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

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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Dean Randal Mercado

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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Approved for the College of Graduate Studies

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figures Page

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)
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Several dependent variables (DV) were identified for this study

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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

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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 though various physiological adaptations. These physiological adaptations are generally negative and can limit an astronauts 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 VO2 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. 11989).

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. Theses 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 are 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 el 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 then 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 VO2 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.

Curteton 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 quadriceps 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 an 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 and 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

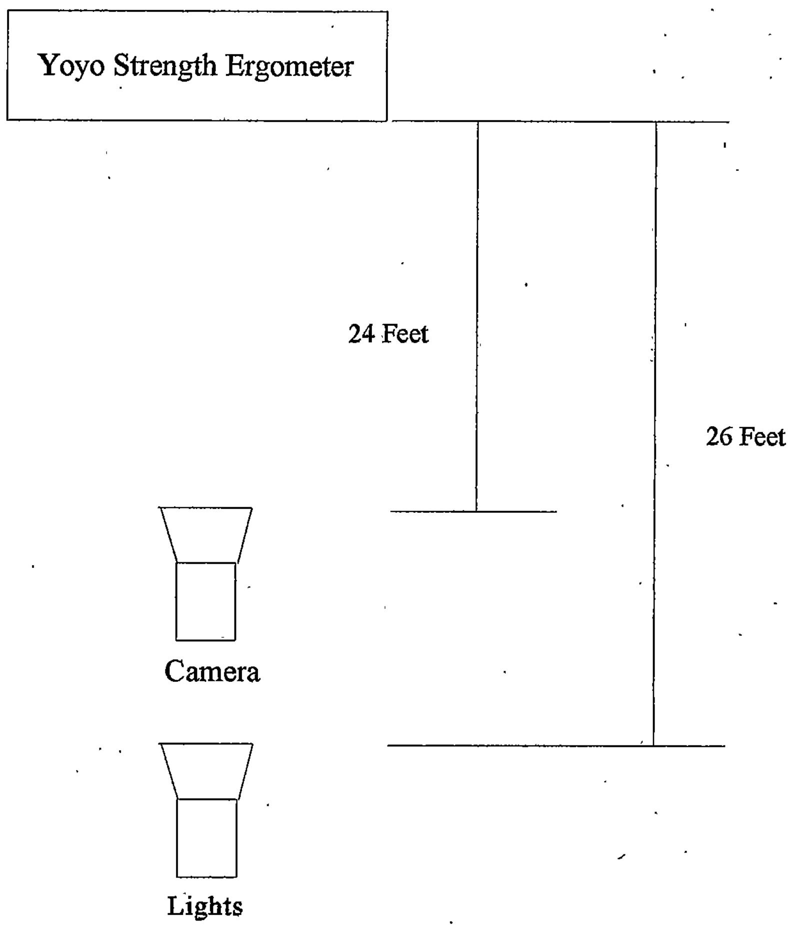

Figure 3.1 Camera and light setup (see Figure 3.5)

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 later epicondyle of the right femur. Lower leg length was determined by the distance between the lateral epicondyle of the right femur and lateral maleoleous 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 maleoleous of the ankle, and on the lateral side of the head of the fifth

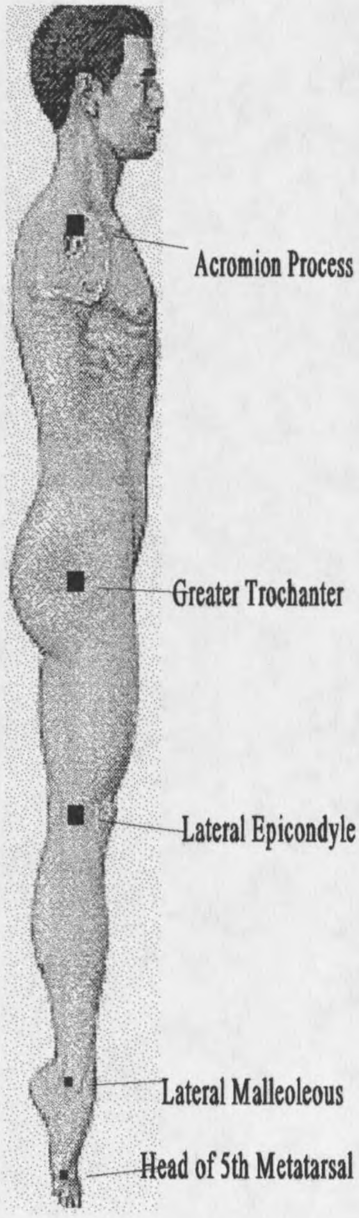

Figure 3.2 Placement of reflective markers (Adapted From ADAM Comprehensive 2.3; ADAM Software Inc., Atlanta, GA)