.50	44.63	20.75	20.00
Ave	25.29	70.83	183.50	36.33	38.81	17.39	17.95
SD	4.86	3.29	37.78	1.18	2.33	1.70	1.17

EMG

EMG activity reported as a percentage of Maximum Isometric Contraction value was calculated on four muscle groups while the subject was performing on the Yoyo Strength Ergometer. The averages and standard deviations for each muscle groups is listed in Table 4.2. All concentric averages were greater then the corresponding eccentric averages. With the statistical methods used, no significant relationships were found between any of the independent variables and any of the muscle groups during either the concentric or eccentric portion of the exercise.

Table 4.2 Percentage of Maximum Isometric Contraction (in %)

	Gluteus Maximus	VMO	Biceps Femoris	Gastrocnemius
Concentric	260.24(63.37)	224.57(77.47)	173.85(15.87)	424.56(138.18)
Eccentric	193.69(101.01)	176.57(104.06)	115.76(36.26)	218.1(37.17)

Motion Analysis

An average angular position at peak muscle contraction, based on EMG analysis, was calculated for the muscle groups tested. The average and standard deviation values are listed in Table 4.3 Based on the statistical methods used and the independent variables, no significant relationships were found between any of the independent variables and the joint

Table 4.3 Joint Angle at EMG Peak (in degrees)

	Hip Angle Gluteus Maximus	Knee Angle VMO	Hip Angle Biceps Femoris	Knee Angle Biceps Femoris	Knee Angle Gastrocn.	Ankle Angle Gastrocn.
Average	85.28(15.19)	81.98(17.03)	89.06(12.22)	95.08(14.93)	134.3(10.51)	95.52(3.84)

angular position at EMG peak in the population tested while performing on the Yoyo Strength Ergometer.

Maximum hip, knee, and ankle angular ROM while performing on the Yoyo Strength Ergometer were calculated. The average and standard deviation values are listed in Table 4.4. Based on the statistical methods used and independent variables used, no significant relationships between any of the independent variables and any of the angular ROM were found while performing on the Yoyo Strength Ergometer.

Table 4.4 Joint ROM while performing on Yoyo (in degrees)

	Hip ROM	Knee ROM	Ankle ROM
Average(SD)	32.59(5.36)	89.29(9.95)	22.46(3.92)

Average angular velocity during the concentric and eccentric portion of the exercise for the hip, knee and ankle was calculated. The average and standard deviation values are listed in Table 4.5. Upon completion of the statistical analysis, several cases of significant correlations were found and are listed below.

Table 4.5 Average Joint Angular Velocity (in degrees/second)

	Hip Extension	Hip Flexion	Knee Extension	Knee Flexion	Plantar Flexion	Dorsiflexion
Average(SD)	15.32(1.60)	18.27(1.15)	43.65(5.05)	50.78(2.96)	11.62(3.32)	13.35(3.53)

Average peak angular velocity during the concentric and eccentric portion of the exercise for the hip, knee and ankle was calculated. The average and standard deviation values are listed in Table 4.6. Upon completion of the statistical analysis, several cases of

significant correlations were found and are listed below.

Table 4.6 Peak Joint Angular Velocity (in degrees/second)

	Hip Extension	Hip Flexion	Knee Extension	Knee Flexion	Plantar Flexion	Dorsiflexion
Average(SD)	38.19(8.52)	37.95(7.81)	83.56(10.6)	87.99(11.79)	59.67(12.6)	58.63(12.16)

By performing various regression calculations, several cases of significant correlations were found. Linear regression and non-linear regressions methods were attempted and

Table 4.7 Statistically Significant Correlations

	R	Alpha	R-squared
Height vs Ave Knee Angular Vel	0.6197	0.018	0.3843
Leg Length vs Ave Knee Ang Vel	0.6116	0.02	0.3741
Leg Length vs Peak Hip Ang Vel	-0.6372	0.014	0.4057
Leg Length vs Peak Knee Ang Vel	0.6213	0.018	0.3861
Leg Length vs Peak Knee Ang Vel - Ecc	-0.6419	0.013	0.4119
Upper Leg Length vs Peak Hip Ang Vel - Ecc	-0.571	0.033	0.3262
Upper leg Length vs Peak Knee Ang Vel - Ecc	-0.6708	0.09	0.4504
Lower Leg vs Ave Hip Ang Vel	0.6107	0.02	0.3734
Lower Leg vs Peak Hip Ang Vel	0.5762	0.031	0.3317
Lower Leg vs Peak Hip Ang Vel - Ecc	-0.6856	0.007	0.4701
Lower Leg vs Ave Knee Ang Vel	0.6641	0.01	0.441
Lower Leg vs Ave Knee Ang Vel - Ecc	-0.5683	0.034	0.3234
Lower Leg vs Peak Knee Ang Vel	0.6731	0.008	0.4527
Lower Leg vs Peak Knee Ang Vel - Ecc	-0.5405	0.046	0.2922

linear regression was selected with no notable decrease in effectiveness. The list of significant correlations and their R values, Alphas, and R-Squared values are listed in Table 4.7. Seven out of the eight correlations with concentric dependent variables are positive. This means that in most cases that as the independent variable increased, greater height for example. So too did the dependent variable, greater average knee angular velocity for example. All six of the correlations with eccentric dependent variables are negative. This means that in all the cases with eccentric dependent variable as the independent variable increased, greater leg length, the dependent variable decreased, decreased peak hip angular velocity - eccentric for example.

By plotting the each independent variable with its's corresponding dependent variable, regression lines were calculated. Figure 4.1 is a plot of Subject Height vs Average Knee

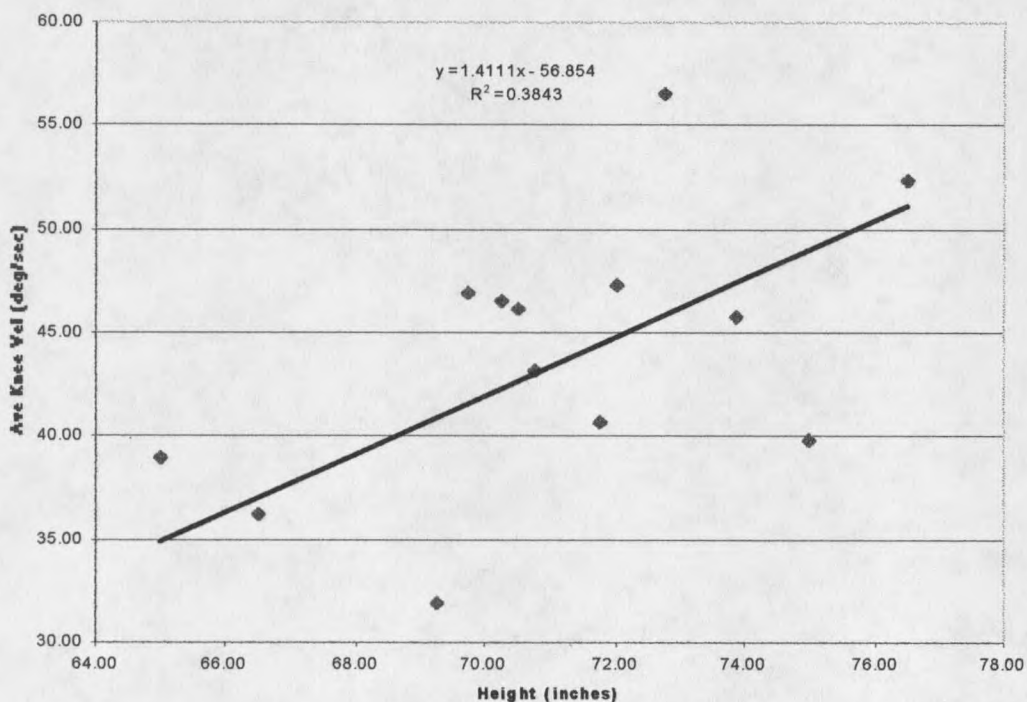


Figure 4.1 Subject Height vs Average Knee Angular Velocity

Angular Velocity and includes the calculated regression line. The R-value equals 0.6197 with P-value of 0.018. Figure 4.2 is a plot of Total Leg Length and Average Knee Angular Velocity and includes the calculated regression line. The R-Value equals 0.6116 with a P-value of 0.02. Figure 4.3 is a plot of Total Leg Length and Peak Hip Angular Velocity - Eccentric and includes the calculated regression line. The R-Value equals 0.6372 with a P-value of 0.014. Figure 4.4 is a plot of Total Leg Length and Peak Knee Angular Velocity and includes the calculated regression line. The R-value equals 0.6213 with a P-value of 0.018. Figure 4.5 is a plot of Total Leg Length and Peak Knee Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.6419 with a P-value of 0.013. Figure 4.6 is a plot of Upper Leg Length and Peak Hip Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.571 with a P-Value of 0.033.

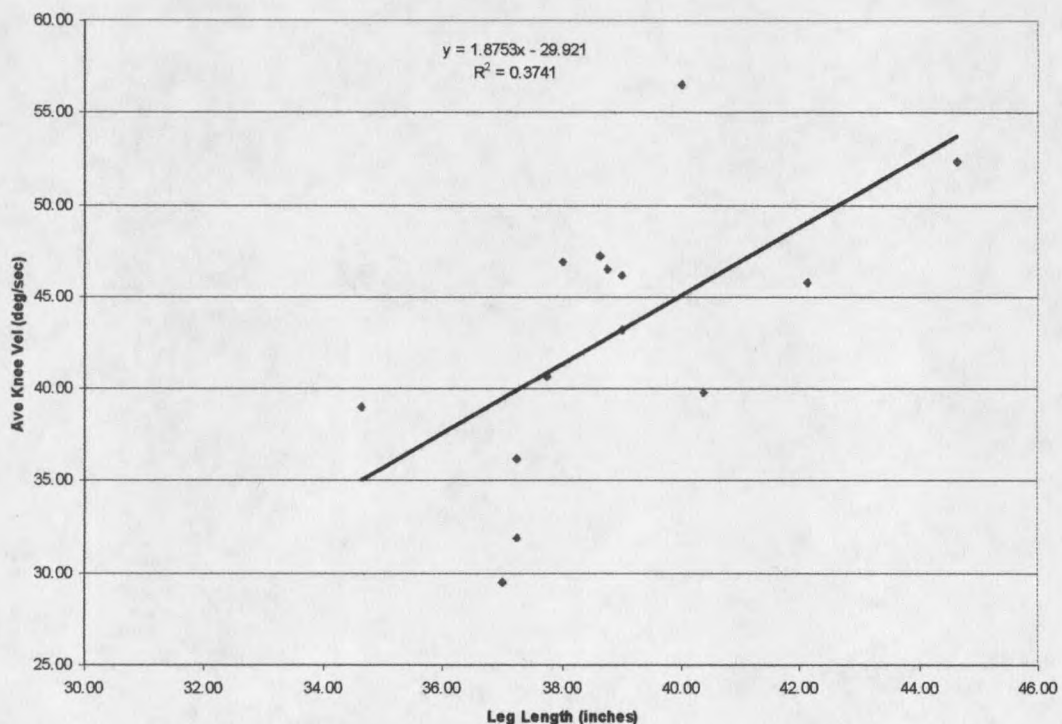


Figure 4.2 Total Leg Length vs Average Knee Angular Velocity

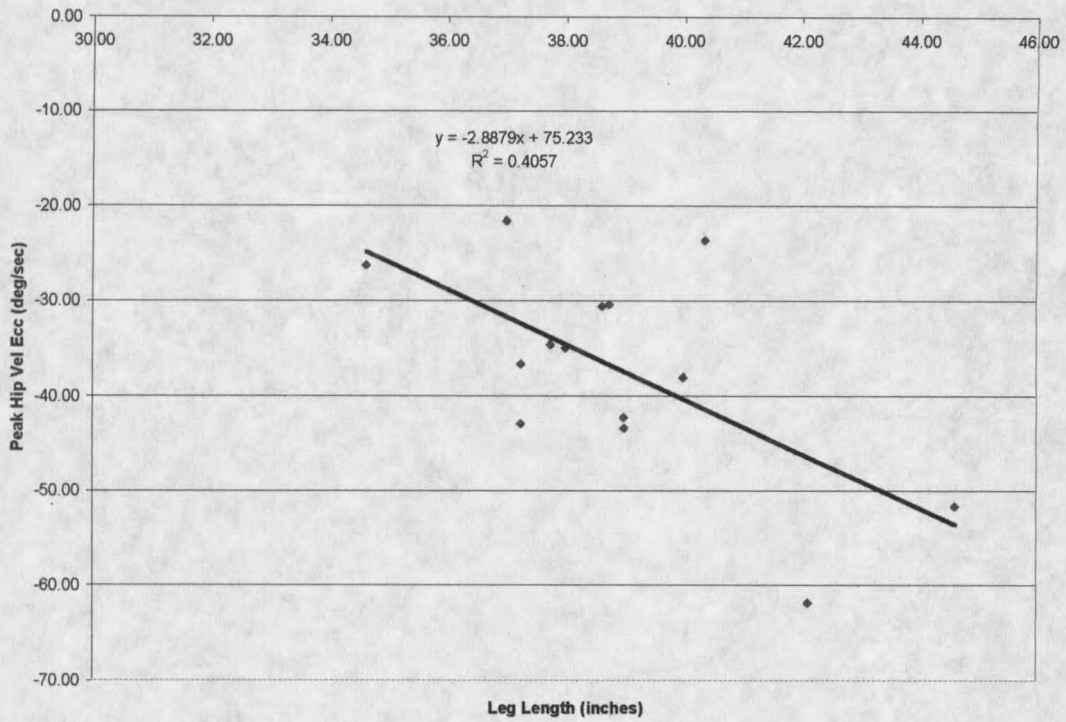


Figure 4.3 Total Leg Length vs Peak Hip Angular Velocity - Eccentric

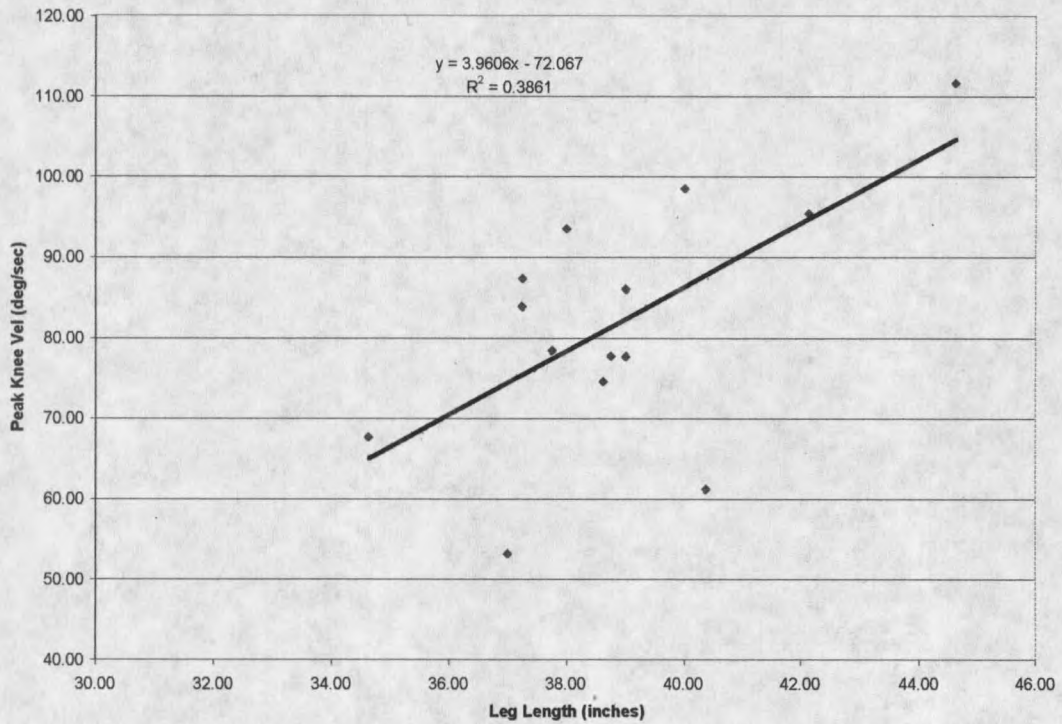


Figure 4.4 Total Leg Length vs Peak Knee Angular Velocity

Figure 4.7 is a plot of Upper Leg Length and Peak Knee Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.6708 with a P-Value of 0.009. Figure 4.8 is a plot of Lower Leg Length and Average Hip Angular Velocity and includes the calculated regression line. The R-value equals 0.6107 with a P-Value of 0.02. Figure 4.9 is a plot of Lower Leg Length and Peak Hip Angular Velocity and includes the calculated regression line. The R-value equals 0.5762 with a P-Value of 0.031. Figure 4.10 is a plot of Lower Leg Length and Peak Hip Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.6856 with a P-Value of 0.007. Figure 4.11 is a plot of Lower Leg Length and Average Knee Angular Velocity and includes the calculated regression line. The R-value equals 0.6641 with a P-Value of 0.01. Figure 4.12 is a plot of Lower Leg Length and Average Knee Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.5683 with a P-Value of 0.034. Figure 4.13 is a plot of Lower Leg Length and Peak Knee Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.6731 with a P-Value of 0.008. Figure 4.14 is a plot of Lower Leg Length and Peak Knee Angular Velocity - Eccentric and includes the calculated regression line. The R-value equals 0.5404 with a P-Value of 0.046. Figures 4.7 and 4.13 represent the regression equations with the greatest R-squared values, 0.4504 and 0.4527 respectfully.

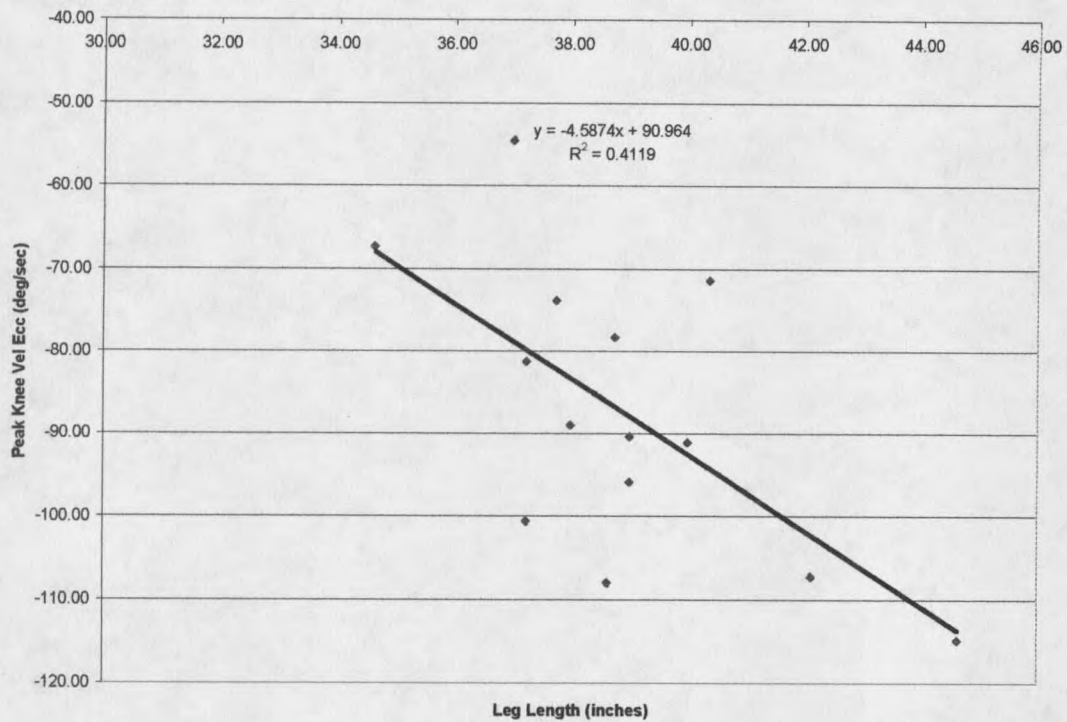


Figure 4.5 Leg Length vs Peak Knee Angular Velocity - Eccentric

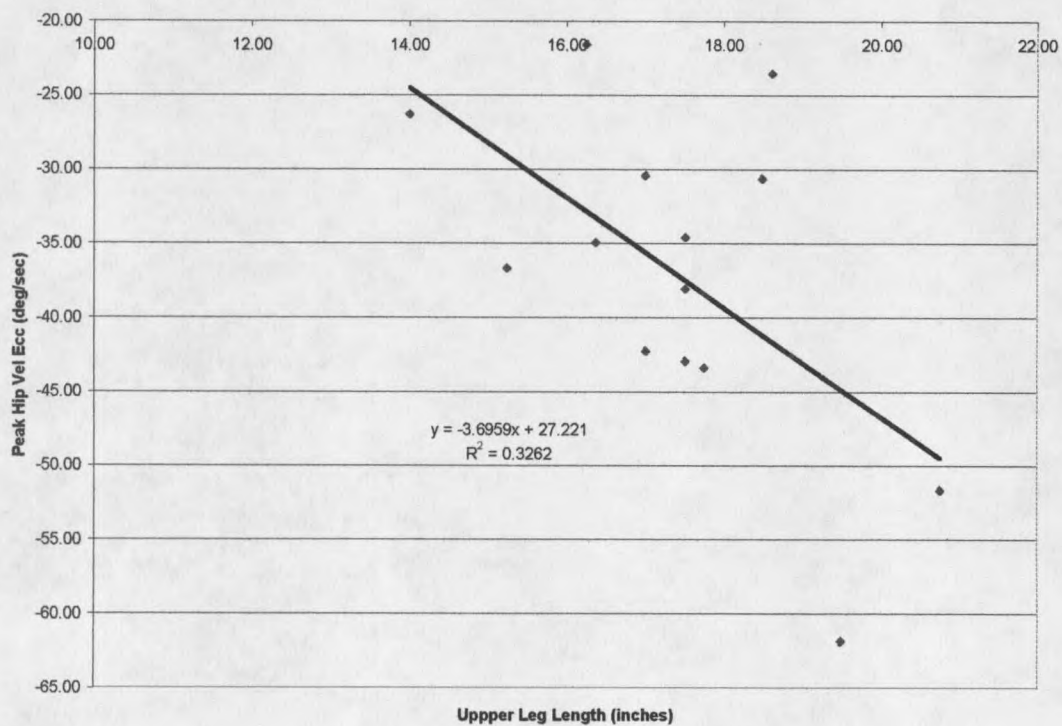


Figure 4.6 Upper Leg Length vs Peak Hip Angular Velocity - Eccentric

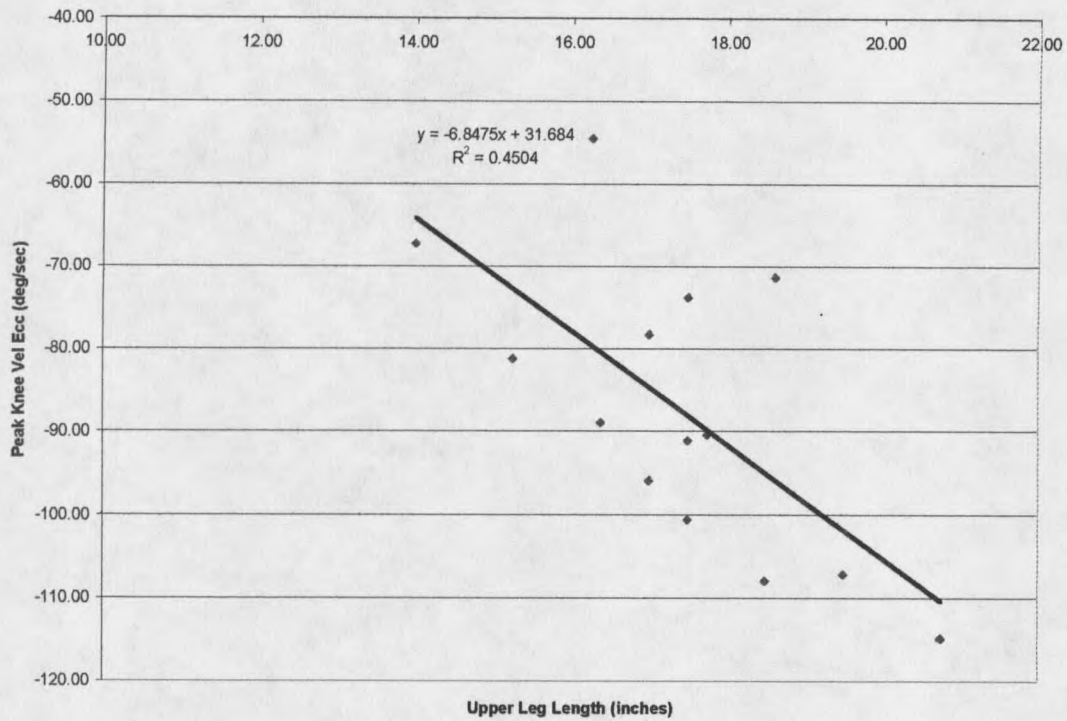


Figure 4.7 Upper Leg Length vs Peak Knee Angular Velocity - Eccentric

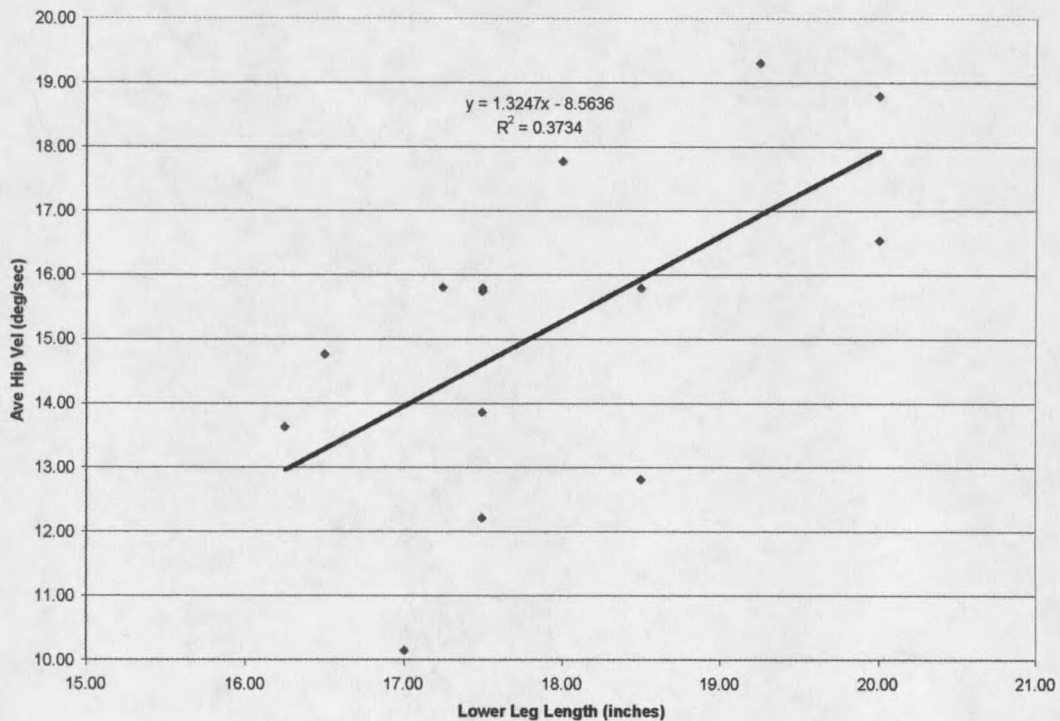


Figure 4.8 Lower Leg Length vs Average Hip Angular Velocity

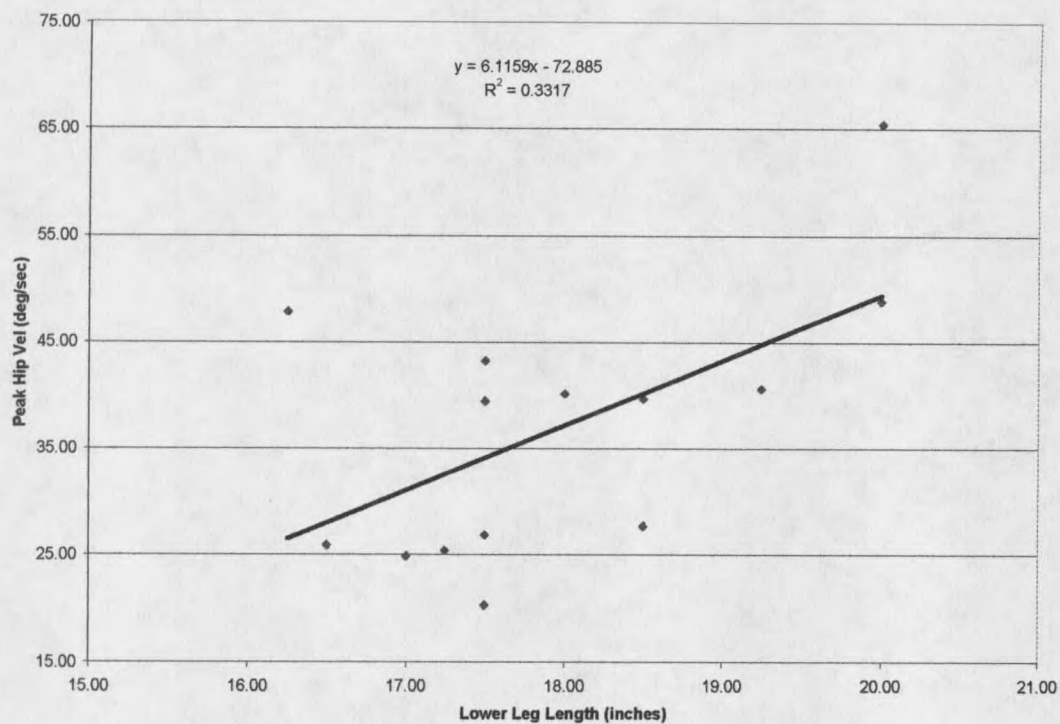


Figure 4.9 Lower Leg Length vs Peak Hip Angular Velocity

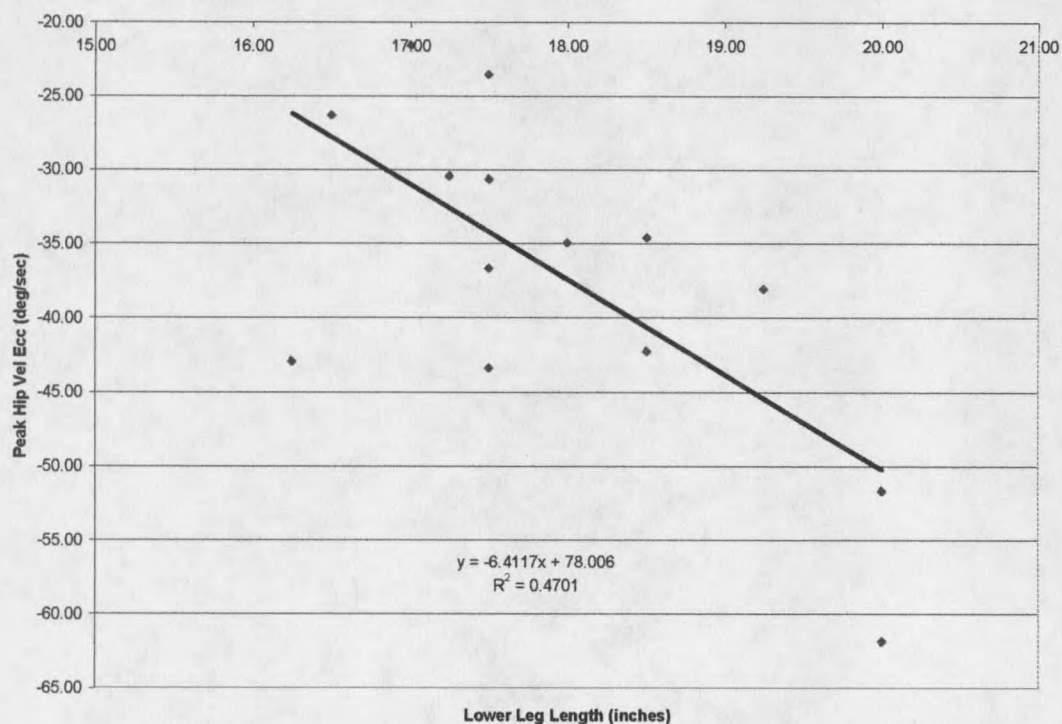


Figure 4.10 Lower Leg Length vs Peak Hip angular Velocity - Eccentric

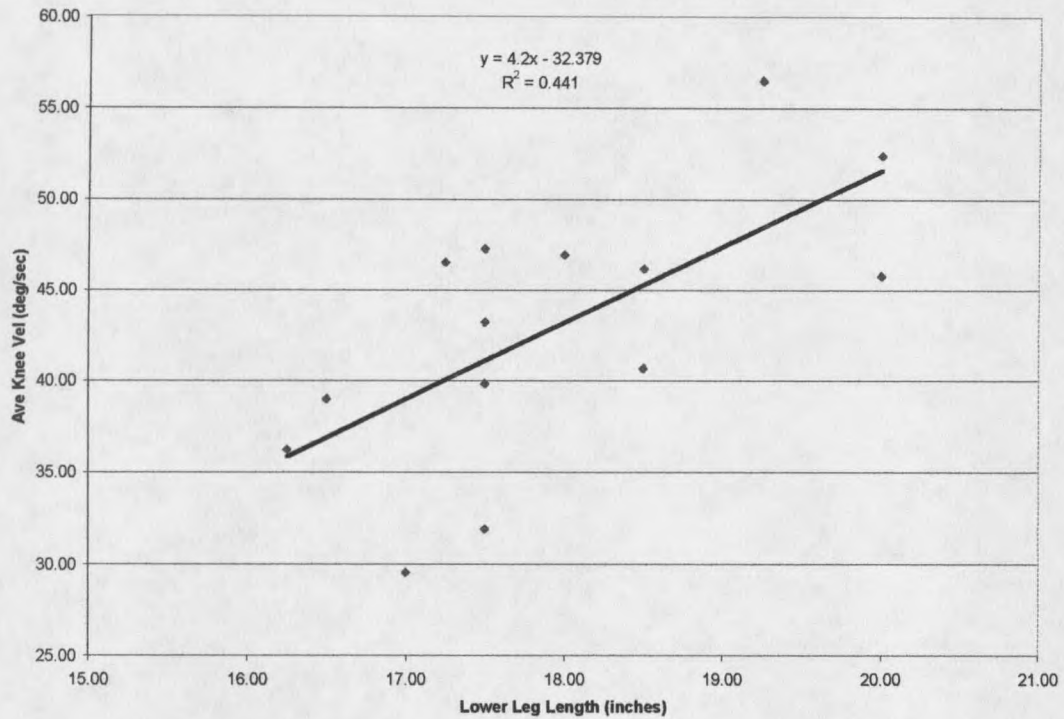


Figure 4.11 Lower Leg Length vs Average Knee Angular Velocity

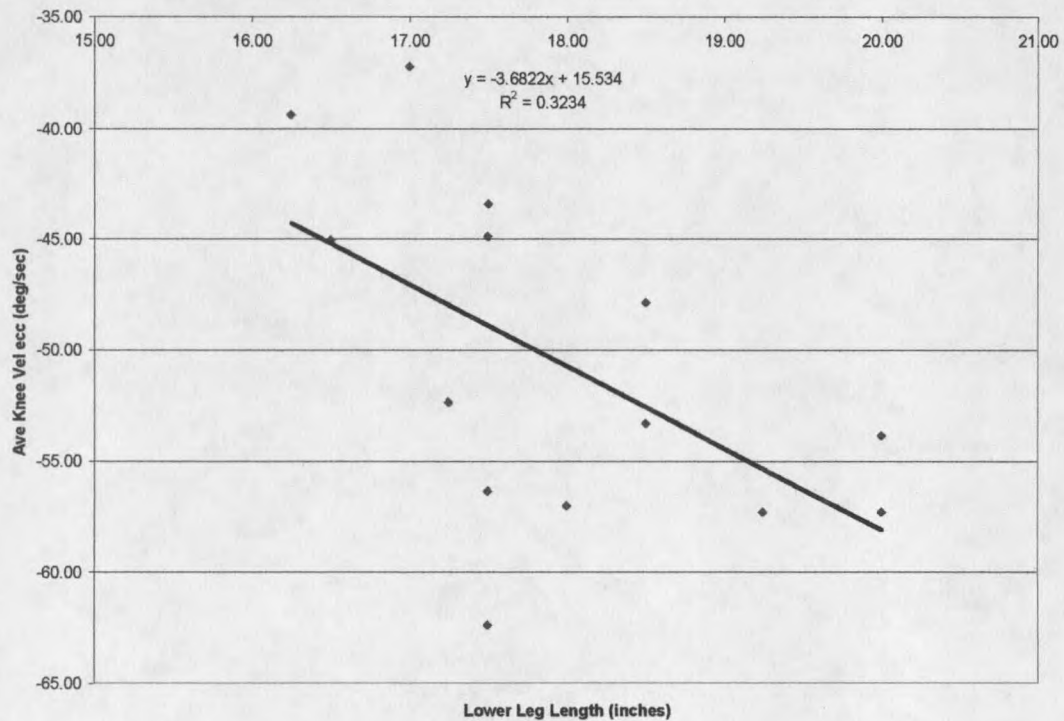


Figure 4.12 Lower Leg Length vs Average Knee Angular Velocity - Eccentric

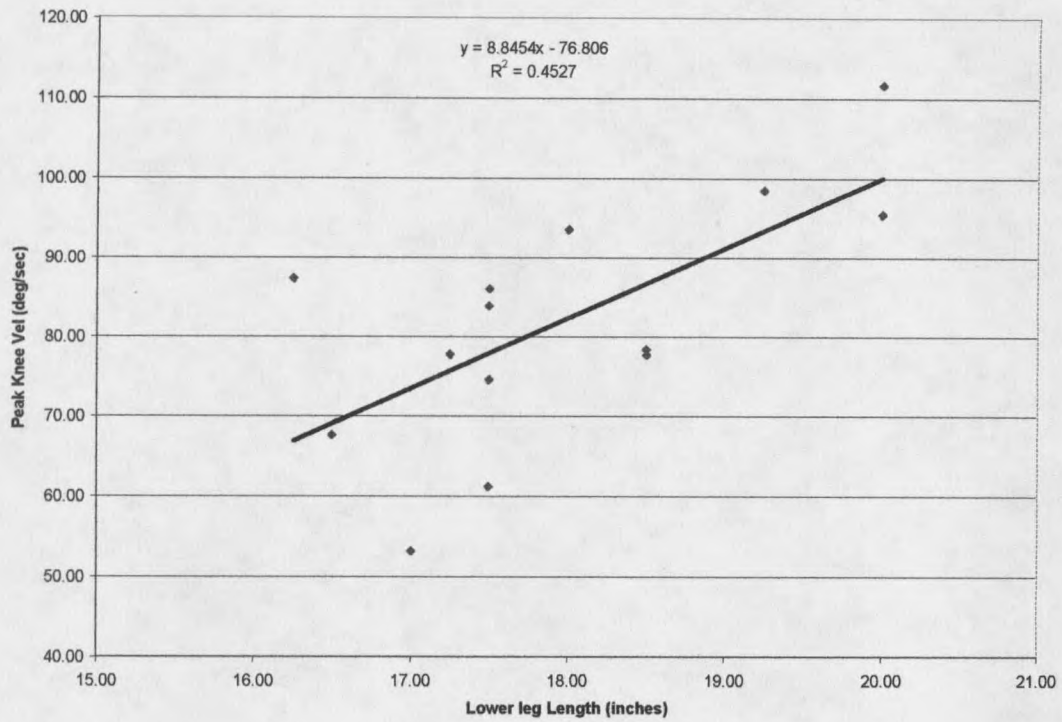


Figure 4.13 Lower Leg Length vs Peak Knee Angular Velocity

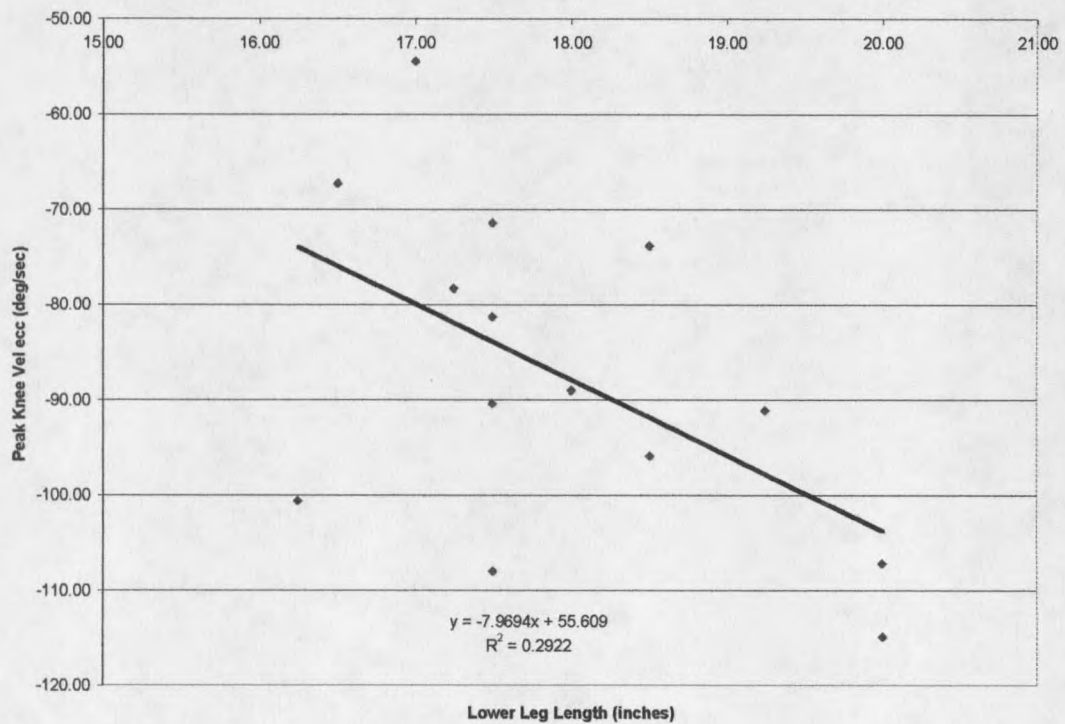


Figure 4.14 Lower Leg Length vs Peak Knee Angular Velocity - Eccentric

CHAPTER 5

DISCUSSION

EMG

Based on the data gathered, the anthropometric characteristics measured in this study, subject height, total leg length, upper leg length, lower leg length, were found to result in no significant linear relationships with the EMG dependent variables. This indicates that, in the individuals tested during this study, certain body proportions had no linear relationship with the level of activity of the four muscle groups tested. In the individuals tested, there did not seem to be a discernable relationship between the anthropometric measurement gathered and the EMG variables tested.

Motion Analysis

Several significant correlations were found indicating a linear relationship between certain independent variables and certain kinematic dependent variables. Various hip and knee angular velocities correlated with one or more of the independent variables. Oddly enough, no significant relationships were found between the independent variables and the ROM at the hip, knee, or ankle while performing on the Yoyo Strength Ergometer. A person might suspect that individuals with different lower limb lengths might have demonstrated different ROM patterns and more importantly that a relationship between limb lengths and

ROM would emerge. However, since no relationships were found there must be explanations other than limb length for the observed difference in technique. Any significant statistical differences in the motion analysis data could be the result of certain individuals applying more force and thus going through the motions at a higher rate. Unfortunately, at the time of data collection, force or torque measurements were not available and the Yoyo Strength Ergometer is not instrumented. Another possibility could be that certain limb lengths offered a mechanical advantage while performing on the Yoyo Strength Ergometer. Different limb lengths might translate into different muscle attachments. With no data to verify this, this is only speculation.

All in all there seemed to be a pattern that individuals with longer legs, especially longer lower legs, tended to demonstrate higher hip and knee concentric angular velocities and lower eccentric angular velocities. If this pattern continued in further research, it could possibly be used to help dictate design specifications or alterations for further Yoyo Strength Ergometers in an effort to eliminate such differences in technique and make the Yoyo Strength Ergometer a more uniform exercise device for a greater population. It should be noted that no attempts were made at multiple regressions because of the high level of correlations between the independent variables.

Since very few significant relationships were found, it might be applicable to compare the results if the entire group with data from other devices to address the appropriateness of the Yoyo Strength Ergometer as a resistance training device. If reasonable comparisons can be made between the Yoyo Strength Ergometer and other resistance training devices, it might offer an additional device to combat the negative physiological adaptations that occur with

microgravity.

The data collected during this study make the Yoyo Strength Ergometer seem credible as a resistance training device. More importantly than the significant relationships found with the angular velocities is the fact that the angular velocities, although relatively low, all fall well within the range of values generally utilized in isokinetic testing devices (Levine et al. 1991, Stam et al. 1993, Feiring et al. 1990). Additionally the angle at which peak muscle activity was recorded grants additional evidence to the appropriateness of this machine as a resistance training device. Depending on the type of devices used in previous research, the angle at which maximum quadriceps EMG activity occurred between 50 and 102 degrees of knee flexion during exercise (Denuccio et al. 1991, Isear et al. 1997, Wilk et al. 1996, Kellis et al. 1996). The average knee angle at peak VMO activity in the present research was 81 degrees. Depending on the method of measuring, either internal or external angles, this number falls well within this range or at worse, slightly above it.

Wretenberg et al. (1983) reported that lower extremity muscle activity increased as depth increased in the squat. Past research has also indicated that the hamstrings are most active from 50 to 90 degrees of knee flexion (Isear et al. 1997, Wilk et al. 1996, Kellis et al. 1996), the gluteus maximus are most active from approximately 60 to 90 degree of hip flexion (Isear et al. 1997, Wilk et al. 1996), and the gastrocnemius are most active in a position which is approximately 60 to 90 degrees at the ankle (Isear et al. 1996). In the present study, the hamstring peak activity on average occurred at approximately 95 degrees of knee flexion, the gluteus maximus peak activity, on average, occurred at approximately 60 degrees of hip flexion, and the gastrocnemius peak activity, on average, occurred at approximately 95

degrees. All of these values are fairly close to those in previous studies.

Also looking at the percentage of maximum isokinetic contraction values it is apparent that the four muscles tested are very active in comparison to an isometric contraction of the lower extremity. Combine this with the relatively slow angular velocity and fairly similar angle at muscle activity peak for the Gluteus Maximus, VMO, Biceps Femoris, and the Gastrocnemius and you have an argument for the appropriateness of the Yoyo Strength Ergometer as a lower extremity resistance training device.

CHAPTER 6

CONCLUSIONS

In conclusion, the initial speculation of a subject size that would deem this device inappropriate was not strongly supported by the data collected. However the information collected forms the basis of an argument of the appropriateness of this device as a resistance training devices. A few linear relationships were found between the independent variables and a few of the kinematic dependent variables. Specifically

1. Subject height and average knee angular velocity
2. Total leg length and average knee angular velocity
3. Total leg length and peak hip angular velocity - eccentric
4. Total leg length and peak knee angular velocity
5. Total leg length and peak knee angular velocity - eccentric
6. Upper leg length and peak hip angular velocity
7. Upper leg length and peak knee angular velocity - eccentric
8. Lower leg length and average hip angular velocity
9. Lower leg length and peak hip angular velocity
10. Lower leg length and peak hip angular velocity - eccentric
11. Lower leg length and average knee angular velocity
12. Lower leg length and average knee angular velocity - eccentric
13. Lower leg length and peak knee angular velocity
14. Lower leg and peak knee angular velocity - eccentric.

However there was no indication of a relationship between the independent variables and the EMG dependent variables. Regardless of subject height, all the individuals tested utilized the four muscle groups similarly.

More importantly than any differences in performance are the similarities with between the performance data collected and other resistance training devices. Furthermore is the simple fact that this device is a gravity independent device. In addressing the negative physiological adaptations that occur as the result of microgravity, resistance training must be considered. Tradition weights are obviously useless in space. This device provided resistance concentrically and eccentrically and in a manner that at the very least is similar to other traditional resistance training devices. In addition, the Yoyo Strength Ergometer is fairly compact. Undoubtedly room is limited on the Space shuttle and size and weight are of a premium and any exercise device intended for space travel should be as compact and light as possible.

Several recommendations can be made as the result of this study.

1. Further research should be carried out, only more focused than the present study and with a larger sample size. A more focused research with more subjects might allow a researcher to find important statistical differences or similarities.
2. Someone should provide instrumentation for the Yoyo Strength Ergometer to measure performance output, force, torque, work, or power for example. This would provide the individuals using the Yoyo Strength Ergometer with a way to easily monitor their workout as well as additional information for a researcher.
3. Additional methods of adjustments should be added to the Yoyo Strength Ergometer. On the model tested there were only two ways to make adjustments. One was an adjustment to move the foot pedal and seemed adequate for the subjects tested. The second was a very crude way to move the back rest. Unfortunately it simply moved

the backrest forward and backwards while maintaining a fixed angle. At the very least additional holes to provide for extra adjustments for subject size and some means to adjust the angle of the backrest might be very beneficial in promoting comfort and effectiveness.

4. More research should be performed to test the long term effects of exercising on the Yoyo Strength Ergometer. In the present study, the Yoyo Strength Ergometer appears to be effective but a more relevant question might be how will long term exposure to the Yoyo Strength Ergometer might combat the negative effects of exposure to microgravity.

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APPENDIXSurface Electrode Placement Guidelines¹

Gluteus Maximus: center the electrodes over the greatest prominence of the middle of the buttocks.

Vastus Medialis Oblique: the inferomedial oval, where the muscle is seen to bulge in a well-muscled person.

Biceps Femoris: center the electrodes in a long vertical oval area on the lateral side of the back of the thigh near its midpoint.

Gastrocnemius (lateral head): place the electrode anywhere over the bulge on the lateral side of the gastrocnemius.

The hip angle was defined as the angle between the torso and the femur measured in the sagittal plane around a mediolateral axis on the anterior side of the body.

The knee angle was defined as the angle between the femur and the lower leg measured in the sagittal plane around a mediolateral axis on the posterior side of the body.

The ankle angle was defined as the angle between the lower leg and the foot measured in the sagittal plane around a mediolateral axis on the anterior side of the body.

¹Taken from Basmajian, J. and Blumenstein, R. (1989)

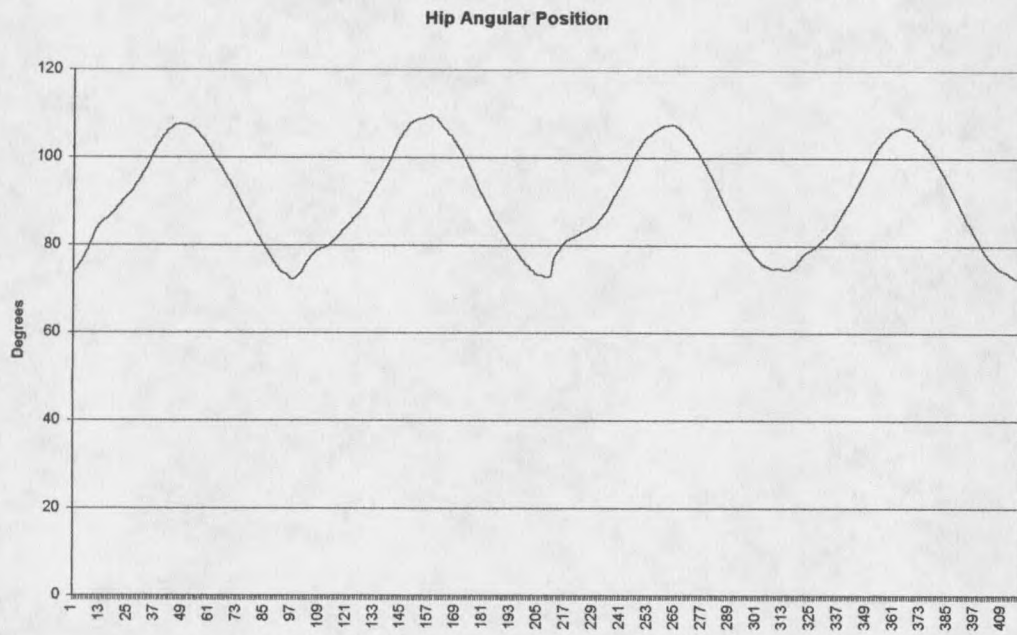


Figure A1. Sample Hip Angular Position

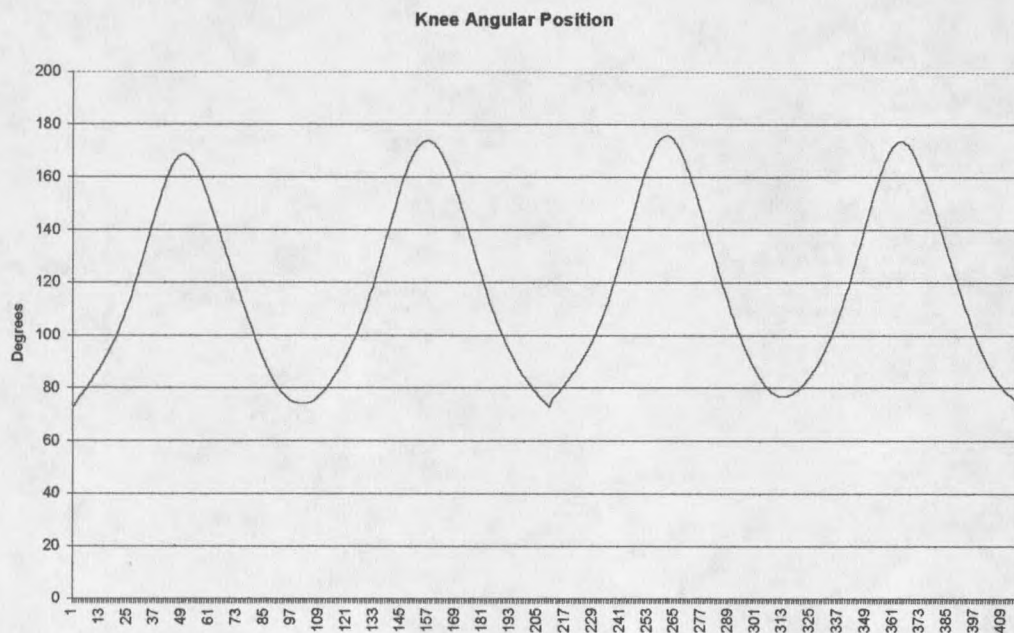


Figure A2 Sample Knee Angular Position

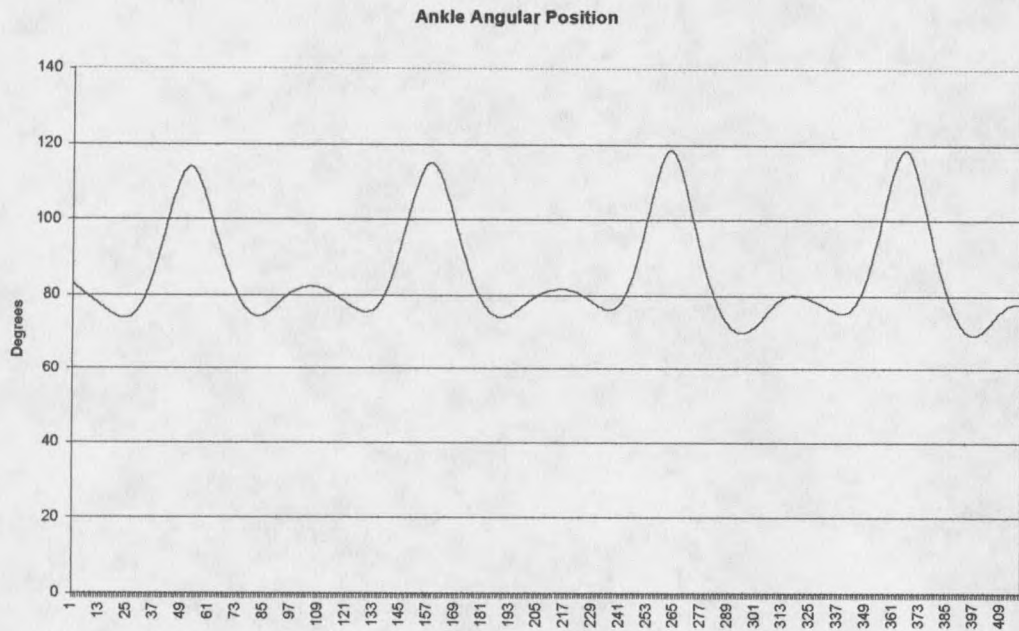


Figure A3. Sample Ankle Angular Position

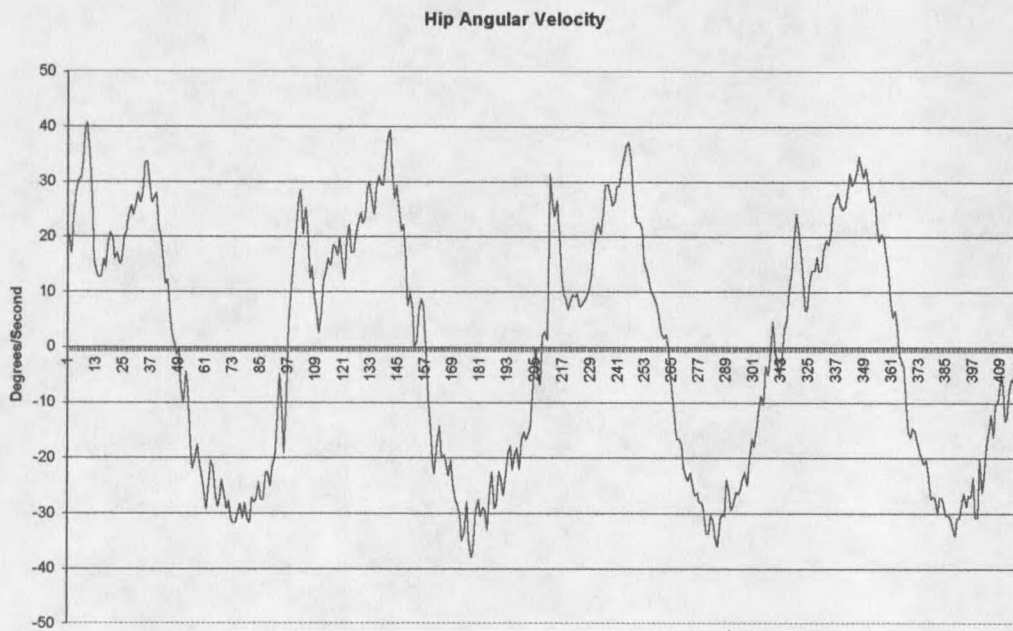


Figure A4 Sample Hip Angular Velocity

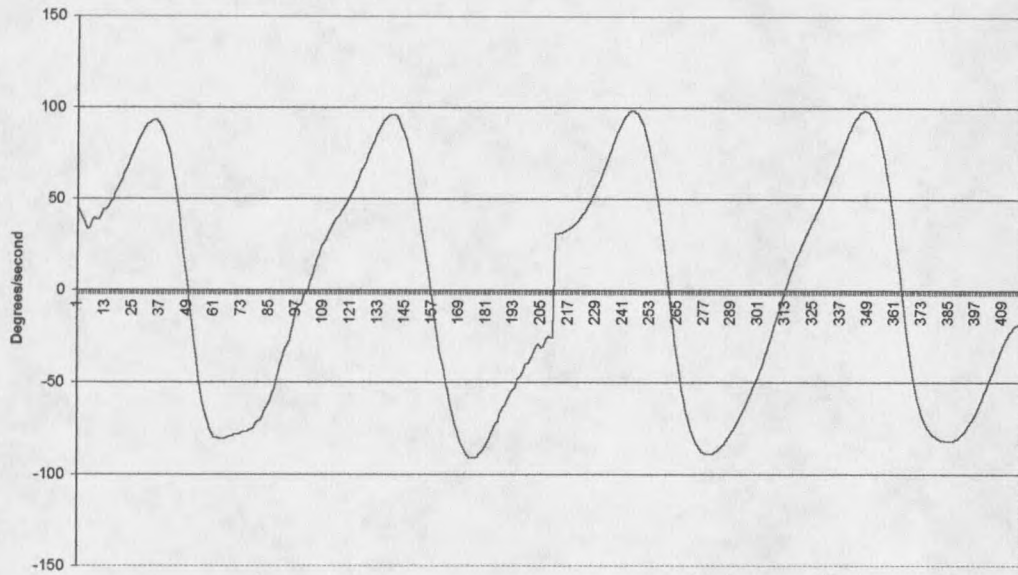
Knee Angular Velocity

Figure A5. Sample Knee Angular Velocity

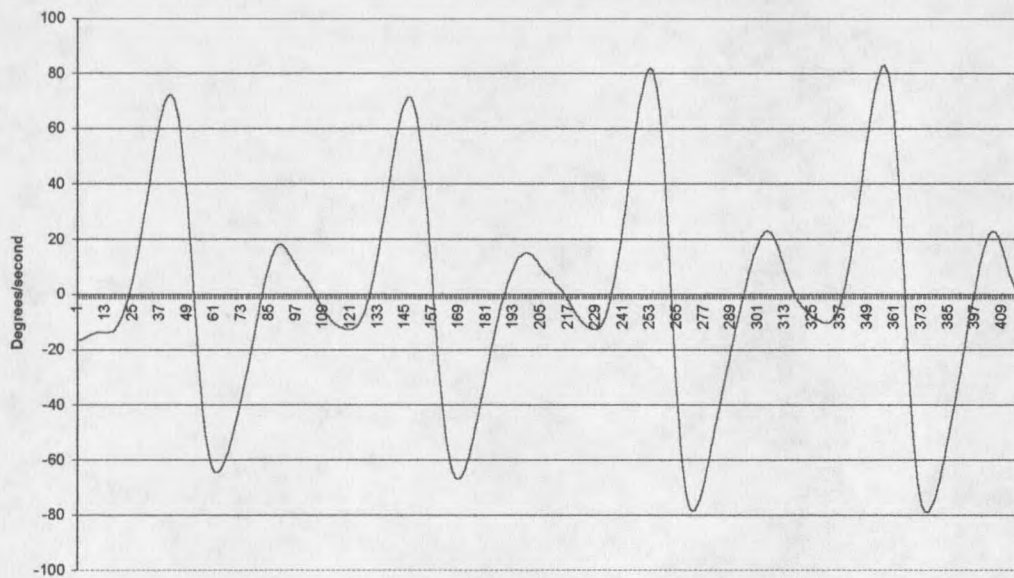
Ankle Angular Velocity

Figure A6. Sample Ankle Angular Velocity

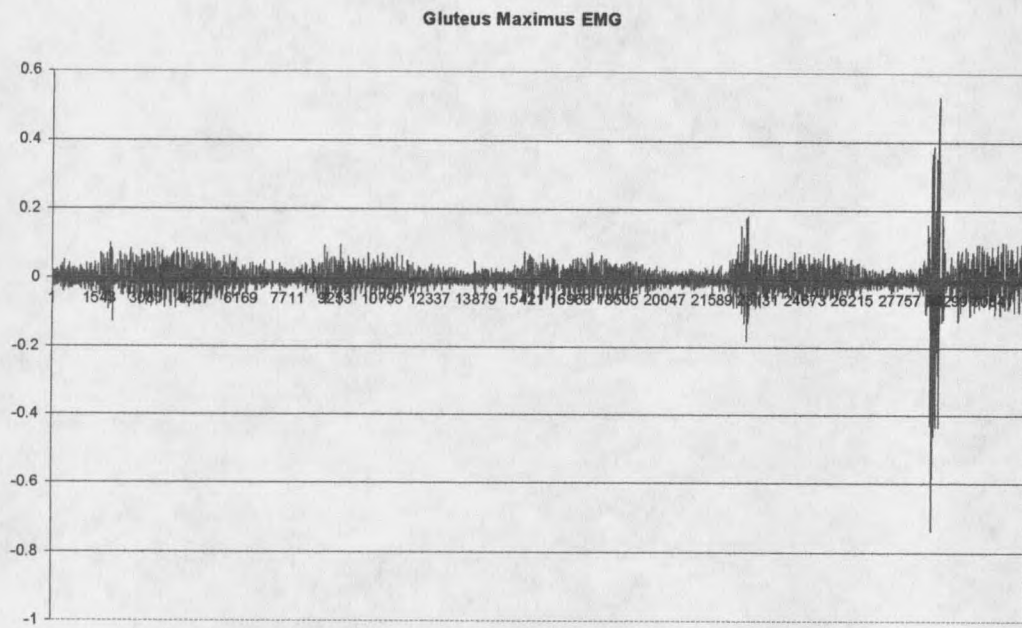


Figure A7. Sample Gluteus Maximus EMG

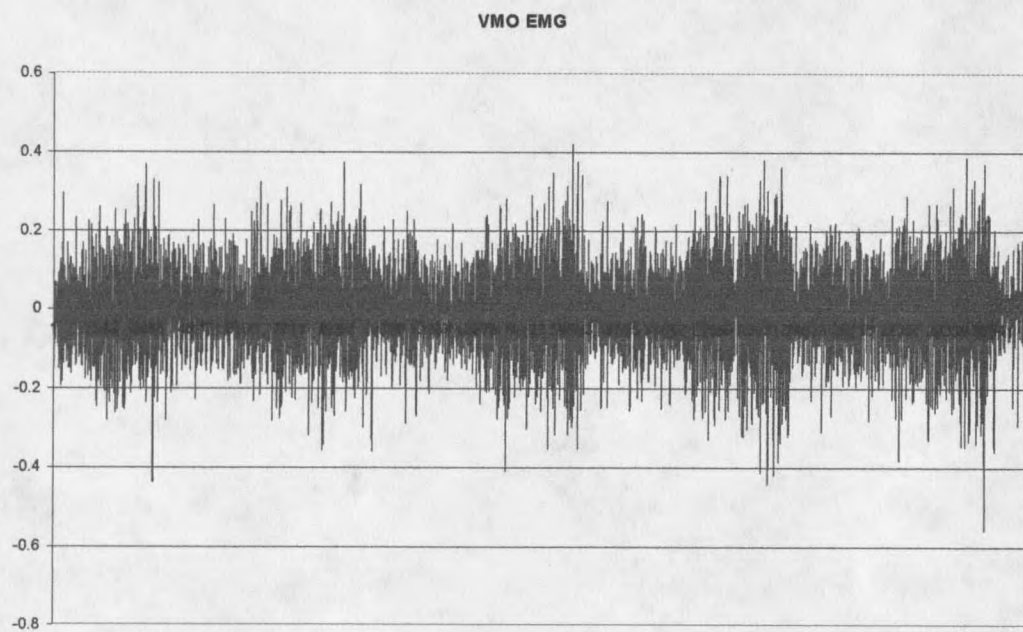


Figure A8. Sample VMO EMG

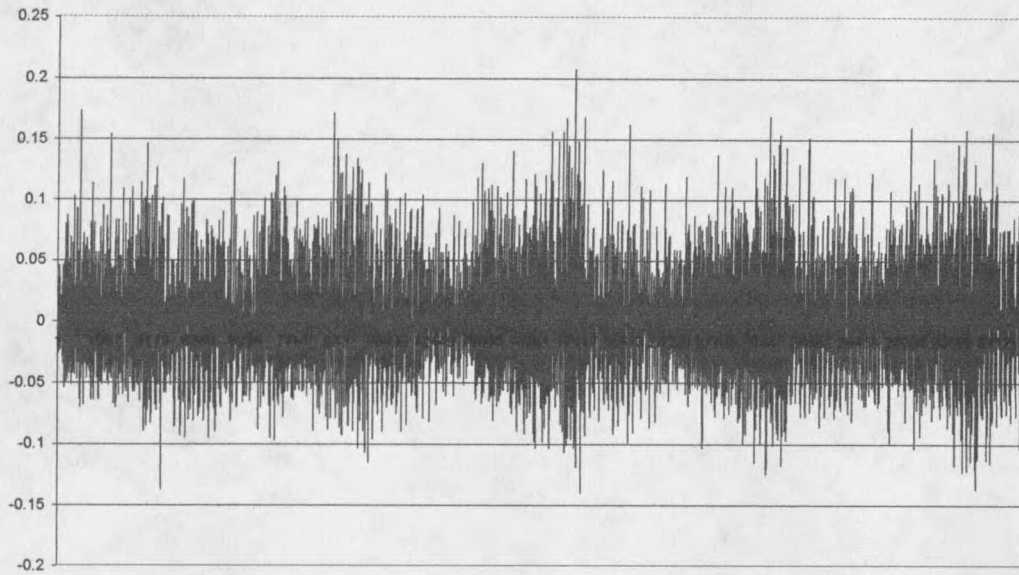
Biceps Femoris EMG

Figure A9 Sample Biceps Femoris EMG

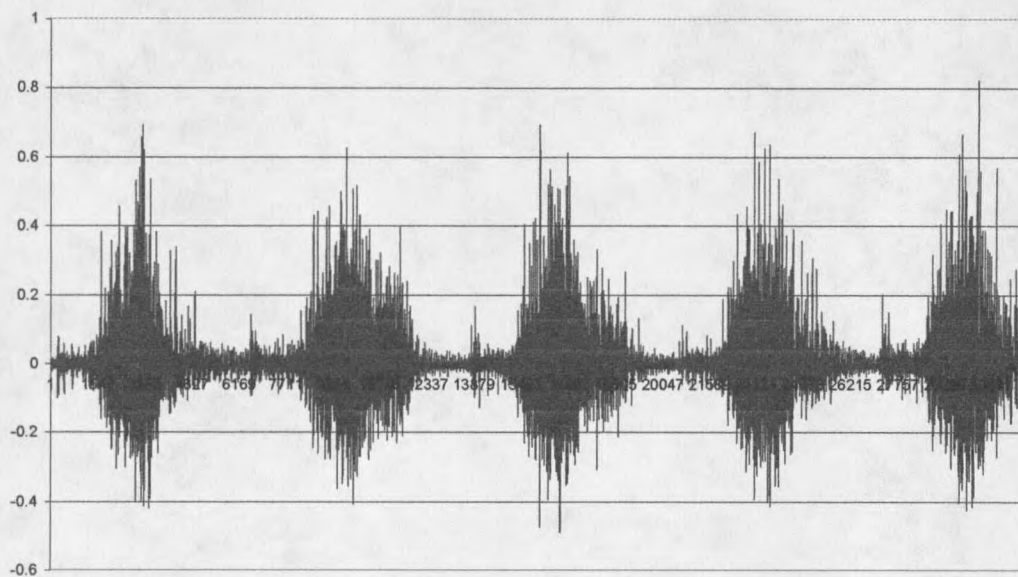
Gastrocnemius EMG

Figure A10. Sample Gastrocnemius EMG

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