The Effects of Gender on Isokinetic Peak Torque and Torque/Time Relationship

Bryan K. Minnich
THE EFFECTS OF GENDER ON ISOKINETIC PEAK TORQUE
AND TORQUE/TIME RELATIONSHIP

BY
BRYAN MINNICH

A thesis submitted
in partial fulfillment of the requirement for the
degree Master of Science
Major in Health, Physical Education, and Recreation
South Dakota State University
1987
THE EFFECTS OF GENDER ON ISOKINETIC PEAK TORQUE
AND TORQUE/TIME RELATIONSHIP

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Dr. Jack Ewing, Associate Professor, Thesis Advisor, and HPER Graduate Coordinator

Dr. James E. Lidstone, Assistant Professor, and HPER Research Coordinator

Dr. Harry L. Forsyth, Professor and Head of HPER Department

Date

8/5/87
ACKNOWLEDGEMENTS

The author thanks Dr. Jack Ewing for his concern, encouragement, guidance and most of all the patience in the completion of this thesis. The author thanks Dr. Jim Lidstone for his assistance in the completion of this thesis. The author also would like to extend special thanks to his wife Peggy and two children, Holly and Joshua, for patiently supporting him throughout this endeavor. But most of all, the author would like to acknowledge and praise the Lord Jesus Christ, for through Him all things are possible.
The purpose of this investigation was to determine if gender had an effect on isokinetic peak torque, time to peak torque, and time to various percentages of peak torque. Twenty-nine college-age males and 21 college-age females were tested isokinetically to determine the peak torque and the torque/time relationship of the right quadriceps muscle at speeds of 3, 30, and 60 degrees per second. Time to 50, 70, 75 and 100 percent of peak torque was determined at each of the testing speeds. The order of testing of the three speeds was randomly assigned, with each session separated by at least 48 hours. At each speed the subjects were instructed to give two successive maximal efforts separated by a short rest. Torque development was recorded every .02 of a second. The results of the analysis indicated that males generated higher peak torques than females at each testing speed (3, 30, and 60 degrees per second). A significant difference was also found between males and females for time required to attain 50 percent of peak torque at each testing speed. The time to reach 70 and 75 percent of peak torque was not significantly different between genders. The time to peak torque for females at three degrees per second, was faster than for males, while at 30 and 60 degrees per second no significant difference was determined.
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CHAPTER I

INTRODUCTION

Americans have become more aware of the importance of physical fitness in recent years. Historically, the term physical fitness has been misinterpreted and at times has been used to identify only a single component of physical fitness. The main components that are commonly attributed to physical fitness are cardiovascular endurance, flexibility, muscular endurance, body composition, and muscular strength (Corbin & Lindsey, 1985). Many individuals have associated physical fitness with only one of these components, particularly, cardiovascular endurance. For one to become truly physically fit, there is a need for a balance of the components.

One of those components of physical fitness that has interested many investigators is muscular strength. The term strength, as defined by Wilmore (1977) "is the ability to apply or resist force" (p. 67). A better understanding of the concept of strength can be gained through the knowledge of how it can be measured. Strength has been described as static or dynamic. Static or isometric strength is defined as the maximal amount of force that can be applied to a fixed resistance. Dynamic strength is the maximal amount of force which can be applied to an object through a range of motion. Dynamic strength can be assessed both by isotonic and isokinetic means. During an isotonic muscle contraction the muscle fibers shorten which cause a joint to move against a constant external resistance throughout the range of motion.
The muscle is exerting various amounts of tension while the external resistance remains constant throughout the various angles of the exercise (Lamb 1984). One of the newest concepts of evaluating strength is by isokinetic movements first introduced by Hislop and Perrine in 1967. "Isokinetic muscle contractions occur as muscle fibers shorten to counteract an 'accommodating' resistance developed by a device that allows a constant rate of movement regardless of the force exerted by the contracting muscle" (Lamb, 1984, p. 240).

The measurements of strength and its related physiological variables have been studied extensively in males (Clarke, 1963; Viitasalo & Komi, 1978; Kearney & Stull, 1981; Hakkinen, Komi & Alen, 1985) and in recent years in females (Wilmore, 1974; Morris, Clarke, & Dainis, 1983; Ewing & Stull, 1984). Prior to puberty, boys and girls tend to be quite similar in strength. But at puberty males begin to show an increase in absolute strength more rapidly than females. This is due primarily to the increased level of the male sex hormone testosterone. Testosterone has an anabolic effect causing an increase in muscle size known as hypertrophy (Malina, 1974). It is interesting to note however that, if strength is expressed in relative terms such as strength per kilogram of body weight or strength per kilogram of lean body weight, the sex difference is greatly diminished. It has been shown that leg muscle strength is similar between men and women after puberty when expressed per kilogram of body weight (Gregor, Edgerton, Perrine, Campion, & Debus, 1979). In one study females had greater leg strength than males when strength was expressed per kilogram of lean
study by Bell and Jacobs (1986) also noted that there was no significant difference between 40 males and 46 females when examining rate of force development of the biceps brachii.

While the studies previously mentioned have provided valuable information pertaining to peak forces and the rate of force development in males and females they all have done so utilizing isometric muscle contractions. Also, there are still discrepancies among research findings between men and women regarding the rate of achieving peak forces and the time to reach specific percentages of peak force. Because of a discrepancy in the literature dealing with the effects of sex differences on the rate of force development and because there exists in the published literature no study examining the torque/time relationship between men and women while generating isokinetic muscle contractions, this investigation was carried out.

The Statement of the Problem

The purpose of this study was to determine if there was a significant difference in the right knee extensor muscles between the peak torque of males and females and various torque/time relationships. More specifically, this investigation was designed to determine the difference between males and females for the time it takes to reach 50, 70, 75 and 100 percent of peak torque of the right knee extensor muscles, isokinetically, at the velocities of 3, 30, and 60 degrees per second.
The Hypotheses

The specific hypotheses to be tested, stated in the null form are as follows:

1. There is no significant difference between males and females in the peak torque of the right quadriceps muscle when measured isokinetically at speeds of 3, 30, and 60 degrees per second.

2. There is no significant difference between males and females in the time to reach 50 percent of peak torque when measured isokinetically at speeds of 3, 30, and 60 degrees per second.

3. There is no significant difference between males and females in the time to reach 70 percent of peak torque when measured isokinetically at speeds of 3, 30, and 60 degrees per second.

4. There is no significant difference between males and females in the time to reach 75 percent of peak torque when measured isokinetically at speeds of 3, 30, and 60 degrees per second.

5. There is no significant difference between males and females in the time to reach 100 percent of peak torque when measured isokinetically at speeds of 3, 30, and 60 degrees per second.

Definition of Terms

Isokinetic exercise. Isokinetic exercise is dynamic muscle activity performed by a joint through a full range of motion at a constant angular velocity (Watkins & Harris, 1983).

Orthotron II. The Orthotron II is an isolated-joint, reciprocal, isokinetic system for knee, ankle, shoulder and hip exercise (Cybex, 1982).
**Torque/Time Relationship.** Torque/time relationship is the amount of torque generated at specific time sequences.

**Torque.** Torque is a force which acts about an axis of rotation (Moffroid, Whipple, Hofkosh, Lowman & Thistle, 1970).

**Concentric Muscle Contraction.** Concentric muscle contraction is the result of shortening of the muscle fibers (Lamb, 1984).

**Isometric Contraction.** Isometric contraction is the contraction of a muscle without the change of the angle of the joint or little or no change in muscular length (Lamb, 1984).

**Isotonic Contraction.** Isotonic contraction is when the muscle is contracting with a constant load throughout a range of motion of a joint(s) (Lamb, 1984).

**Assumptions**

It is assumed that all subjects were motivated to generate a maximal isokinetic contraction throughout the full range of motion in all testing conditions. It is also assumed that varying levels of activity of the subjects and/or fitness levels of the subjects did not have any effect on the outcome of the investigation. The assumption was made that the environmental factors, such as, temperature of the room and placement of equipment in the testing area did not change the outcome of the research investigation.

**Scope of the Study**

The study was conducted in the spring semester of 1986 at South Dakota State University. Twenty-nine college-age males and 21 college-
age females, who were recruited from the university Fitness and Lifetime Activities Program, read and signed an informed consent form prior to any participation in testing sessions. Testing sessions were approximately 20 minutes in length. Two familiarization sessions were completed by each subject and any questions were answered.

A warm-up stationary bicycle at a work load of 75 watts for five minutes. Following the warm up the subjects were seated on the Orthotron II bench and stabilized by straps. They then performed five submaximal contractions to familiarize them with the testing speeds. Each subject was given a one minute rest following the five submaximal contractions. The subjects were instructed to elicit two successive maximal isokinetic contractions of the right quadricep muscles at speeds of 3, 30, and 60 degrees per second with a 90 second rest between speeds. The testing speeds were randomly assigned. Peak torques and torque/time relationships were recorded utilizing the hardware interface developed by Isotechnologies, Inc. and were analyzed with an IBM Personal Computer using the Isoscan Software also developed by Isotechnologies, Inc.

Significance of the Study

Studies examining rate of force development of males and females by means of isometric contractions are numerous but confusing regarding how fast one is able to attain a given percentage of their peak force (Komi & Karlsson 1978; Kearney & Stull 1981; Ewing & Stull 1984). Research is limited when investigating peak torques and the rate of
torque development by isokinetic contraction. This study contributes to our understanding of this type of dynamic muscle contraction while examining torque/time relationships between males and females. Questions have been raised as to whether females can generate peak force as quickly as males (Komi and Karlsson 1978). Since no studies have been published comparing males and females while performing isokinetic contractions to determine torque/time relationships, more studies need to be conducted to clearly identify differences and similarities between the sexes while eliciting this type of dynamic muscle contraction. The following study was designed to add to our knowledge of understanding the similarities and differences in isokinetic muscle contraction between males and females.
CHAPTER II

THE REVIEW OF LITERATURE

This chapter reviews the published literature which is relevant to this study. This chapter is divided into five major areas: (a) Isokinetic Exercise, (b) Force/Time Relationships, (c) Effects of Gender on the Force/Time Relationship, (d) Training Effects on the Force/Time Characteristics, and (e) Summary.

Isokinetic Exercise

In 1987 Hislop and Perrine introduced a new concept of exercise called isokinetics. The unique characteristic of isokinetic exercise is that the speed of the muscle contraction is held constant. The resistance to movement is not provided by gravity or friction, as is the case in most exercise modes, but is the result of the energy absorption by the machine. In isometric and isotonic exercise, energy is only partially absorbed and the remainder is dissipated as the acceleration increases in the exercise motion. The authors state "the acceleration of isokinetic exercise does not influence the loss of energy, because the machine disallows it. The energy is converted to resisting force that is proportional to the magnitude of muscular force" (Hislop & Perrine, 1967, p. 116). They concluded that isokinetic exercise places greater demands on the muscle through a full range of motion than either isometric or isotonic exercise.

Moffroid, Whipple, Hofkosh, Lowman, and Thistle (1969)
investigated the validity and reliability of isokinetic exercise. The variables which were measured and recorded were torque, power, work, range of motion, and speed of contraction. These variables were obtained by using pen recorder tracings of torque created at the axis of rotation of the isokinetic device. The reliability of torque was determined by hanging loads of 5, 10, 20, 30, 40, 50, and 60 pounds perpendicular to the horizontal lever arm of the isokinetic device at a distance of two feet. It was determined that hanging the known weights at constant distance and position produced a true linear relationship. Ten test-retest sessions using the seven loads at this one position produced a coefficient of reliability of \( r = 0.995 \). Validity of torque measurements of various angles were determined by placing the same loads at various positions through an arc of 180 degrees. The torque values at the various angles were obtained by setting the lever arm at given positions with a speed setting of the device at 0 degrees per second and hanging a 30 pound weight on a lever arm 1.5 feet from the axis of the device. The predicted torque values to the obtained torque values at a given angular position was found to have a coefficient of validity of \( r = 0.999 \). To determine work, a thirty pound weight was hung from an 18 inch lever arm and allowed to fall at a speed of 24 degrees per second through a distance of 180 degrees in seven and a half seconds. The results of work were recorded on graph paper at a paper speed of one and a half inches per second. The work was assumed to be equivalent to the area under the torque/time curve. The validity of this measurement was determined by using mechanical computations. Five separate weights were
used in this testing procedure (10, 20, 30, 40, and 50 pounds) and the correlation between the mechanical computation and the measured value was $r = .946$. It was concluded that the isokinetic device measured torque reliably through a range of motion. When measuring power a 60 pound weight was hung from the isokinetic device's two foot lever arm and dropped through 180 degrees at three speeds (16, 32, and 72 degrees per second). The correlation between predicted power and obtained power was $r = .999$.

Another study which examined the reliability of isokinetic torque measurement was completed by Patton, Hinson, Arnold, and Lessard (1978) using an Orthotron II as the testing device. Isokinetic contractions of the elbow joint of 16 college-age men and 16 college-age women were examined. Prior to the actual test, the Orthotron II was tested for reliability. A reliability coefficient of $r = .96$ was determined. The results of the data revealed that the fatigue curves were curvilinear, were independent of sex differences, and were a function of initial strength.

Although the validity and reliability of isokinetic torque measurement appears to be good, some limitations have been identified. Sapega, Nicholas, Sokolow, and Saraniti (1982) investigated the phenomenon of torque "overshoot". The purpose of the study was to determine if the initial force generated by humans and known weights using an isokinetic device was artifact or a true production of maximal muscular force. Cinematographic analysis was used for observations of the lever arm moving through a range of motion. The study revealed that when the speed was set at 30 degrees per second the torque curve
generated by the falling weight fell through an arc of four degrees before the dynamometer's resistance engaged, causing the torque trace on the oscilloscope to exceed the baseline. Between frames four and five the highest velocity was determined at 77 degrees per second, while between frames five and ten there was noted a sharp deceleration before stabilization occurred after frame 25 to the preselected speed of 30 degrees per second. When the subjects were tested for hip abduction at a speed of 30 degrees per second the lever arm moved through an arc of four degrees before any engagement of resistance occurred. The limb-lever arm system reached a maximal angular velocity of 90 degrees per second between frames four and five before the occurrence of deceleration between frames five and nine. Stabilization of the preset speed occurred at frame 20. The study concluded that initial forces generated by inert weights or human subjects possibly should be regarded as artifact or overshoot and not be confused with true muscular force.

In a study comparing free-weight and isokinetic bench pressing Lander, Bates, Sawhill, and Hamill (1985) obtained results similar to those of Sapega et al. (1982). The investigation showed that isokinetic speeds of 0.47, 1.06, and 1.75 radians per second (26.9, 60.7, and 102.7 degrees per second, respectively) did not elicit constant resistance throughout the range of motion. The investigation revealed that at 0.47 radians per second the isokinetic exercise device was only 70 percent truly isokinetic throughout the entire range of motion. As the speed increased to 1.06 radians per second the activity was only 62 percent isokinetic, and when attaining a rotational speed of 1.75 radians per
second the exercise activity was found to be only 50 percent isokinetic. The study concluded that when performing on an isokinetic modality that this phenomenon called "overshoot" should be taken into account when determining peak torques.

**Force/Time Relationship**

Wilkie (1950) investigated various facets of force/velocity relationships, including the rise of isometric tension with time. Five subjects were tested for maximal isometric contraction of the elbow. By constructing a force/time curve, it was revealed that maximal force was generated in less than 200 milliseconds and the time to attain 50 percent of maximal force was approximately 65 milliseconds.

The examination of rate of tension development and release under extreme temperature was investigated by Clarke and Royce (1962). Thirty-one young male adults were instructed to squeeze a hand ergometer as fast and as hard as they could to produce a maximum muscle contraction. Following one minute's rest the subjects immersed their arm in cold (10 degrees centigrade) or hot (46 degrees centigrade) water for 10 minutes. When the 10 minute period concluded the subjects were instructed to repeat the maximal muscle contraction. The study revealed that temperature does have an effect on rate of force development. Under normal conditions 95 percent of maximal force was reached in 26.3 centiseconds (255 milliseconds). There was no significant difference between these two conditions. Whereas, with the cold treatment the time to reach maximal force was 41.4 centiseconds, which was significantly longer than either the control or hot water condition.
Effects of Gender on Force Time Relationship

Kearney and Stull (1981) examined the effects of fatigue on the rate of force development by contraction of the grip-flexor muscles. Fifteen college-age males participated in the experiment. The subjects were tested in five sessions with a period of at least 48 hours between sessions. The subjects grasped the hand-grip dynamometer and were instructed to generate a maximum muscle contraction. It was noted that the time to reach 50 percent of maximal force in the non-fatigued state of the hand grip muscles was 62 milliseconds. The study also revealed that the time for the male subjects to reach 70 percent of peak force was 102 milliseconds.

A similar study conducted by Ewing and Stull (1984) investigated the rate of force development of the grip-flexor muscles by testing twenty-eight young adult women. The investigation revealed that the time for the women to reach 50 percent of peak torque during an isometric contraction of the right grip-flexor in the non-fatigued state was 82 milliseconds and the time to 70 percent of peak force was 122.1 milliseconds. For both measurements the times were slower in the females than in the males of Kearney and Stull's (1981) study, although statistical analyses were not completed.

An investigation by Morris, Clarke, and Dainis (1983) examined the time to voluntary maximal isometric contraction of five different muscle groups in nine male and ten female college-age students. The five actions that were examined were hand gripping, wrist flexion, knee extension, elbow flexion, and ankle dorsiflexion. During each isometric
muscle contraction the subjects were instructed to contract as hard and as fast as possible and to hold the contraction for one to two seconds. Each subject was given a one to two minute rest between the five trials. The time to 50 percent of peak torque of the hand gripping muscle in the women was 65.6 milliseconds and 117.3 milliseconds to 75 percent of peak force. The time to reach 50 and 75 percent of peak force in males was 95.0 milliseconds and 161.9 milliseconds, respectively. When examining knee extension it was revealed that in females the time to reach 50 percent of peak force isometrically was 86.7 milliseconds and to 75 percent of peak force was 154.9 milliseconds. The times for males to attain 50 and 75 percent of peak force were 99.0 and 170.7 milliseconds, respectively. The times for females to generate 50 and 75 percent of peak force for wrist flexion was 43.7 and 90.5 milliseconds, respectively. The males obtained 50 and 75 percent of peak force during the wrist flexion exercise in 64.2 and 115.0, respectively. The females also generated a significantly faster time to peak force when elbow flexion and ankle flexion was examined. All muscle groups examined between the males and females revealed a significant difference to attain the various percentages to maximal voluntary contraction.

Komi (1979) investigated the rate of force development of the knee extensor muscles in male skiers and found the mean time to reach 50 percent of peak force was 223 milliseconds. An earlier study by Komi and Karlsson (1978) examined muscle fiber types, enzyme activities, and physical performance using 20 male and 11 female twins. It was revealed that the time to reach 70 percent of peak force in females was 749.1 milliseconds and 376.3 milliseconds for males. It was suggested that
this dramatic difference could be partially explained by enzymatic differences and possibly a difference in the nature of the elastic structure of the muscle between males and females.

A study conducted by Buchthal and Schmalbruch (1970) examined muscle contraction times in male and female subjects ranging in age from 16 to 63 years. A needle that was connected to small transducers was inserted in a tendon of various muscle bundle fiber groups of normal humans. The measurement of force and the time course of the twitches were recorded. When examining the contraction times of the biceps brachii the study revealed no significant differences between males and females.

A more recent study by Bell and Jacobs (1986) compared 46 males and 40 females with regard to electric-mechanical response variables and the rate of force development. The subjects were instructed to generate a maximal contraction of the biceps brachii while holding a bar attached to a force transducer. The results were similar to Buchthal and Schmalbruch (1970) in that there were no significant differences between males and females in regards to rate of force development. The results revealed a significantly greater absolute force generated by the males than the females. This significant difference was still maintained when expressed relative to body weight. There were no significant differences between males and females when rate of force development were expressed in the relative values of 25, 50, 75, or 100 percent of maximal voluntary contractions. The time to reach 50 percent of maximum force for male and female groups was approximately 63


milliseconds. Seventy-five percent of maximum force was achieved by both males and females in approximately 118 milliseconds.

Viitasalo and Komi (1978) investigated the relationship between fiber type and force-time characteristics. The study included eight subject groups: ski jumpers, male skiers, female skiers, speed skaters, volleyball players, male monozygous and dizygous twins, and a reference group (male firemen). A muscle fiber biopsy was taken from the vastus lateralis muscle to determine the fiber type. A device called an electromechanical dynamometer was used to measure the maximal isometric forces. In the study no quantitative values were given, but it was expressed by the authors that the females generated less force and the rate of force development was slower.

Training Effects on Force-Time Characteristics

Sukop and Nelson (1974) examined the effects of isometric training on force-time characteristics of muscle contractions. Seven male subjects from a physical education class participated in the training program which consisted of 10 training sessions. The subjects executed 10 isometric contractions of the right elbow flexors designed to reach peak force as quickly as possible. A special on-line computer system was used to record and analyze the data. The 10 training sessions were held every other day over a period of 22 days. Muscle tension was examined in intervals of 33.3 milliseconds up until peak tension was developed. The results of the investigation revealed that as the result of a training program the subjects were able to generate a specific tension unit in less time and an increase of tension in a
specific time period.

The effects of isometric and dynamic training on the mechanical properties of human muscle were studied by Duchateau and Hainault (1984). Twenty male and female subjects were chosen, with ages ranging from 17 to 30 years. The training program consisted of exercising the adductor pollicis muscle of the non-dominant hand 10 minutes each day for three months. The first group of 10 subjects trained by isometrically contracting the muscle for five seconds and resting 50 seconds, until 10 minutes of exercise were completed. The second group performed an exercise that consisted of 10 sets of 10 fast adduction and abduction movements of the thumb. Exercises were performed 10 minutes daily for three months. The post test revealed that both training regimens elicited increases in peak rate of force development. The dynamic exercise group increased the rate of tension development to a greater extent than the isometric trained group by 13 percent. The study suggests that the contraction time of muscle can be shortened by a physiologically induced training program of this type.

An investigation of the effects of a strength training program on electromyography (EMG) tracings of human muscle was done by Thorstensson, Karlsson, Viitasalo, Luhtanen, and Komi (1976). Many variables were studied, but only the one dealing with the isometric rate of force development of the knee extensor muscle will be reviewed. Eight male students from a physical education class participated in the study. The mean age for the group was 24 years. The strength training program consisted primarily of "squats", knee bends with the weight on
the shoulders. The protocol employed was three sets of six repetitions for a period of eight weeks. The results revealed after an eight week strength training regimen that a specific amount of isometric force could be generated in less time. The researchers attributed the change to improved capability by the enhancement of fast twitch motor units.

A recent study by Hakkinen, Komi, and Alen (1985) investigated the effects of explosive type strength training on isometric force. The study included 10 male subjects who went through a 24 week progressive training regimen of primarily jumping exercises. The study showed that the training program had specifically changed the force/time curves of the male subjects. Significant shortening of times to reach an absolute value was observed. On the relative scale the time to reach the force levels of 30, 60, and 90 percent of maximal force all decreased, with 30 percent having a decrease of 22 percent. The change in force/time curve correlated significantly with the apparent change in fast twitch to slow twitch muscle fibers.

Summary

In summary, this chapter reviews the published literature related to isokinetic exercise and rate of force development of muscle contraction.

Isokinetic exercise has been shown to have the ability to record torque through an entire range of motion at a predetermined speed (Hislop et al., 1967). Several studies have examined the effects of the acceleration and deceleration phase associated with the use of the isokinetic device and have suggested that the collision of the
acceleration and deceleration phases may cause an artificially high torque value during the period of force generation (Sapega et al., 1982). It was identified that the muscle does not maintain a true isokinetic contraction through the entire range of motion. (Sapega et al., 1982; Clarke & Manning, 1985).

Research utilizing both sexes as subjects have not agreed on the effect of gender on the time to reach peak force or percentages of peak force. Several investigators have revealed that males obtained relative values of peak forces more quickly than did females (Komi & Karlsson, 1978; Kearney & Stull, 1981; Ewing & Stull, 1984). Morris et al. (1985) reported that females generated relative forces more quickly than males, whereas Buchthal & Schmalbruch (1970) and Bell & Jacobs (1986) found no significant difference in the rate of force development between males and females.

Most of the research reviewed suggested that an increase in strength of an individual causes an increase in the absolute rate of force development. Recent research has shown that improvement in relative rate of force development may occur using specific training techniques (Hakkinen, et al., 1985). It has been noted that one important determinant of rate of force development and peak force is the ratio between fast and slow muscle fiber types.
CHAPTER III

METHODS AND PROCEDURES

This chapter describes the subjects, facilities, equipment, procedures, and statistical analyses utilized in the present study. These major areas are subdivided to aid in the organization and presentation of the materials.

Subjects

Twenty-one female and 29 male subjects, age 18 to 26 years, from the South Dakota State University Fitness and Lifetime Activities Program were recruited for this study. Prior to any testing all subjects read and signed an information and consent form (Appendix A).

Facilities

The study was carried out during the spring semester of the 1985-86 academic year in the Human Rehabilitation Laboratory in the Stanley J. Marshall HPER Center at South Dakota State University. The laboratory is not air conditioned but the temperature range of 20 to 24 degrees centigrade should not have affected the results of this study.

Test Equipment

The device used to determine torque was an isokinetic rehabilitation unit known as an Orthotron II (Lumex, Inc). The Orthotron II is an isolated-joint, reciprocal, isokinetic system for the knee, ankle, shoulder, and hip that is used for training and
rehabilitation purposes. The device provides accommodating resistance to match the exercise force output at each angular velocity at the full range of motion by an isolated joint (Adeyanju, K., Crews, T.R., and Meadows, W.J., 1983). The torque/time relationship was recorded utilizing the hardware interface by Isotechnologies, Inc. The hardware interface involved the placement of a force transducer in the hydraulic system of the Orthotron II and a potentiometer on the axel of rotation to facilitate measurement of changes in angular position. The resultant electrical signals were converted to meaningful data with an IBM Personal Computer using the Isoscan software also developed by Isotechnologies, Inc. The reliability of the Orthotron II/Isoscan system has been established at $r = .98$ (Amundson, M., 1987).

Prior to each testing day the Orthotron II dynamometer was calibrated. Calibration was determined by placing a known weight (50 pounds) on the end of the lever arm. The weight was hung on the lever arm 12 inches from the input axis of the dynamometer and was allowed to fall at an angular velocity of 3 degrees per second. The calibration of the speed controlled dynamometer was determined utilizing the Isoscan software each time the subject changed speeds.

Testing Procedures

Familiarization Session

All subjects participated in two familiarization sessions prior to any data collection. Sessions were separated by at least 48 hours. The participants were individually scheduled in a time slot and were
encouraged to come at this time throughout the testing period.

Environmental factors were consistent throughout the testing sessions. Music was not permitted in the room and a sign was posted on the outside of the door identifying that testing was in progress and not to disturb. Also, there were never more than two subjects in the room at one time, with one being tested and the other participating in the warm-up behind a screen. An attempt was made to keep all equipment located in the rehabilitation lab in the same place throughout the study.

Upon arrival at each session the subjects were asked if he or she had any condition that would aggravate a maximal contraction of the right quadriceps muscles. For the warm-up the subjects rode a Schwinn Airdyne stationary bike. The seat was adjusted so that when fully extended with the pedal at the bottom of its arc the leg was bent slightly at the knee. Once on the bike the subjects were instructed not to generate force with their arms but to pedal at a work load of 75 watts. An automatic timer located on the Schwinn Airdyne exercise bike was set for five minutes. While the first subject warmed up, calibration for the first testing speed was completed.

Following the warm-up period, the subject was asked to sit on the testing apparatus and had his/her position stabilized. The back rest of the Orthotron II was slid out of the way and the subject was positioned on the bench so that the back of the knees were tight against the edge of the bench. The back rest was slid forward to contact the lower back and locked into place. The waist belt was tightened snugly around the subject and fastened by a velcro strap. After the belt was
fastened around the subject's waist, a strap was fastened over the right thigh. Once this occurred the height of the accuator was adjusted so that the axis of rotation of the dynamometer was aligned so as to be at the same height as the axis of rotation of the knee. The shin pad was adjusted so it was located just above the malleoli. Data were entered into the computer which included: name, sex, date, age, height, weight, length of lever arm, speed setting, back rest position, and accuator height. When the velocities were set to 30 and 60 degrees per second the subject was instructed to move through the full range of motion by giving five submaximal contractions of the right knee extensor muscle to experience an isokinetic contraction. At three degrees per second the subject was instructed to give two submaximal contractions for two seconds with a 15 second rest between contractions. The submaximal contractions were separated from the actual test contractions by a one minute rest.

The subjects were instructed to perform two maximal consecutive contractions of the right knee extensor muscles at speeds of 3, 30, and 60 degrees per second with at least a 90 second rest between speeds. This procedure was similar to that described by Clarkson, Johnson, Dextradeur, Leszczynske, Wai, and Melchionda (1982). Strong verbal encouragement was given to produce a maximal effort. The command given to the subject to begin generating the maximal contractions was "Ready, Set, Begin". Prior to the begin command the F1 key on the computer was hit to begin data collection. After the subject performed two successive contractions the F1 was hit again to stop collection of data.
The subject was then unstrapped and instructed to move from the bench and rest while calibration for the next speed setting was completed. The data collected were stored on a floppy diskette. After calibration of the speed, the subject was instructed to return to the bench and was positioned as he or she had been previously. These same procedures were carried out until data at all three speeds had been collected.

Testing Session

The testing session followed the same format as the two familiarization sessions except that the speed settings were randomly assigned for each subject. The subjects were tested at 3, 30, and 60 degrees per second. Only the data collected from the contraction which generated the greatest torque were used for analysis at each testing speed.

Statistical Analyses

The Statistical Analysis System (SAS) computer analysis package was used for the calculation of both descriptive and inferential statistics. Means and standard deviations for the torque/time relationship of the right knee extensor muscles at 50, 70, 75, and 100 percent of peak torque at velocities of 3, 30, and 60 degrees per second were determined. Time to the various percentages of peak torque was determined by multiplying the percentage by the peak torque and identifying the corresponding time. Since the computer recorded torques in .02 second intervals it was often necessary to extrapolate to get the time value. This calculation assumed there was a linear relationship
between time and torque for each .02 second. A repeated measures analysis of variance procedure was used to determine if there were any significant differences between males and females at each of the three testing speeds for time to 50, 70, 75, and 100 percent of peak torque. The alpha level was set at .05 for this investigation.
CHAPTER IV

RESULTS AND DISCUSSION

Presented in this chapter are the results and discussion dealing with the effects of gender on the torque/time relationship of 29 college-age males and 21 college-age females. The chapter has been subdivided according to the dependent variables as follows: (a) absolute peak torque generated, (b) the time required to achieve 50 percent of peak torque at isokinetic speeds of 3, 30, and 60 degrees per second, (c) the time required to achieve 70 percent of peak torque at isokinetic speeds of 3, 30, and 60 degrees per second, (d) the time required to attain 75 percent of peak torque at isokinetic speeds of 3, 30, and 60 degrees per second, and (e) the time required to achieve 100 percent of peak torque at isokinetic speeds of 3, 30, and 60 degrees per second. A discussion which compares the results of the current study with these of previous research concludes this chapter.

Peak Torque

The descriptive statistics for peak torque are presented in Table 1. The mean peak torque for males at 3 degrees per second was 230.1 footpounds with a standard deviation of 48.9. The mean peak torque for females at 3 degrees per second was 141.8 footpounds with a standard deviation of 18.3. The mean peak torque for males and females respectively, at 30 degrees per second were 234.0 footpounds with a standard deviation of 40.6 and 144.2 footpounds and a standard deviation
TABLE 1

Descriptive Statistics for

Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th>F (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/second</td>
<td>230.12 ± 48.9</td>
<td>141.76 ± 18.3</td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>234.02 ± 40.6</td>
<td>144.21 ± 17.3</td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>209.48 ± 43.5</td>
<td>130.86 ± 16.4</td>
</tr>
</tbody>
</table>

a Means & Standard deviations measured in footpounds

b Significantly different from female group (p < .05)
of 17.3. The mean peak torque for males at 60 degrees per second was 209.5 footpounds with a standard deviation of 43.5. The mean peak torque for females at 60 degrees per second was 130.9 footpounds with a standard deviation of 16.4. As was expected the males generated a significantly greater peak torque at each isokinetic speed (Figure 1). The analysis of variance applied to peak torque is presented in Table 2. A significant difference for the main effect of sex was indicated by an F value of 208.79, which was significant at the .05 level. This indicates that at all three testing speeds males were able to generate significantly greater peak torques than females. As can be seen in Table 2 there was not a significant difference at the .05 level for peak torque at the three different speeds or was there a significant sex by speed interaction.

Time to 50 Percent of Peak Torque

The length of time required to reach 50 percent of the maximal torque generated at 3, 30, and 60 degrees per second was determined in order to provide information on the effects of gender on the torque/time relationship. The means and standard deviations for these parameters are presented in Table 3 and a graphic representation of the data in Figure 2. The mean and standard deviations for time to 50 percent of peak torque at 3 degrees per second for males and females, respectively, were .088 ± .036 seconds and .108 ± .087 seconds. The mean and standard deviation for males to attain 50 percent of peak torque at 30 degrees per second was .087 ± .031 seconds and for females .110 ± .073 seconds. The means and standard deviation for time to 50 percent of peak torque
Figure 1

PEAK TORQUE

TORQUE (FOOT POUNDS)

3 DEG/SEC  30 DEG/SEC  60 DEG/SEC

SPEED OF ISOKINETIC CONTRACTION

MALE  FEMALE
## TABLE 2

Summary of Analysis of Variance for Peak Torque

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
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<td>267729.25</td>
<td>267729.25</td>
<td>208.79</td>
<td>.0001</td>
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<td>Speed</td>
<td>2</td>
<td>10027.80</td>
<td>5013.90</td>
<td>3.91</td>
<td>.0222</td>
</tr>
<tr>
<td>Speed Sex</td>
<td>2</td>
<td>901.51</td>
<td>450.76</td>
<td>.35</td>
<td>.7042</td>
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<tr>
<td>Error</td>
<td>144</td>
<td>18652.53</td>
<td>1282.31</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 3

Descriptive Statistics for time to
50 Percent of Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th>F (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/seconds</td>
<td>0.088 ± 0.036</td>
<td>0.108 ± 0.087</td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>0.087 ± 0.031</td>
<td>0.110 ± 0.073</td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>0.073 ± 0.030</td>
<td>0.086 ± 0.032</td>
</tr>
</tbody>
</table>

a  Means + Standard deviations measured in seconds  
b  Significantly different from female group (p < .05)
Figure 2

TIME TO 50% OF PEAK TORQUE

<table>
<thead>
<tr>
<th>SPEED OF ISOKINETIC CONTRACTION</th>
<th>TIME (SECONDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 DEG/SEC MALE</td>
<td>0.08</td>
</tr>
<tr>
<td></td>
<td>0.10</td>
</tr>
<tr>
<td>30 DEG/SEC FEMALE</td>
<td>0.11</td>
</tr>
<tr>
<td>60 DEG/SEC MALE</td>
<td>0.12</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
at 50 percent of peak torque at 60 and 0.086 ± 0.032 seconds. A repeated measures analysis of variance was applied to these data. A summary of the ANOVA Table 4 indicates that the F value of 5.24 for the main effects of sex was significant at the .05 level. Therefore, at each of the testing speeds the males generated 50 percent of peak torque faster than the females. Again the main effects for speed and sex by speed interaction was not significant at the .05 level.

Time to 70 Percent of Peak Torque

The means and standard deviations for the time required to reach 70 percent of peak torque are presented in Table 5. Figure 3 shows the comparative mean values for males and females for each testing speed of contraction. The mean and standard deviation for males to reach 70 percent of peak torque at 3 degrees per second was 0.176 ± 0.041 seconds and for the females it was 0.178 ± 0.088 seconds. For the time to attain 70 percent of peak torque at 30 degrees per second the means and standard deviation for men and women, respectively, were 0.160 ± 0.038 seconds and 0.186 ± 0.095 seconds. The means for the time to achieve 70 percent of peak torque at 60 degrees per second for men was 0.139 seconds with a standard deviation of 0.052 and for women was 0.155 seconds with a standard deviation of 0.045. An analysis of variance with repeated measures was carried out to determine the effect of gender on time to reach 70 percent of peak torque. A summary of the results of the analysis is presented in Table 6. The analysis for the main effect of sex revealed an F value of 2.03. This was not significant at the .05 level. The sex by speed interaction was again not significant at the
TABLE 4

Summary of Analysis of Variance
for Time to 50 Percent
of Peak Torque

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
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<td>.01321831</td>
<td>5.24</td>
<td>.0236</td>
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<td>Speed</td>
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<td>.01207426</td>
<td>.00603713</td>
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<td>.0951</td>
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<td>Speed Sex</td>
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<td>.8837</td>
</tr>
<tr>
<td>Error</td>
<td>144</td>
<td>.36349840</td>
<td>.00252429</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 5

Descriptive Statistics for Time to
70 Percent of Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th>F (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/second</td>
<td>0.176 ± 0.041</td>
<td>0.178 ± 0.088</td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>0.160 ± 0.038</td>
<td>0.186 ± 0.095</td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>0.139 ± 0.052</td>
<td>0.155 ± 0.045</td>
</tr>
</tbody>
</table>

a Means & Standard deviations measured in seconds
b Significantly different from female group (p < .05)
Figure 3
TIME TO 70% OF PEAK TORQUE

TIME (SECONDS)

0.000 0.010 0.020 0.030 0.040 0.050 0.060 0.070 0.080 0.090 0.100 0.110 0.120 0.130 0.140 0.150 0.160 0.170 0.180 0.190 0.200

3 DEG/SEC 30 DEG/SEC 60 DEG/SEC

SPEED OF ISOKINETIC CONTRACTION

MALE FEMALE
TABLE 6

Summary of Analysis of Variance
for Time to 70 Percent
of Peak Torque

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>.00756323</td>
<td>.00756323</td>
<td>2.03</td>
<td>0.1565</td>
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<tr>
<td>Speed</td>
<td>2</td>
<td>.02618559</td>
<td>.01309279</td>
<td>3.51</td>
<td>0.0324</td>
</tr>
<tr>
<td>Sex Speed</td>
<td>2</td>
<td>.00342210</td>
<td>.0017110</td>
<td>.46</td>
<td>0.6329</td>
</tr>
<tr>
<td>Error</td>
<td>144</td>
<td>.53685349</td>
<td>.00372815</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
0.05 level although an F value of 3.51 did indicate a significant difference (p < .05) for the main effects of speed.

Time to 75 Percent of Peak Torque

In order to further examine the torque/time relationship the time required to generate 75 percent of peak torque was determined for each of the testing speeds (3, 30, and 60 degrees per second). The means and standard deviation for the time to 75 percent of peak torque are presented in Table 7. Figure 4 shows bar graphs of the means for these data. The means and standard deviations for the time required to attain 75 percent of peak torque at 3 degrees per second for males and females, respectively, were .201 ± .057 seconds and .202 ± .093 seconds. The time required to reach 75 percent of peak torque at 30 degrees per second for males was .204 seconds with a standard deviation of .087 and for females was .214 seconds with a standard deviation of .100. The means and standard deviations for time required achieve 75 percent of peak torque at 60 degrees per second for men and women, respectively, were .161 ± .054 seconds and .172 ± .055 seconds. A summary of peak torque is found in Table 8. The F value for the main effect of sex is 0.37 and is not significant at the .05 level demonstrating that at all testing speeds there were no significant differences between the males and females when generating 75 percent of peak torque. A significant F ratio of 4.4 was calculated for the main effects of speed, while the F ratio for sex time speed interaction was not significant.
**TABLE 7**

Descriptive Statistics for Time to a 75 Percent of Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th></th>
<th>F (N=21)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/second</td>
<td>.201 ± .057</td>
<td></td>
<td>.202 ± .093</td>
<td></td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>.204 ± .087</td>
<td></td>
<td>.214 ± .100</td>
<td></td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>.161 ± .054</td>
<td></td>
<td>.172 ± .055</td>
<td></td>
</tr>
</tbody>
</table>

a Means & Standard deviations measured in seconds
b Significantly different from female groups (p < .05)
Figure 4
TIME TO 75% OF PEAK TORQUE

SPEED OF ISOKINETIC CONTRACTION

MALE  FEMALE

3 DEG/SEC  30 DEG/SEC  60 DEG/SEC


**TABLE 8**

Summary of Analysis of Variance for Time to 75 Percent of Peak Torque

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>1</td>
<td>0.00209532</td>
<td>0.00209532</td>
<td>0.37</td>
<td>0.5438</td>
</tr>
<tr>
<td>Speed</td>
<td>2</td>
<td>0.04977454</td>
<td>0.02488727</td>
<td>4.40</td>
<td>0.0140</td>
</tr>
<tr>
<td>Sex Speed</td>
<td>2</td>
<td>0.00066302</td>
<td>0.0003151</td>
<td>0.06</td>
<td>0.9431</td>
</tr>
<tr>
<td>Error</td>
<td>144</td>
<td>0.81468528</td>
<td>0.00565754</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Time to Peak Torque

Further examination of the torque/time relationship between male and female times to peak torque was conducted for the isokinetic speeds of 3, 30, and 60 degrees per second. Descriptive statistics for these are presented in Table 9 and a graphic representation in Figure 5. The mean and standard deviations for time required to reach peak torque at 3 degrees per second for men and women, respectively, were $0.991 \pm 0.263$ seconds and $0.728 \pm 0.235$ seconds. The mean for time to reach peak torque at 30 degrees per second for men was $0.690$ seconds with a standard deviation of $0.210$ and for women was $0.688$ seconds with a standard deviation of $0.184$. The means and standard deviations for time to peak at 60 degrees per second for men and women respectively, were $0.384 \pm 0.101$ seconds and $0.429 \pm 0.100$ seconds. The resultant F value from the analysis of variance with repeated measures for the main effects of sex was $5.26$ which was significant at the .05 level (Table 10). Again the main effects of speed demonstrated a significant F ratio. It should also be noted that the F value for sex by speed interaction was also significant ($F = 8.84, \ p > .05$) indicating an unsystematic response by males and females to the three testing speeds. In order to identify the significant difference(s) the P diff analysis was utilized (Table 11). It was revealed that it took significantly longer for the males to attain peak torque at 3 degrees per second than the females. At speeds of 30 and 60 degrees per second there were no significant differences between the male and female responses.
TABLE 9

Descriptive Statistics for Time to a Peak Torque

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th>F (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/second</td>
<td>.991 + .263</td>
<td>.728 + .235</td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>.690 + .210</td>
<td>.688 + .184</td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>.384 + .101</td>
<td>.429 + .100</td>
</tr>
</tbody>
</table>

a Means & Standard deviations measured in seconds

b Significantly different from the females (P < .05)
Figure 5
TIME TO PEAK TORQUE

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 DEG/SEC</td>
<td>1.100</td>
<td>0.700</td>
</tr>
<tr>
<td>30 DEG/SEC</td>
<td>0.900</td>
<td>0.600</td>
</tr>
<tr>
<td>60 DEG/SEC</td>
<td>0.500</td>
<td>0.400</td>
</tr>
</tbody>
</table>

SPEED OF ISOKINETIC CONTRACTION

\[\square\] MALE  \[\blacktriangle\] FEMALE
TABLE 10

Summary of Analysis of Variance for Time to Peak Torque

<table>
<thead>
<tr>
<th>Source:</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
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<td>0.19888128</td>
<td>0.19888128</td>
<td>5.26</td>
<td>0.0233</td>
</tr>
<tr>
<td>Speed</td>
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<td>5.10545399</td>
<td>2.55272699</td>
<td>67.53</td>
<td>0.0001</td>
</tr>
<tr>
<td>Sex Speed</td>
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<td>0.66803532</td>
<td>0.33401766</td>
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<td>0.0002</td>
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<tr>
<td>Error</td>
<td>144</td>
<td>5.44352996</td>
<td>0.03780229</td>
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<td></td>
</tr>
</tbody>
</table>
### TABLE 11

Table of Time to Peak Torque

for Sex by Speed

<table>
<thead>
<tr>
<th></th>
<th>M (N=29)</th>
<th>F (N=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 degrees/second</td>
<td>±.991</td>
<td>±.728</td>
</tr>
<tr>
<td></td>
<td>±.263</td>
<td>±.235</td>
</tr>
<tr>
<td>30 degrees/second</td>
<td>±.690</td>
<td>±.688</td>
</tr>
<tr>
<td></td>
<td>±.210</td>
<td>±.184</td>
</tr>
<tr>
<td>60 degrees/second</td>
<td>±.384</td>
<td>±.429</td>
</tr>
<tr>
<td></td>
<td>±.101</td>
<td>±.100</td>
</tr>
</tbody>
</table>

a Means ± Standard Deviations measured in seconds.

b Significantly different from the females. (p < .05)
Discussion

In the present study it was found that regardless of the isokinetic speed, the mean peak torque generated during maximal contractions was greater for males than for females. This result was expected, however, and merely confirms the well known fact that males are able to generate greater absolute forces and torques than females (Kearney & Stull, 1978; Ewing & Stull, 1984; Komi & Karlsson, 1978).

The results of this investigation comparing the time required to attain 50 percent of peak torque between males and females indicates that the males reached 50 percent of peak torque at three degrees per second in .088 seconds whereas, the females attained 50 percent of peak torque in .108 seconds. At 30 degrees per second the mean time required to achieve 50 percent of peak torque between males and females, respectively, was .087 seconds and .110 seconds. When the isokinetic speed was increased to 60 degrees per second the times were .073 seconds for males and .086 seconds for females. All of these differences were significant at the .05 level. In a pair of studies utilizing similar procedures with isometric hand grip flexion Kearney and Stull (1981), examining men, and Ewing and Stull (1984) examining women, reflected similar patterns for time to reach 50 percent of peak torque as the present study. Kearney and Stull (1981) reported that the time required for males to attain 50 percent of a maximal isometric contraction was 0.062 seconds while Ewing and Stull (1984) reported a time of .082 seconds for females. The time to 50 percent of peak torque in the present study was greater for both males and females than those reported by Kearney and Stull (1981) and Ewing and Stull (1984), but can be most
likely attributed to the difference in muscle groups tested and/or the mode of testing (isokinetic versus isometric).

The results of the present study do not support those of Morris, Clarke, and Dainis (1983). In their study, examining isometric contractions of the right knee extensor muscles, they reported that the time required to reach 50 percent of maximal voluntary contraction was 0.087 seconds for women and .099 seconds for men. These times are similar to that of the isokinetic contraction of 3 degrees per second that were in the present study, although the gender results are reversed. The reason for this reversal is not clear. Morris et al. (1983) speculated that the generation of greater force by males may be due to the activation of a greater number of subcellular contractile elements, which could cause a longer time to maximal voluntary contraction. Certainly, the results of the present study do not lend support to this theory.

A comparison of electrical-mechanical response time and the rate of force development of the biceps brachii between males and females was studied by Bell and Jacobs (1986). They reported no significant difference between males and females when determining the time required to attain 50 percent of an isometric maximal contraction. The results of the present study may in fact support these findings when the limitations of isokinetic testing are taken into account. Although the present study found a significant difference between males and females at 50 percent of peak torque at isokinetic speeds of 3, 30, and 60 degrees per second it is interesting to note that an observation of torque/time curves (Figure 6) reveals a phenomenon that has been
Figure 6
TORQUE/TIME CURVE

TORQUE (FOOT POUNDS)

TIME (SECONDS)

\( \square \) FEMALE  \( + \) MALE
referred to as torque "overshoot" by Sapega, Nicholas, Sokolow, and Saraniti (1982). In their study it was identified that, when using an isokinetic device, the torque recorded during the period of greatest rate of torque development may be inflated due to the collision of the lever with the speed control mechanism at the point of set speed attainment and is indicated by an unexpected hump in the torque/time curve. As can be seen in Figure 6 the increase in torque development for males reflects this "overshoot" during the steep portion of the curve. To further examine this phenomenon the male and female data were normalized (Figure 7). Data were normalized by dividing the peak torque attained by the torque generated at each point in time. This produced values which are, in fact, percentages of peak torque attained. This process allows a more appropriate comparison of torque/time curves between men and women regardless of peak torque. It can be noted that if the "overshoot" in the male curve is eliminated by flattening the curve no difference would probably exist between time to 50 percent of peak torque for the male and female subjects, just as there are no differences for time to 70 percent and 75 percent of peak torque. The explanation for why male subjects produced an "overshoot" while female subjects did not is unclear. One possible explanation is that higher torques are required to produce an "overshoot". The significant difference between the males and females for the time required to achieve 50 percent of peak torque may not be due to physiological mechanisms but to mechanical limitation of the testing device.

In an investigation of rate of force development in the knee extensors Komi and Karlsson (1978) reported that the time necessary to
Figure 7
NORMALIZED TORQUE/TIME CURVE

% OF PEAK TORQUE

TIME (SECONDS)

□ FEMALE + MALE
extensors Komi and Karlsson (1978) reported that the time necessary to attain 70 percent of maximal isometric contractions was .376 seconds for males and was .748 seconds for females. Utilizing the grip flexors Kearney and Stull (1981) Ewing and Stull (1984) reported that the time for females to reach 70 percent of maximal peak force of the grip flexors was .121 seconds. The present study failed to find any significant difference when testing the right knee extensor muscles at 3, 30, and 60 degrees per second between the male and female subjects for time to 70 percent of peak torque. The discrepancy of the present results with those of Komi and Karlsson (1978) may be due to the differences in types of muscle contraction and/or the differences in the physical activity histories and the abilities to perform a maximal muscle contraction. Although no statistical analyses were carried out on the data of Kearney and Stull (1981) and Ewing and Stull (1984) it is noted that the females were 22 percent slower at achieving 70 percent of maximal isometric force of the hand-grip flexors. The difference between the results of these two studies and the present one may be due to the type of muscle group tested and/or the difference in the types of muscle contractions (isokinetic versus isometric).

No difference was evident between males and females when examining time to reach 75 percent of peak torque in the present study at the isokinetic speeds of 3, 30, and 60 degrees per second. This supports the study by Bell and Jacobs (1986) who utilized maximal isometric contractions of the biceps brachii and revealed no significant difference for time to 75 percent of peak force between males and females. In contrast Morris, Clarke, and Dainis (1983) observed that
times to 75 percent of maximal isometric force of the right knee extensor muscles were significantly faster for females than males.

In the present study it was revealed that the females were able to generate a significantly faster time to attain peak torque than males at an isokinetic speed of three degrees per second. While this supports the study of Morris, Clarke, and Dainis, (1983) it conflicts with Bell and Jacobs (1986) who found no significant difference in time to peak force between males and females. The differences in the results of the present study with those of Bell and Jacob's study (1986) could be due to the duration of the muscle contractions. In the present study it was revealed that no significant difference was found for time to peak torque between males and females when tested at isokinetic speeds of 30 and 60 degrees per second.
SUMMARY AND CONCLUSIONS

Summary

The purpose of this study was to determine if there was a significant difference between males and females when examining peak torque and the torque/time relationship of the right knee extensor muscles. More specifically, this investigation was designed to determine the differences between males and females for the time required to attain 50 percent, 70 percent, 75 percent, and 100 percent of peak torque isokinetically at velocities of 3, 30, and 60 degrees per second.

The subjects, 29 college-age males and 21 college-age females, completed two familiarization sessions and one testing session all conducted in a similar manner. Each session consisted of a submaximal warm up of riding a stationary bicycle for five minutes at a workload of 75 watts. Following the warm up the subjects were seated and secured on the Orthotron II bench and instructed to perform five submaximal isokinetic contractions to familiarize the individual to the speeds at which the subject was tested. The order of testing at the three speeds was randomly determined. Each subject was given a one minute rest following the submaximal contractions at the speed being tested. At speeds of 30 and 60 degrees per second each maximal bout was performed by generating two successive maximal contractions of the right knee extensor muscles. A 90 second rest was allowed between speeds. The
determination for peak torque at three degrees per second consisted of two, two second contractions of the right quadriceps muscle with the contractions separated by a 90 second rest. The maximal torque and the torque/time relationship were recorded utilizing the hardware interface developed by Isotechnologies, Inc. and were analyzed with an IBM Personal Computer using the Isoscan Software.

The statistical analyses included the calculations of descriptive statistics, analysis of variance with repeated measures across time and sex, and the P diff procedure for significant mean differences where needed. The results of the statistical analysis indicated that there was a significant difference between males and females for peak torques at 3, 30, and 60 degrees per second. It was found that the males generated 50 percent of peak torque significantly faster than the females. The time to 70 percent and 75 percent of peak torque was not significantly different between males and females. A significant difference existed between males and females for time to peak torque at three degrees per second, but no significant difference was found at the speeds of 30 and 60 degrees per second for time to 100 percent of peak torque.

Conclusions

Within the limitations of this study the following conclusions can be drawn regarding the isokinetic measurement of torque in college-age males and females.
1. Males generate significantly greater peak torques than females at the isokinetic testing speeds of 3, 30, and 60 degrees per second.

2. The time to 50 percent of peak torque at speeds of 3, 30, and 60 degrees per second is accomplished more quickly by males than by females, although this may possibly be due to a phenomenon known as "overshoot".

3. The time to 70 and 75 percent of peak torque is not significantly different between males and females at 3, 30, and 60 degrees per second.

4. Females generate time to 100 percent of peak torque more rapidly than males at a speed of three degrees per second, while at 30 and 60 degrees per second no significant differences between males and females exist.

Recommendations for Further Study

The present study found a significant difference for time to attain 50 percent of peak torque at 3, 30, and 60 degrees per second between males and females. It is hypothesized that this may not be due to physiological mechanisms, but a limitation of the isokinetic device. The phenomenon of "overshoot" was apparently present with the generation of peak torque among the male subjects who also were significantly stronger, but was not present among the female subjects. Therefore, additional research comparing college-age trained females with college-age sedentary females would be justified to see if the "overshoot" phenomenon would be demonstrated among the trained subjects.
BIBLIOGRAPHY


Amundson, M.A. Effects of Increasing Hamstring Flexibility on Peak Quadriceps Torque in College-age Females. Unpublished Master's Thesis, South Dakota State University, Brookings, SD.


APPENDICES
INFORMATION AND CONSENT FORM

THE EFFECTS OF GENDER ON ISOKINETIC PEAK TORQUE
AND TORQUE/TIME RELATIONSHIP

You are asked to participate in a study which will be conducted in the Human Rehabilitation Lab of the Department of HPER. The purpose of this study is to investigate the differences of peak torques and rate of torque development at three isokinetic speeds (3, 30, and 60 degrees per second) by comparing sexes.

If you choose to be involved in this study you will be asked to report to the laboratory three times over a two week period. The sessions in the lab consist of two days of familiarization of the procedures and equipment to be used and one day of actual data collection. Each session will last approximately fifteen minutes and there will be at least a 48 hour period between testing sessions.

The sessions will involve the testing of the right knee extensor muscles. You will be instructed to sit on the Orthotron II bench, where you will be securely positioned by placement of a strap around the waist and right thigh. There will be a padded lever arm attached to the lower leg just above the malleoli. Following five submaximal warm-up leg extensions your maximal voluntary strength will be measured by having you exert two successive maximal isokinetic contractions of the right knee extensor muscles. Following this, you will be instructed to get up from the bench and wait until the next speed has been set and calibrated. You will than be instructed as previously. At the speed of
three degrees per second the warm-up will consist of two submaximal contraction, while the test you will exert a maximal effort for a period of one second.

There are minimal risks involved in this type of strength for healthy males and females. There is a remote possibility of muscle strain, pulling, or cramps of the leg being tested. Although we do not anticipate anyone developing any injuries while performing in this investigation, the Human Rehabilitation Lab has standard procedure for dealing with this type of injury. The college of Physical Education, Health, and Recreation doesn't provide any financial reimbursement in order to cover the medical costs related to injuries. In the event that this research design results in physical injury, payment for treatment must be provided by you or your third payer (e.g. health insurance, medicare).

You may also receive some benefits from the investigation. During the testing sessions you will see your peak torques at various isokinetic speeds. Results will be made available to you so that you may compare your efforts with that of the other participates involved in the study, without reference to name.

The experimenter will be at access to answer any questions that you may have regarding testing procedures. Your name will not be used in any way in the reports of the study. All data will be reported by a code form that is known only by the experimenter. Your permission to perform this isokinetic exercise is voluntary. You are free to deny consent any time during the study without prejudice.
three degrees per second the warm-up will consist of two submaximal contraction, while the test you will exert a maximal effort for a period of one second.

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The experimenter will be at access to answer any questions that you may have regarding testing procedures. Your name will not be used in any way in the reports of the study. All data will be reported by a code form that is known only by the experimenter. Your permission to perform this isokinetic exercise is voluntary. You are free to deny consent any time during the study without prejudice.
I ___________________________ have read the above description of this research project entitled "Peak Torques and Rate of Torque Development in Relation to Sexes" and I understand the procedures entailed in this investigation. I also understand the remote possible risks involved in performing these isokinetic exercise procedures and the possible benefits to being a volunteer in this investigation. An offer to answer any questions concerning the procedures of testing has been made, and I understand that my name and all the information regarding my results will be in the strictest of confidence. I have been informed that I may withdraw from this study at any time if I so desire without prejudice. I have been informed that if I have any further questions I should contact Bryan Minnich at the HPER center or call him at 688-5725.

__________________________  __________________________
Signature                        Date

__________________________  __________________________
Signature                        Date