ABSTRACT

KLUCKHOHN, J. C. Isokinetic evaluation of the knee flexors and extensors of male and female sprinters and distance runners. MS in Exercise and Sport Science - Human Performance, August 1997, 55pp. (M. Miller)

Peak torque/body weight (PT/BW) of the knee flexor (KF) and knee extensor (KE) muscles and KF/KE strength ratios in male and female control, distance, and sprint groups were studied. A total of 48 Ss performed leg extension and flexion using the Biodex Inc. isokinetic dynamometer at 60, 180, and 300 degrees/second (deg/sec) on both legs. Distance and sprint groups came from the University of Wisconsin-La Crosse track teams, while control subjects came from the student population. Significance ($p < .05$) was identified between groups and speeds on the PT/BW data using a 2-way ANOVA with repeated measures. A Fisher's LSD post-hoc test found the male sprint group significantly different than all female groups, except for the female sprint group at the left KF muscles. Male distance runners were significantly ($p < .05$) different than the female distance group in the left and right KF muscles. Speeds were significantly ($p < .05$) different at 60 deg/sec from 180 deg/sec, and 300 deg/sec for left and right KE and right KF muscles and significantly ($p < .05$) different between all speeds for the left KF muscles. Significance ($p < .05$) existed between speeds using a 2-way ANOVA with repeated measures on KF/KE data. A Fisher's post-hoc test revealed that 60 deg/sec was significantly different than 180 deg/sec and 300 deg/sec for both right and left KF/KE ratios.

ISOKINETIC EVALUATION OF THE KNEE FLEXORS AND EXTENSORS OF MALE AND FEMALE SPRINTERS AND DISTANCE RUNNERS

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CHAPTER I

INTRODUCTION

Background

The use of isokinetics in the assessment of muscular strength, development of strength, and the rehabilitation of injured limbs has become popular in the past 15 years. Introduced first by Hislop and Perrine (1967), isokinetics has become the preferred method used in musculoskeletal assessment and rehabilitation. The advantages of using isokinetics include: quantification of torque, work, and power, isolation of weak muscle groups, accommodating resistance providing maximal resistance throughout the exercised range of motion, and inherent safety mechanisms. In addition the reliability of isokinetic testing has been established by Johnson and Siegel (1978) and Montgomery, Douglass, and Deuster (1989) using the Cybex and Biodex equipment respectively. The disadvantages are that reliable assessment is limited to isolated muscle groups through the cardinal planes of motion, exercise occurs primarily from nonweight bearing open-kinetic-chain positions, and the high cost of the equipment is prohibitive for some settings (Perrin, 1993).

Throughout the literature pertaining to isokinetic strength, the knee joint is the most commonly tested and studied joint using isokinetic equipment. Normative data has been accumulated by numerous researchers (Davies, Kirkendall, Leigh, Lui, Reinbold, & Wilson, 1981; Holmes & Alderink, 1984; Rankin & Thompson, 1983; Wyatt & Edwards,

(1981) for both athletic and nonathletic populations. Among the athletic population, athletes from football, basketball, soccer, skiing, and track and field are perhaps the most often studied. Within the sport of track, few researchers have focused on the differences between sprinters and distance runners and how they differ from the normal population. Alexander (1990) Campbell (1979) and Morris, Lussier, Bell, and Dooley (1983) were the only researchers who specifically investigated sprinters and distance runners. Several authors (Fry & Powell, 1987; Gleim, Nicholas, & Webb, 1978; Grace, Sweetser, Nelson, Ydens, & Skipper, 1984; Johansson, 1992; Nicholas, Strizak, & Veras, 1976; O'Toole, 1992; Prietto & Caiozzo, 1989; Singer, 1986) have speculated that muscular strength imbalances are the etiology of many injuries seen among athletes, including sprinters and distance runners. Kendall, McCreary, and Provance (1983) stated "Muscle imbalances result from occupational and recreational activities in which there is persistent use of certain muscles without adequate exercise of opposing muscles" (p. 5). This describes what sprinters and distance runners undergo during their training and competition in a typical track season. Therefore, it is reasonable to assume that muscle imbalances could develop in these athletes. Several researchers have suggested that strength training could be beneficial in correcting these strength imbalances (Getmanets & Travin, 1987; Suslov, 1994; Symons, 1989). Knowing that a strength imbalance exists could assist the coach, athlete, and medical staff in correcting and preventing training injuries.

Purpose of the Study

The purpose of this study was to identify and compare the peak torque relative to body weight, strength ratios of the ipsilateral knee flexor (KF) and knee extensor (KE) muscle groups, and the influence of testing speed on peak torque and the ipsilateral strength ratios of male and female runners. By identifying these factors it can be established if there is a significant difference in the peak torque and ipsilateral strength ratios of the KF and KE muscles among the test groups. In addition, comparisons to other strength data will be provided. These data could be used as a guide in determining whether or not strength training is warranted for specific groups to correct any deficiencies or imbalances. Information obtained from this study will be provided to the subjects upon request in an effort to maximize their opportunity to perform at the highest level.

Need for the Study

The need for this study is based on the fact that little attention has been directed at sprinters and distance runners when discussing the proper strength of the KF and KE muscles. According to Johansson (1992), "Different techniques recruit not only different fiber types within the muscles, but also involve changes in predominance between different muscle groups" (p. 78). This information shows that sprinters and distance runners may develop different peak torque and strength ratios. Knowledge of these results between sprinters and distance runners may result in benefits to prevent injuries. This information can benefit the participants of this study by identifying muscular weaknesses or imbalances. Several authors (Fry & Powell, 1987; Nicholas, et al., 1976; O'Toole, 1992; Rolf, 1995; Singer, 1986) have stated that muscular strength imbalances may contribute to injuries in runners and that strengthening exercises could help prevent these. According to O'Toole (1992) "functional abnormalities such as muscle imbalance around a joint, inadequate strength, or inadequate range of motion are more important risk factors" (p. s360). The knee joint in runners is the most commonly injured portion of the lower extremity, with a majority of these injuries involving overuse of the knee extensors. Some of the other commonly injured areas are the pelvis, hip, back, leg, ankle, and foot. There has been no proof which shows that muscular imbalances occur as a result of training; however, little attention has been directed to this area.

Hypotheses

This study had the following hypotheses:

1. There will be a significant difference ($p < .05$) between the relative strength of the KF or KE muscle groups between the control, distance, or sprint groups.
2. There will be a significant difference ($p < .05$) in the relative strength of the KF and KE muscle groups between all testing speeds.
3. There will be a significant difference ($p < .05$) between the ipsilateral KF/KE strength ratios between the control, distance, or sprint groups.
4. There will be a significant ($p < .05$) increase in the ipsilateral KF/KE strength ratio with each increase in testing speed for the control, distance, and sprint groups.

Assumptions

This study had the following assumptions:

1. Subjects were free of any lower extremity injuries which would limit their production of force while performing knee extension and flexion.

2. All subjects understood and followed instructions given to them before and during the testing procedure.
3. The movements used can evaluate muscle strength in the knee flexor and knee extensor muscle groups.
4. The Biodex testing equipment was accurately calibrated prior to each testing session.
5. The subjects gave a maximal effort for each of the five repetitions performed at each of the three testing speeds.

Delimitations

This study had the following delimitations:

1. The test subjects for the sprinters and distance runners were limited to those who volunteered for the study from the University of Wisconsin-La Crosse Men's and Women's intercollegiate track teams.
2. The control subjects were between the ages of 18 to 25 years of age and were recruited from the student body of the University of Wisconsin-La Crosse and voluntarily participated in this study.
3. The test speeds for this study were delimited to 60, 180, and 300 deg/sec.
4. The study was delimited to subjects who had no acute injury in the lower extremity.
5. The sample size was delimited to 8 males and 8 females for each sprint, distance, and control group.

6. The order of testing was delimited to proceed from 60 deg/sec to 180 deg/sec and conclude at 300 deg/sec.
7. Stabilization straps on the thigh, waist, and chest were used to prevent any increased leverage which could be gained from movement of the upper body.
8. Subjects were tested in a slightly reclined, seated position created by the backrest adjustment positioned at marker number two.

Limitations

This study had the following limitations:

1. The activities of the subjects outside of this study were not controlled.
2. Control subjects were selected from volunteers who routinely participated in running or jogging recreationally 2-4 times per week.
3. It was assumed that the researcher was competent with regards to operation of the Biodex testing equipment.
4. The motivation level of the subjects was limited to asking for maximal efforts prior to each set of five repetitions at each testing speed.

Definition of Terms

Distance Runner - an athlete who trains and competes in track and field events of 1500 meters or greater.

Isokinetic Exercise - a method of strength training or testing in which the speed of segmental rotation is kept constant throughout the range of muscular contraction (Kreighbaum & Barthels, 1985).

KE/BW - a ratio produced by the amount of torque generated by the knee extensor muscles during knee extension relative to the body weight of the subject.

KF/BW - a ratio produced by the amount of torque generated by the knee flexor muscles during knee flexion relative to the weight of the subject.

KF/KE - a ratio produced by the amount of torque generated by the knee flexor muscles during knee flexion relative to the amount of torque generated by the knee extensor muscles during knee extension.

Knee Extensors (KE) - those muscles which primarily contribute to the extension of the knee. This muscle group is commonly called the quadriceps muscle group and consists of the rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis muscles.

Knee Flexors (KF) - those muscles which primarily contribute to the flexion of the knee. This muscle group is commonly called the hamstring muscle group and consists of the biceps femoris, semitendinosus, and semimembranosus muscles.

Length-Tension Relationship - states that the contractile tension the muscle is able to produce increases with the length of the muscle and is maximum when the muscle is at its resting length (Kreighbaum & Barthels, 1985).

Muscle Balance - a condition where the agonist and antagonistic muscle groups contain enough strength to move a body part and stabilize the joint sufficiently to avoid injury under sport specific conditions.

Muscle Strength - the ability to produce or resist a force.

Overshoot Phenomenon - deceleration of the overspeeding limb and lever arm producing a transient peak, or spike, in the isokinetic torque curve (Perrin, 1993).

Peak Torque - the maximal amount of force produced about a joints axis (Perrin, 1993).

Sprinter - an athlete who trains and competes in track and field in events of 400 meters or less.

Torque - the amount of force that can be produced throughout the range of motion (Reed, 1995).

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Since the of the concept of isokinetic exercise was introduced by James Perrine in 1967, isokinetic exercise has been used to evaluate the strength of various muscle groups. Prior to the development of isokinetics, isotonic and isometric exercise were the sole methods used to test muscular strength. The knee joint is perhaps the most widely studied joint of the human body. Very few of these studies have compared the differences in the musculature surrounding the knee in the distance runner and sprinter. Review of pertinent literature must consider factors affecting the reliability and validity of isokinetic testing, criteria measured by the study, various testing components, and gender differences related to isokinetic testing.

Reliability and Validity of Isokinetic Testing

The reliability of testing the knee musculature using isokinetic equipment has been adequately established in the literature (Perrin, 1993). Johnson and Siegel (1978) reported reliability coefficient of R = .93-.99 using the Cybex dynamometer to test for peak torque during knee extension of nondisabled women. These results were confirmed by Montgomery, Douglass and Deuster (1989) while testing 9 nondisabled men and 11 women in a seated position with speeds varying from 90 to 330 deg/sec. Reliability coefficients (R = .86-.92) increased as the speed of testing increased on Biodex equipment. Montgomery and colleagues (1989) also noted that reliability was greater for the KE compared to the KF muscle groups. Some of the variables influencing reliability and validity of isokinetic testing are functional performance, order of testing speeds, stabilization of the subject, calibration of the equipment, and the testing protocols (Reed, 1995).

The most important factor in determining the functional performance of testing the KF and KE is the speed at which the joint normally functions. The limitation of isokinetic testing is that many activities in sport cannot be tested at speeds commonly found while performing the movement. These speeds often exceed the speed which can be tested by the equipment. As stated by Wilk (1991), "Several estimates of functional speeds have been identified for the knee: walking - 233 deg/sec, running - 1,200 deg/sec, and punting - 2,865 deg/sec" (p. 74) (Reed, 1995). According to Johansson (1992) the estimated optimal angular velocity to test for knee extensor mean power output in sprinters is approximately 450 deg/sec while in marathoners 270 deg/sec is optimal. When the speed of the movement exceeds the limitations of the isokinetic equipment, currently between 1 - 480 deg/sec, other factors must be considered when selecting testing speeds. Other factors to consider in selecting testing speeds include the ability to compare the selected speeds to relevant literature and the degree of difference between several selected speeds.

The experience and preparation of the subjects must also be controlled to insure adequate reliability of testing. This is controlled by the use of practice sessions and adequate warm-up. Wilhite, Cohen, and Wilhite (1992) found that reliability is diminished when the subjects did not receive adequate warm-up. In general, Perrin (1993) stated that a warm-up consisting of three submaximal and three maximal repetitions are adequate to obtain peak torque, work, and power. Wilhite, et al. (1992) stated, "Normal persons being tested on different speeds should experience slower speeds prior to being tested at the higher speeds" (p. 182). This allows the subject to adapt more easily to the faster testing speeds.

Stabilization of the testing subject is another variable that has been questioned in reference to the reliability of torque output. Magnusson, Geismar, Gleim, and Nicholas (1993), tested four different stabilization methods with varying degrees of stabilization of the back and hands at 60 deg/sec. Results showed that the greatest amount of torque was produced when the back, thigh, and pelvis were stabilized with straps and the hands were grasping underneath the seat. Perrin (1993), however stated that the classic seated knee test position entailed stabilization around thigh, waist, and chest with the arms folded across the chest. The arms should be folded across the chest and the feet should be nonweight bearing if the purpose of the test is to isolate a target muscle group and eliminate the contribution of accessory muscle groups. According to Nosse (1982), who reviewed 50 reports pertaining to KF and KE muscular strength, "Without adequate stabilization to maintain axis alignment, force generation could have been dependent upon the subject's ability to move to maximize their effort, rather than the force generated having been related to specified conditions that could be duplicated" (p. 82). Consistency in the stabilization procedures as well as the calibration of the equipment and strict enforcement of the testing protocol must be used to produce valid and reliable results.

Until recently all isokinetic testing has been performed as an "open-kinetic-chain" (OKC) exercise (Perrin, 1993). This type of exercise is one in which the foot is not in a fixed position such as would occur when the athlete's foot is in contact with the ground. The validity of OKC testing involving the lower extremity has recently been questioned by Suslov (1994) due to the fact that it prevents the popliteus to initiate knee flexion and the gastrocnemius to assist in knee flexion. In recent years the use of "closed-kinetic-chain" (CKC) exercise assessment using the isokinetic dynamometer has been applied to the rehabilitation setting. This type of exercise is one in which the foot is in a fixed position against a stable object. These CKC exercises are said to be more related to the activities that are performed in the athletic world and are replacing OKC assessment in rehabilitative settings. The preference toward using OKC testing procedures may occur for three reasons. First the cost and subsequent availability of CKC testing equipment has limited the use of this type of testing. Also most researchers have little familiarity with these testing procedures and equipment and therefore, testers have little expertise in this area. Finally these CKC equipment have no proven reliability which limits their use in research studies. The area of CKC isokinetic strength testing is an opportune area for future research.

Criteria Measured

The criteria used to assess the strength and muscular balance of the KF and KE muscles varies within the literature. Some of the measures used are peak torque, mean torque, mean power, endurance, strength relative to body weight, and KF/KE or hamstring/quadriceps ratio. Peak torque is the maximal amount of force measured through the testing range of motion over several repetitions while mean torque is the average torque produced at every angle through the full range of motion of the joint. Mean power is recorded as the average power produced over several repetitions through the joint's range of motion. Another common criteria measured for aerobic activities is endurance. This is tested with a greater number of repetitions and measures the ability to maintain strength over time. Relative strength is another common criteria used to evaluate muscular strength. This measure expresses the strength of a muscle group relative to the subject's own body weight using the peak torque produced. Finally strength ratios, such as KF/KE, are used to express strength of one muscle group relative to another, typically the antagonistic muscle group.

One parameter that is most commonly measured is peak torque since it is the easiest criteria to measure. Wyatt and Edwards (1981) reported the peak torque of 50 males and females at 60, 180, and 300 deg/sec. The mean peak torque value for the males was 135 foot pounds (ft lbs) and 79 ft lbs for the females at 60 deg/sec and 66 ft lbs and 38 ft lbs at 300 deg/sec for the quadriceps muscle group. The peak torque recorded for the hamstring muscle group was 96 and 56 ft lbs for the males and females respectively at 60 deg/sec and 54 and 32 ft lbs at 300 deg/sec. The peak torque for both the quadriceps and hamstring muscle groups significantly decreased as the velocities increased. Appen and Duncan (1986) reported the peak torque of the knee joint of 10 male sprinters and distance runners at 60, 180, 240, and 300 deg/sec. The reported nongravity corrected torque values for the quadriceps of 149 ft lbs at 60 deg/sec were very similar to those reported by Wyatt and Edwards (1981) at 135 ft lbs. Gravity corrected values from Appen and Duncan (1986) were higher for the quadriceps muscles and lower for the hamstring group which is expected when comparing gravity corrected and nongravity corrected values.

Mean peak torque has been used by researchers and is considered to be a valuable criterion. Levine, Klein, and Morrissey (1991) stated that "two advantages of this variable (average torque) are its control of joint positions and muscle lengths, and its measurement of torque production throughout the range of motion (ROM) versus torque production at a particular angle" (p. 126). Statements by both Levine et al. (1991) and Perrin (1993) suggest that there are no significant differences between the use of peak torque and average peak torque. Other researchers (Aagaard, Simonsen, Trolle, Bangsbo, & Klausen, 1995; Prietto & Caiozzo, 1989) disagree with this method and prefer to use an angle specific method that measures the maximal torque at each degree along a specified range of motion. The interest in using this method is based on identifying a peak torque measurement at certain important points in the range of motion which relate to the joint function.

Peak torque measurements have been reported in numerous sports without correction for gravity. Primarily this practice was done previous to the mid 1980's before equipment was made available to accurately measure the effects of gravity. Appen and Duncan (1986) concluded that "When gravitational forces are neglected there is an overestimation of active flexor muscle torque and an underestimation of active extensor muscle torque" (p. 234). Berg, Blanke, and Miller (1985) reported the peak torque of the dominant leg extension and flexion of female college basketball players at 60 deg/sec at

121.8 and 76.2 ft lbs, respectively. In a study of college baseball pitchers, Tippett (1986) reported peak torque extension and flexion values of 194 and 123 ft lbs, respectively at 60 deg/sec. Stafford and Granna (1984) studied 60 college football players using speeds of 90, 180, and 300 deg/sec. These researchers reported peak torque values at 180 deg/sec for knee extension and flexion at 122.1 and 88.2 Nm, respectively.

Several researchers (Alexander, 1990; Campbell, 1979; Morris, et al., 1983) have reported peak torque specifically in distance runners and sprinters. Campbell (1979) compared the peak torque of sprinters and distance runners at 60 and 210 deg/sec. His reported peak torque values for knee extension in sprinters and distance runners was 143.6 and 109.1 ft lbs at 60 deg/sec and 76.4 and 49.9 ft lbs at 210 deg/sec. The reported knee flexion values for peak torque were 81.5 and 60.5 ft lbs at 60 deg/sec and 55.9 and 34.5 ft lbs at 210 deg/sec. In a study of 12 male middle distance runners from the Big Ten Conference, Morris et al. (1983) tested the athletes at 30, 60, 180, 240, and 300 deg/sec. Torque values at 60 deg/sec were the highest recorded. The peak torque values for KF ranged from 87.0-51.4 ft lbs while the KE values ranged from 139.2-59.3 ft lbs. Morris et al. stated that the force-velocity curves obtained were similar to those from Wyatt and Edwards (1981). Alexander (1990) studied elite male and female sprinters and reported extension values of 196.9 and 126.1 ft lbs at 30 deg/sec and 156.4 and 93.7 ft lbs at 230 deg/sec for males and females. His reported peak torque values for flexion were 124.6 and 81.9 ft lbs at 30 deg/sec and 122.4 and 80.0 ft lbs at 230 deg/sec. These values are much greater than those from Morris et al. (1983) and may result from the greater mass of the subjects in Alexander's study or because of the different training methods used by sprinters versus distance runners.

Other measured parameters reported in the literature are endurance and average power. Endurance of the KF and KE muscle groups has been minimally investigated. Wilkerson, Martin, and Sparks (1980) studied elite marathon runners and reported an average endurance ratio of the quadriceps muscles at 90% using a 40 second test. Meaning that these elite marathon runners could produce up to 90% of their maximal torque output after 40 seconds of work performing knee extension and flexion using isokinetic equipment. DeNucio, Davies, and Rowinski (1991) used a standard fatigue protocol of 40 repetitions through a range of motion of 75 degrees to test for muscular endurance of the KF and KE. They found significant torque fatigue developed in both eccentric and concentric exercises. Average power was also investigated by Wilkerson et al. (1980) who reported that average power increased exponentially as velocities increased in both KF and KE. KE produced significantly greater power than KF at speeds below 60 deg/sec, while at speeds greater than 120 deg/sec the opposite was true.

The strength ratio of the KF/KE muscles has been reported most often in the literature. It has been commonly reported that this ratio should be approximately 60% in all athletes, however, scientific proof of this ratio is unfounded. This value seems to be derived from Klein and Allman (1969) who suggested that male high school seniors maintain a ratio of 1:2 while college football players maintain a 6:10. Many researchers (Holmes & Alderink, 1984; Morris et al., 1983; Nosse, 1982; Rankin & Thompson, 1983) have reported this ratio is not fixed and changes to approximately 1:1 because the strength of the KE muscles decreases more than the KF muscles as the testing speed increases to 300 deg/sec. In an attempt to establish normative data concerning different sports, Rankin and Thompson (1983) reported track distance runners had KF/KE ratios of 64% at 60 deg/sec and 88% at 300 deg/sec. The mean KF/KE ratio for all incoming athletes in different sports was reported to be 83, 73, and 63% for 300, 180, and 60 deg/sec, respectively. This closely corresponds to Morris et al. (1983) who reported ratios of 62% at slower speeds and 87% at faster speeds. These data follow the trend presented by others that the KF/KE is not fixed and increases as the testing speed increases. According to Suslov (1994), Russian experts have found that jumpers and weightlifters have a ratio nearer 80%, therefore, it may be assumed that different activities could produce altered strength ratios.

Sometimes the strength of the KE and KF muscles are compared relative to the subject's body weight. It has been established that size and height of the subject are closely related to strength therefore, it only makes sense that comparing the strength from a 120 pound wrestler to that of a 250 pound lineman should be done while using a relative measure (Bishop, 1983). Rankin and Thompson (1983) attempted to establish normative strength values from their preseason screening of all athletes at Michigan State University. Their data suggest that quadriceps/body weight (Q/BW) and hamstring/body weight (H/BW) ratios are more reliable than the hamstring/quadriceps (H/Q) ratio. Little differences were found between athletes while comparing the H/Q ratio while significant differences were found between athletes with Q/BW and H/BW. Other researchers (Alexander, 1990; Holmes, & Alderink, 1984; Yamamoto, 1993) have used strength values relative to body weight using peak torque to pounds of body weight, mean peak torque per kilogram of body weight, and strength per kilogram of body weight measured with the use of a strain gauge.

Testing Components

There are several factors that must be controlled to establish meaningful results such as body position, stabilization, testing speed, number of repetitions performed, gravity correction, damping, and equipment calibration. The importance of accurately establishing the same body position for each test subject is related to the length-tension relationship. As the body position changes, so does the length-tension relationships of the KF and KE. Extension of the knee is accomplished by a combination of the rectus femoris, vastus medialis, vastus intermedius, and vastus lateralis muscles. The rectus femoris is a two-joint muscle crossing both the hip and knee joints. Its dominance in extension of the knee joint can be enhanced by extension of the hip joint (Worrell, Perrin, & Denegar, 1989). The knee flexion produced by the hamstring muscle group consisting of the biceps femoris, semitendinosus, and semimembranosus is also affected by the position of the hip because of the two-joint nature of all these muscles with the exception of the short head of the biceps femoris (Worrell et al., 1989). Both the supine and prone body positions are more closely related to the position of the body while running (Worrell, Denegar, Armstrong, & Perrin, 1990). Few studies have used these two positions to evaluate the KF and KE muscle groups.

A wide range of speeds have been used to test the KF and KE, including 30, 50, 60, 90, 120, 150, 180, 200, 230, 240, 270, 300, 330, 360, 400, and 450 deg/sec (Perrin, 1993). Variations in the speed of isokinetic testing have a direct influence on the results obtained. Many researchers have stated that the strength of the KF and KE decreases as the speed of testing increases (Aagaard et al., 1995; Knapik & Ramos, 1980; Morris, et al., 1983). While the strength of both the KF and KE diminishes as the testing speed increases, the KF strength diminishes less, resulting in the KF/KE ratio migrating toward 1:1 as speeds approach 300 deg/sec. In a study comparing sprinters and distance runners, Appen and Duncan (1986) concluded that there was not a significant difference in the H/Q ratio except at 300 deg/sec.

The number of repetitions performed is another important factor to establish in the testing procedure. Throughout the literature there are varying numbers of repetitions used to obtain peak torque, mean power, and endurance. Perrin (1993) suggested the use of three to four repetitions to obtain peak torque measurements while Baltzopoulos and Brodie (1989) stated that typically two to six contractions are used. When endurance is measured, the number of contractions are typically much greater. DeNucio, Davies, and Rowinski (1991) used a "standard fatigue protocol" having subjects perform 40 repetitions at 180 deg/sec to establish endurance.

Many of the early studies using isokinetic testing did not account for the effects of gravity when testing different muscle groups. Nelson and Duncan (1983) measured the maximal torque values produced by knee extension and flexion using the Cybex II isokinetic dynamorneter and found these to be altered by the effect of gravity. The authors stated, "Gravity significantly affects the recordings, resulting in an overestimation of active flexor muscle torque and an underestimation of active extensor muscle torque" (p. 674). Their results showed that a failure to account for the effects of gravity could cause a 4% error in the knee extensors and a 15% error in the knee flexors. Appen and Duncan (1986) stated, "In both sprinters and endurance runners, there is less variability of the gravity-corrected hamstrings to quadriceps r [illegible] ver the isokinetic velocities" (p. 234). Recently Aagaard et al. (1995) concluded that a gravity corrected H/Q ratio remained constant across testing speeds of 30, 120, and 240 deg/sec while noncorrected H/Q ratio increased during concentric contraction over the same speeds. It is therefore important that gravity correction be used in all studies concerning isokinetic testing.

The use of isokinetic dynamometers for testing muscular strength often produces an "overshoot phenomenon". This is observed by a spiked torque level on the strip chart and is caused by the deceleration of the moving limb and resistance lever (Perrin, 1993). This spike can confound interpretation of the muscle's true capacity to produce force and is corrected by the use of damping, ramping, or preloading. The greater the amount of force being produced by the tested muscles, the greater the amount of damping needed. It is important to understand that damping causes a shift in the torque curve relative to the range of motion and therefore the level of damping must be recorded.

Gender Differences

Recent studies (Berg, et al., 1985; Hedgepeth, 1987; Rankin & Thompson, 1983; Wyatt & Edwards, 1981) regarding muscular strength of the KF and KE have compared males to females. Before these studies were completed, little data had been collected on female subjects due to females having less access to college and universities where research studies are often performed. Hence, studying the differences between men and women was difficult. Within the past 20 years, a large amount of data has been collected on women and a clearer trend of the gender differences has emerged. It has long been recognized that men are generally bigger, stronger, and faster than women. Bishop (1983) studied the biological determinants of the gender difference in muscular strength. The main factor shown to affect the differences in strength was due to the difference in body size, mainly muscle. It was found that if direct strength measures were used, which accounted only for the lean muscle mass, then the differences in strength were much less. This is due to the fact that only lean muscle mass accounts for force production and women commonly have a higher percentage of body weight stored as adipose tissue.

Other factors relating to gender differences in muscular strength were level of activity, type of normal activity, and neuromuscular differences (Bishop, 1983). It was shown that if men and women were compared with similar activity levels and types of activities normally performed, the differences in strength decreased slightly. The other factor investigated was a possible neuromuscular advantage associated with men. No evidence was collected to establish that men had any neuromuscular advantage over women. In general women generate approximately two-thirds the strength of men (Bishop, 1983). This difference is greater in the upper body and less in the legs. The decreased difference in strength associated with the legs of women is traced to the fact that women have a greater percentage of muscle in their legs relative to total fat-free weight (Bishop, 1983). In all the studies found relating to KF and KE, peak torque was significantly greater in men than women (Berg et al. 1985; Hedgepeth, 1987; Rankin & Thompson, 1983; Wyatt & Edwards, 1981).

Summary

The review of pertinent literature regarding strength testing of the knee musculature of male and female runners includes a great deal of information. The most important factors involved are reliability and validity of isokinetic testing, criteria measured by the testing, testing components, and gender differences. Within this review of literature very little attention was focused on specifically distance runners and sprinters. Hopefully the attention given to this subject by this study will give a better understanding of the strength differences among these groups of runners.

CHAPTER III

METHODS

Introduction

The purpose of this study was to identify and compare the peak torque relative to the subjects' body weight, strength ratios of the ipsilateral KF and KE muscle groups, and the influence of testing speed on peak torque and the ipsilateral strength ratios of male and female runners. The subject population, excluding the control group, was selected from the University of Wisconsin-La Crosse Track and Field team based on their willingness to volunteer for the study. These athletes were highly competitive members of an NCAA Division III intercollegiate athletic program. These athletes were appropriate subjects for this study because of the high volume of training required to maintain competitiveness at this level.

The testing speeds utilized in this study were selected based on the high number of occurrences that these speeds were observed in the literature, therefore, results from this study can be easily compared to others. The second factor used in selecting these testing speeds was the equal separation between the three testing speeds. Each testing speed was separated by 120 deg/sec, hence, it could be observed if the differences in strength values between testing speeds followed a pattern.

Subjects

The subjects for this study were divided into three male and three female groups consisting of a control, distance, and sprint group. Each group consisted of eight subjects, excluding the male distance runners and sprinters which consisted of nine and seven subjects respectively, for a total of 48. Group size varied because of athlete interest and availability to participate in the study. Each of the control groups consisted of eight volunteers who were students at the UW-L. All study participants in the sprint and distance running groups were members of the UW-L Track and Field teams.

Table 1. Subject Characteristics for Age, Height, and Weight.

Groups	Age (years)	Height (inches)	Weight (lbs)
Male Control n = 8	22.3	70.0	159.0
Male Distance n = 9	21.0	71.0	151.0
Male Sprint n = 7	19.7	70.6	168.4
Female Control n = 8	21.9	64.8	136.1
Female Distance n = 8	20.1	65.4	122.1
Female Sprint n = 8	19.5	66.1	128.8
Group Averages	20.8	68.0	144.2

Testing was carried out in the Athletic Training room in Mitchell Hall at UW-L. Informed consent forms (see Appendix A) and subject data forms (see Appendix B) were completed prior to testing. If subjects were unable to perform maximal contractions, they were disqualified from the study.

Practice and Warm-up

Several researchers have stated the importance of allowing proper practice when performing isokinetic testing to maintain reliability (Axtell, 1984; Brennan, 1983; Perrin, 1993). Each subject was required to participate in one practice session on the Biodex isokinetic dynamometer (Biodex Corporation). This practice session was setup between 6 p.m. and 10 p.m. on weekday evenings, when both the researcher and subject were available. This provided the opportunity for any questions to be answered by the researcher. To begin the practice session, subjects were read the informed consent form and then were instructed to read the form themselves followed by signing and dating the form if they understood and agreed with the statements. The sessions consisted of a 5 minute warm-up on a stationary bike followed by hamstring and quadriceps stretching. Any additional questions were answered regarding the study. A minimum of 10 repetitions were completed with each leg at each of the three testing speeds of 60, 180, and 300 deg/sec. The first three of the 10 repetitions were to be performed at approximately 50% effort followed by 5 repetitions at approximately 100% of perceived effort, with two easy repetitions to finish the set.

Equipment and Setup

The Biodex isokinetic dynamometer was utilized for testing differences in peak torque with knee flexion and extension and peak torque/body weight. The system was calibrated prior to each testing session according to the Biodex Application Manual

(1987). The appropriate knee fixture was secured to the shaft with a locking knob and the balance was adjusted according to the manual. The subject was seated to bring the axis of the knee to the same vertical and horizontal plane as the powerhead shaft. The seat position was adjusted forward or backward depending on the length of the femur. The fixture was securely fixed to the limb with the shin strap so that the calf pad was placed proximal to the malleoli and below the prominent calf musculature. The range of motion limits were set by taking the knee to full extension and flexion and assuring proper positioning and subject comfort. Finally, the subject was stabilized with the use of thigh, pelvic, and shoulder straps and was instructed to position the arms across the chest with hands on opposite shoulders. Testing then commenced.

Testing Procedure

Prior to the actual testing session, the Biodex equipment was calibrated according to the application manual. The test protocol was explained to each subject as he/she performed a 5 minute warm-up on a stationary bike and performed hamstring and quadriceps stretching. Subjects practiced on the equipment at each testing speed, with a minimum of ten repetitions at each speed prior to the actual testing session. The subject was encouraged to ask questions about the study and each question was answered to the best of the researcher's ability. The importance of maximal exertion was explained and stressed at this time. The subject was properly positioned for testing of the right knee and stabilized on the equipment with shoulder, waist, thigh, and leg straps. Correction for the effects of gravity were performed by having the subject extend the right leg as far as possible and then a stop button was depressed which allowed the equipment to measure the weight of the leg. The subject was instructed to relax and not move while the reading was made and accepted by the computer.

For the test, the subject was instructed to perform three submaximal efforts, followed by a brief rest period, then three efforts of extension and flexion of the right knee at approximately 95% of perceived effort. This protocol was followed to allow the computer to calibrate as to the general strength of the subject. Following calibration, the subject was instructed to perform five efforts of knee extension and knee flexion as hard and as fast as possible on the command of "go". The subject was than given 45 seconds of rest while the tester adjusted the Biodex equipment for 180 deg/sec. The tester monitored the subject for comfort and well being until the rest period was complete. The same procedures used at 60 deg/sec were followed for testing knee extension and flexion at 180 and 300 deg/sec. At the completion of testing at 300 deg/sec, the subject was removed from all straps and asked to stretch the left leg again. Once the subject felt ready to begin (approximately 3-4 minutes), the left leg was positioned on the Biodex equipment to complete the same testing that was done on the right leg.

Statistical Analyses

Data were analyzed using the SPSS 6.0 (1995) statistical computer program. Group means for age, height, and weight along with peak torque values for each muscle group, peak torque/body weight for each muscle group, and the KF/KE strength ratio for both right and left legs were calculated. Significant differences in the peak torque values and peak torque/body weight at 60, 180, and 300 deg/sec among the testing groups were determined with the use of a two-way ANOVA with repeated measures. A two-way

ANOVA with repeated measures was also used to identify any significant differences in KF/KE ratio for each leg across each of the three testing speeds. A Fisher's LSD post-hoc test was used to determine significant differences.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to identify and compare the peak torque of the KF and KE muscle groups relative to body weight, and to establish and compare the strength ratio created by the KF and KE muscles between 3 groups of runners. The data were collected on both right and left legs over three testing speeds of 60, 180, and 300 deg/sec. Data were collected using the Biodex isokinetic dynamometer and analyzed with the use of a two way ANOVA with repeated measures for significance along with Fisher's LSD post-hoc test to identify specific differences. Each of the three male and female groups were tested in the same manner during a one month period of time which occurred at the end of a full indoor season and before the beginning of the outdoor track season.

Subjects

A total of 50 subjects volunteered to participate in the study at the University of Wisconsin-La Crosse. A goal of eight subjects for each testing group was established prior to subject recruitment and was achieved in two groups, with the exception of the male sprinters. Two male sprinters withdrew from the study for fear of injury which might limit their competitive season, leaving only seven subjects willing to participate in this group. Therefore, the total number of subjects reached 48. Both the sprint and distance groups had high fitness levels as a result of recently completing a full indoor track season. The control groups had a moderate fitness level established by their reportedly running 2-4 times per week. Group characteristics can be found in the Methods section under the heading subjects.

Peak Torque/Body Weight

Peak torque data at 60 deg/sec for males and females can be found in Appendix C and D respectively. The male sprinters had the greatest mean values for both right and left KF and KE muscle groups. Their right KE peak torque/body weight value was found to be 103% which was 14.4% greater than the left KE value. This was the only ipsilateral strength ratio imbalance greater than 10% which Nunn and Mayhew (1988) stated could predispose an athlete to injury.

A two-way ANOVA with repeated measures was used to determine significance on all right and left KE peak torque/body weight data. A significant difference ($p < .05$) was found between groups and speeds. A Fisher's LSD post-hoc analysis was performed and a significant difference between the groups was found to exist between the male sprint group and all female groups in the study. A significant difference was also found between the testing speed of 60 deg/sec and speeds 180 and 300 deg/sec, however, no significant difference was identified between 180 deg/sec and 300 deg/sec. The analysis of the left KE peak torque/body weight data found a significant difference ($p < .05$) between both group and speed variables. Male sprinters were found to be significantly different than all female groups with the use of a Fisher's LSD post-hoc analysis. This post-hoc analysis also identified male distance runners as significantly different than female distance runners. The speed variable difference was identified with the post-hoc analysis to lie between 60 deg/sec and both 180 deg/sec and 300 deg/sec. No other differences were identified. Both the right and left KE peak torque/body weight data show the male sprint group were different than all female groups. Peak torque/body weight data decreased as the testing speed increased, but it did not significantly decrease from 180 deg/sec to 300 deg/sec which was expected.

Both right and left KF muscle group data were analyzed and a significant differences ($p < .05$) between the groups and speeds was discovered. The use of a Fisher's LSD post-hoc analysis identified the group differences between the male sprinters and all female groups. It also identified the male distance group as significantly different than the female distance group. Significant differences in the speed variable were found between 60 deg/sec and both 180 deg/sec and 300 deg/sec. Finally the left KF muscle group data were analyzed with the use of a two way ANOVA with repeated measures which found significant differences ($p < .05$) between group and speed variables. A Fisher's LSD post-hoc test was used to identify where the differences existed. The male sprinters and distance runners were found to be significantly different than both the female control and distance groups. A significant difference in the speed variable was found between all three speeds. The left KF peak torque/body weight mean data for all groups were significantly different at 60 deg/sec, 180 deg/sec, and 300 deg/sec. Figures 1 and 2 depicts peak torque/body weight values for the male and female runners for all speeds.

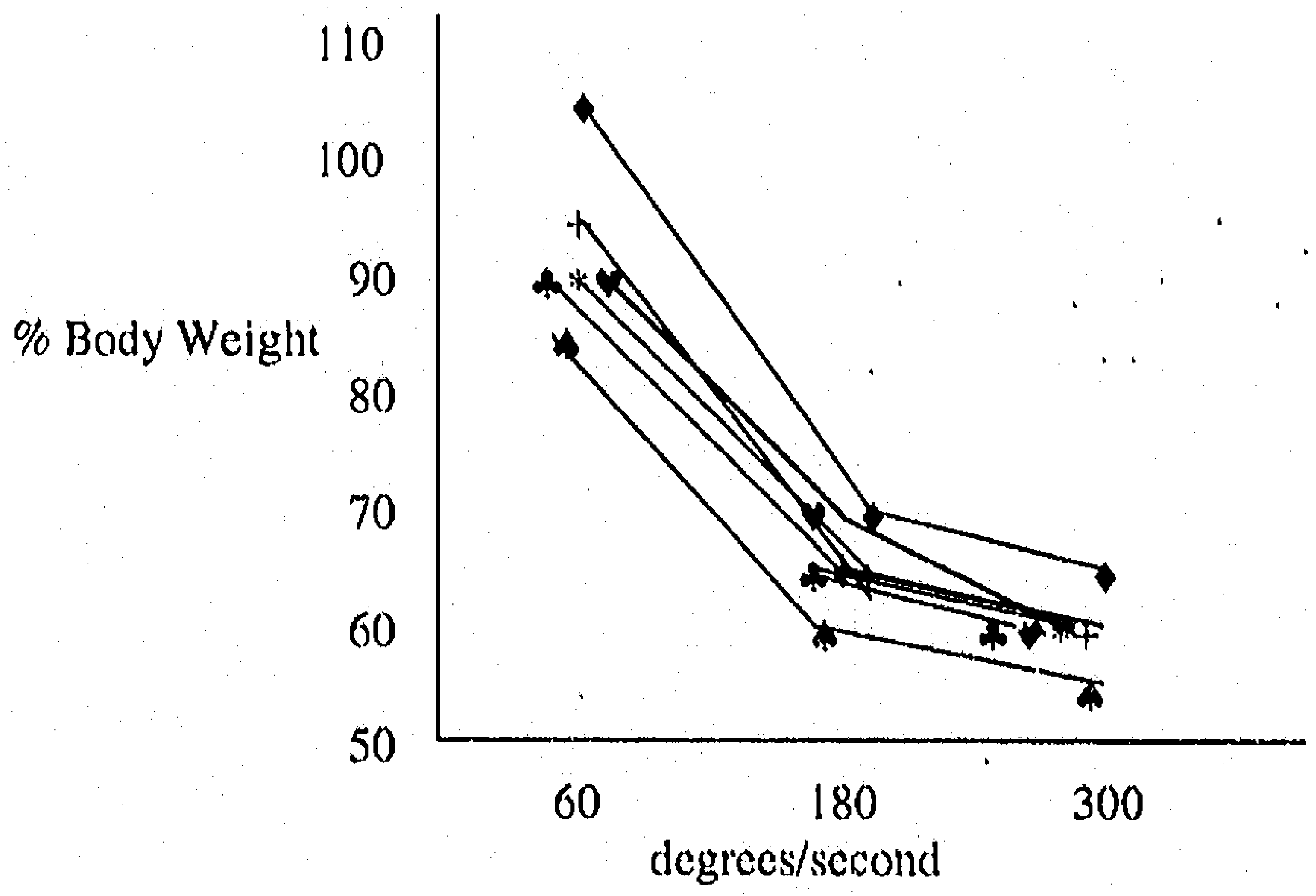

Figure 1. Peak Torque/Body Weight of Male Subjects.

♣ Rt. KE Control + Rt. KE Distance ♦ Rt. KE Sprint
♠ Lt. KE Control * Lt. KE Distance ♥ Lt. KE Sprint

Mean peak torque data for both right and left KE muscles are illustrated in Table 2. The male sprint group had the largest mean peak torque values at 172.0 foot/pounds (ft-lbs) followed by the male distance group. The female distance group had the smallest mean peak torque values at 89.0 ft-lbs. Mean peak torque data for both right and left KF groups are depicted in Table 3. The male sprint group had the largest peak torque values at 92.1 ft-lbs followed by the male distance runners at 76.8 ft-lbs. The female distance runners had the lowest peak KF values at 49.9 ft-lbs.

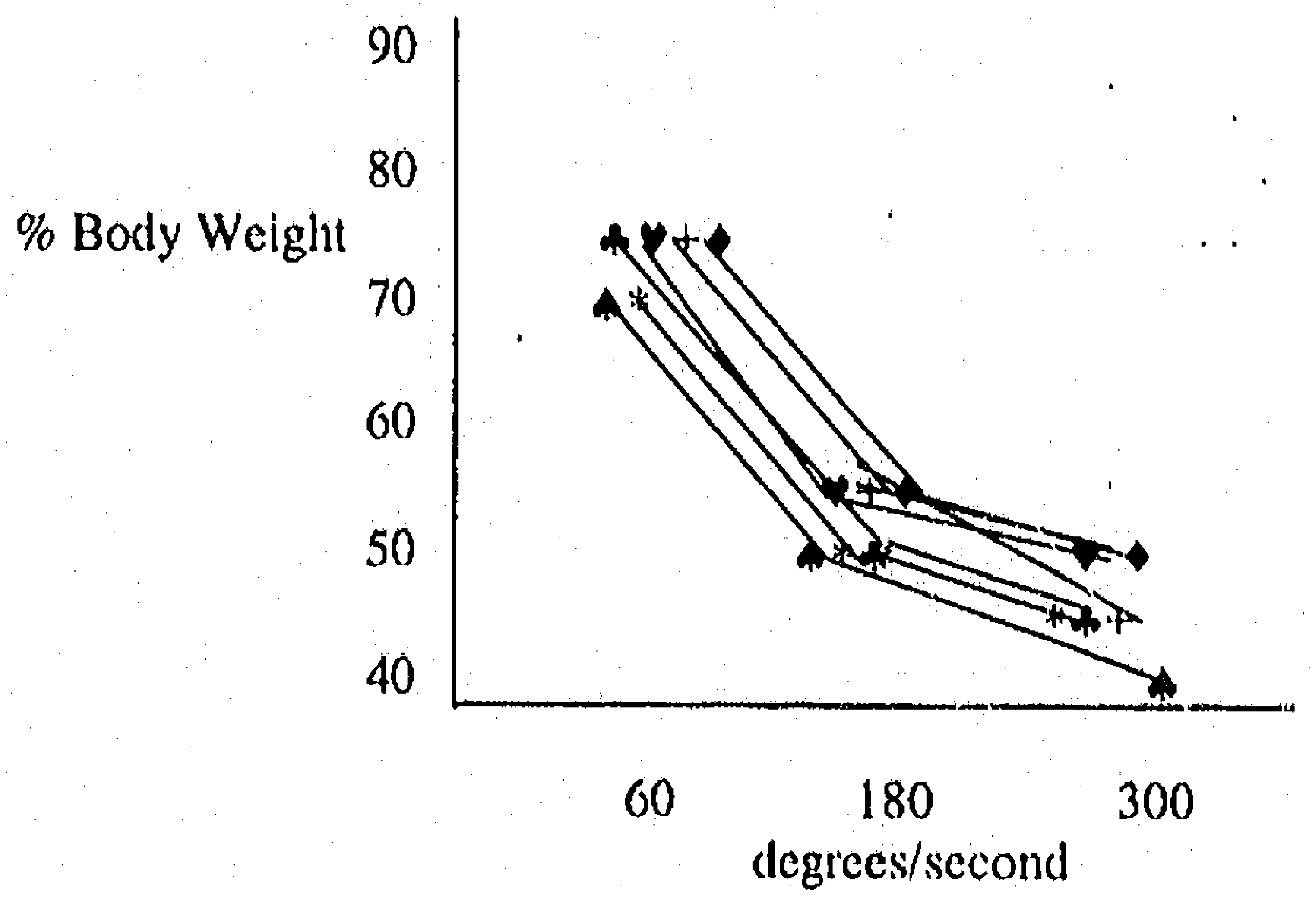

Figure 2. Peak Torque/Body Weight of Female Subjects

♣ Rt. KE Control + Rt. KE Distance ♦ Rt. KE Sprint
♠ Lt. KE Control * Lt. KE Distance ♥ Lt. KE Sprint

Table 2. Knee Extensor Mean Peak Torque Data at 60 deg/sec.

Group	Right KE	S.D.	Range	Left KE	S.D.	Range
Male Control	141.0	26.5	107-187	133.4	25.3	112-191
Female Control	104.0	16.5	75-119	97.0	14.5	73-113
Male Distance	143.3	16.7	114-162	137.3	18.5	104-154
Female Distance	89.0	16.1	68-120	87.5	13.9	68-84
Male Sprint	172.0 *	26.1	136-214	151.4 *	14.3	133-170
Female Sprint	97.9	19.8	77-137	95.9	16.6	81-129

* Significantly different than all female groups

Table 3. Knee Flexor Mean Peak Torque Data at 60 deg/sec

Group	Right KF	S.D.	Range	Left KF	S.D.	Range
Male Control	74.1	13.2	55-96	74.0	13.4	60-97
Female Control	51.6	7.0	42-61	49.6	7.8	39-57
Male Distance	76.8**	9.1	60-91	74.0***	9.4	57-85
Female Distance	49.9	9.0	33-63	48.1	9.3	31-61
Male Sprint	92.1*	9.5	82-106	85.6***	8.1	77-96
Female Sprint	52.8	8.0	40-61	50.4	5.1	43-57

* Significantly different than all female groups.
** Significantly different than only the female distance group.
*** Significantly different than female control and distance groups.

KF/KE Strength Ratios

The KF/KE strength ratios data on both right and left legs for all six experimental groups are listed in Table 4. The right KF/KE data for all groups were analyzed with a two-way ANOVA with repeated measures. A significant difference ($p < .05$) was found in the main effect of speed. No significant difference ($p > .05$) was found between group mean data for the right KF/KE strength ratios. The significant difference was found with the use of a post-hoc test between 60 deg/sec and both 180 deg/sec and 300 deg/sec. There was no significant difference between speeds of 180 and 300 deg/sec.

Table 4. Mean Data for the KF/KE Strength Ratios at 60 deg/sec.

Group	Rt. Leg	S.D.	Range	Lt. Leg	S.D.	Range
Male Control	.52	.04	.48-.59	.56	.06	.51-.65
Female Control	.50	.06	.39-.58	.51	.04	.47-.59
Male Distance	.54	.05	.48-.64	.54	.04	.45-.61
Female Distance	.56	.07	.47-.71	.55	.04	.46-.61
Male Sprint	.55	.11	.38-.71	.57	.08	.47-.68
Female Sprint	.55	.10	.39-.68	.54	.08	.42-.67

Table 5. The KF/KE Strength Ratios for Right and Left Legs at all Speeds.

Group	Rt. 60 *	Rt. 180	Rt. 300	Lt. 60 *	Lt. 180	Lt. 300
Male Control	.52	.60	.63	.56	.61	.64
Female Control	.50	.76	.76	.51	.72	.76
Male Distance	.54	.65	.62	.54	.63	.63
Female Distance	.56	.56	.58	.55	.57	.60
Male Sprint	.55	.69	.70	.57	.67	.69
Female Sprint	.55	.59	.64	.54	.57	.61

Significant difference between 180 and 300 deg/sec

The left KF/KE data for all six groups were analyzed and a significant difference ($p < .05$) was found within the speed variables. No significant difference ($p > .05$) was found between the groups. A Fisher's post-hoc test was done to establish the location of the differences in the speed variables. It was established that the slow speed of 60 deg/sec was significantly different than 180 deg/sec and 300 deg/sec. There were no differences between speeds of 180 deg/sec and 300 deg/sec ($p > .05$). Table 5 illustrates the KF/KE values for right and left legs for all groups.

Discussion of Results

The results obtained from using the Biodex isokinetic equipment to test for peak torque/body weight shows that the male sprint group had the greatest mean peak torque and mean peak torque/body weight ratio. These subjects had the greatest weight at 168.4 pounds and therefore would be expected to have a larger peak torque. When comparing the peak torque/body weight, the male sprinters again had the greatest values, being significantly ($p < .05$) greater than all female groups. These data corresponds to what Bishop (1983) found with male subjects having greater strength values. Bishop found the differences to arise from the larger amount of lean muscle mass in male subjects. It can not be determined if this is the cause of the differences found here without the collection of body composition measurements in this study. It is strongly suspected that the lean body weight of the male subjects was greater, therefore allowing for significant differences among male sprinters and distance runners and their female counterparts for all groups, excluding the right KE muscles. Significant differences among male groups across all three speeds were not found in this study.

The results of this study correspond with other researchers (Aagaard et al., 1995; Knapik & Ramos, 1980; Morris et al., 1983) concerning the decreased generation of peak torque as the speed of testing increased. For all KF and KE muscle groups, there was a significant decrease in the peak torque/body weight variable from 60 deg/sec to 180 deg/sec and 300 deg/sec, however, there was not a significant difference as the speed of testing increased from 180 deg/sec to 300 deg/sec except for the left KF muscles. For the left KF muscles there was a significant difference between all three speeds. The peak torque/body weight values were very similar between 180 deg/sec and 300 deg/sec except in the left KF muscles.

The establishment of normative data by Rankin and Thompson (1983) have made it more useful to measure the KF/KE strength ratios isokinetically. Their data on track distance runners reported KF/KE ratios of .64 at 60 deg/sec and .88 at 300 deg/sec. The data collected in this study show a ratio lower than reported by Rankin and Thompson (1983) of .54 for both right and left legs at 60 deg/sec and .62 and .63 for right and left legs at 300 deg/sec. The data from this study had significant differences among the speed variable but, no significant differences among the groups. The KF/KE strength ratio data from 180 deg/sec and 300 deg/sec were significantly greater than data collected at 60 deg/sec but, not significantly different from each other. Other researchers (Morris et al., 1983; Wyatt & Edwards, 1981) have found that as the speed of testing increased to approximately 300 deg/sec, the KF/KE ratio increased to near 1:1. The degree to which the ratio increases varies from study to study and has been noted to increase less when correction for gravity has been applied to the data. The data in this study were corrected for the effects of gravity and therefore follow a pattern more closely to that reported by Appen and Duncan (1986) who reported that there is less variability in the KF/KE ratio when the gravity corrected method is used.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to identify and compare the peak torque values relative to body weight, strength ratios of the ipsilateral KF muscles and KE muscles, and the influence of testing at 60 deg/sec, 180 deg/sec, and 300 deg/sec in control, distance, and sprint-trained groups. Subjects were informed of the purpose of the study and asked to participate in one practice session prior to testing which included ten repetitions of extension and flexion of the knee at each speed for both right and left legs. A total of 48 subjects volunteered to participate in the study with only 2 subjects withdrawing. Data were collected over a 3 week period of time during the early part of the outdoor track season. Subjects were required to warm-up on a stationary bike for 5 minutes and then stretch their hamstring and quadriceps muscles prior to testing. Testing began after the subject was properly strapped to the equipment with leg, thigh, waist, and two shoulder straps. Subjects placed their arms across their chest in the classic testing position. Correction for gravity was performed by measuring the static limb weight of the leg at a fully extended position. The data were automatically entered into the resulting torque values obtained by the computer.

Subjects performed three submaximal efforts of knee extension and flexion at 60 deg/sec followed by three efforts at approximately 95% of maximal effort to establish an approximate torque range for the computer. Approximately 15 seconds after the completion of this set, the subject was asked to extend and flex his/her leg "as hard and as fast as possible" for five repetitions. The subject was then given 45 seconds rest before the next series of testing was done at 180 deg/sec. After testing at 180 deg/sec the same procedure was performed at 300 deg/sec. Following this test, the straps were taken off the subject and he/she was allowed to stretch the left KF and KE muscles prior to the same testing sequence being performed on the left leg.

Data were collected and analyzed for the purpose of identifying and comparing the peak torque of the KF and KE muscle groups relative to body weight, and to establish and compare the strength ratio created by the KF and KE muscles between three groups of runners. A two-way ANOVA with repeated measures was used to detect significant differences among any of the six groups across all three speeds for peak torque/body weight data. There was a significant difference ($p < .05$) between the groups; hence, a Fisher's LSD post-hoc test was performed to detect where the difference occurred. It was concluded that the male sprint and male distance group had significant differences compared to the female control and female distance group. A two-way ANOVA with repeated measures also identified significance ($p < .05$) within the speed variable. A Fisher's LSD post-hoc test was performed to identify where significant differences occurred. Significant differences occurred between 60 deg/sec and 180 deg/sec as well as 60 deg/sec and 300 deg/sec for peak torque/body weight. There were no significant differences found between 180 deg/sec and 300 deg/sec, with the exception of the left KF muscle group, which had significant differences between all speeds.

The ipsilateral strength ratios of the KF and KE muscle groups were calculated using the group mean peak torque data at each of the three testing speeds. A two-way ANOVA with repeated measures was used to detect for significance. Significance ($p < .05$) was detected for speed only. A Fisher's LSD post-hoc analysis was performed and determined that both right and left KF/KE strength ratios were significantly different between 60 deg/sec and 180 deg/sec as well as 60 deg/sec and 300 deg/sec. Peak torque/body weight data at 180 deg/sec was not significantly different than at 300 deg/sec.

Conclusions

Based on the statistical analysis of the data the following conclusions were reached:

1. Relative strength of the KF and KE muscle groups was significantly different among control, sprint, and distance group based on gender only. No differences lie within groups of the same gender.
2. The relative strength of the KF and KE muscle groups did change across testing speeds of 60 deg/sec to 180 deg/sec and 60 deg/sec to 300 deg/sec in right KF and KE muscles and left KE muscles. In the left KF muscles significant differences exist between all three testing speeds.

3. There was no significant difference between all six groups when analyzing the ipsilateral KF/KE strength ratios. All groups have relatively the same basic KF/KE strength ratios.
4. There was a significant increase in the ipsilateral KF/KE strength ratio from 60 deg/sec to 180 deg/sec and 300 deg/sec but not between 180 deg/sec and 300 deg/sec. A significant increase was not found in the ipsilateral KF/KE strength ratio across all testing speeds.

Recommendations

Based upon the results of this investigation, the following recommendations for future study were made:

1. A similar investigation should be performed using the same subject groups but with a larger number of total subjects in each of the six groups.
2. A similar investigation should be done with open-kinetic-chain exercises to compare differences between open and closed-kinetic-chain exercises.
3. A similar investigation should be performed with subjects receiving greater motivation to perform maximal effort for each of the test repetitions.
4. A similar investigation should be performed with subjects who have a greater degree of experience using isokinetic equipment.
5. A similar investigation should be performed which utilizes faster speeds than was used in this study.

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APPENDIX A

INFORMED CONSENT FORM

Isokinetic Evaluation of the Knee Flexors and Knee Extensors of Male and Female Sprinters and Distance Runners

INFORMED CONSENT

I,________________________,give my informed consent to participate in this study to test the strength of the knee flexors and knee extensors of sprinters, distance runners, and a control group. I consent to publication of study results so long as the information is anonymous and disguised so that no identification can be made. I further understand that although a record will be kept of my having participated in the study, all experimental data collected from my participation will be identified by number only.

I have been informed that participation in this study involves my performing five maximal efforts will of knee flexion and extension at 60, 180, and 300 degrees/second with both the right and left legs at separate times.

I have been informed that the general purpose of this study is to identify the mean peak torque, strength ratios of the knee flexor and knee extensor muscle groups, and relative strength of these muscles in sprinters and distance runners in comparison to a normal population.

I have been informed that during the strength testing, I may feel tired or light headed. There are minimum identified risks involved with isokinetic strength testing including muscle strains, muscle spasms, and fainting. These risks and discomforts will be minimized by incorporating a warm-up, stretching of the hamstring and quadriceps muscles, and administering of the test by trained personnel.

I have been informed that there are no "disguised" procedures in this experiment. All procedures can be taken at face value.

I have been informed that the investigator will gladly answer any questions regarding the procedures of this study when the experimental session is completed.

I have been informed that I am free to withdraw from the experiment at any time without penalty of any kind.

Concerns about any aspects of this study may be referred to James Kluckhohn at 782-2611 or Dr. Marilyn Miller at 149 Mitchell Hall or 785-6527.

____
Experimenter

____
Experimental Participant

____
Date

APPENDIX B

SUBJECT DATA FORM

SUBJECT DATA FORM

Name:

Testing time/date:
(Tester use only)

Age:

Height:

Weight:

Years of Track Experience:

1. What are your main events for the 1997 outdoor track season?

2. What are your best performances in these events?

3. List any injuries in the past year that have kept you from competing.

4. If you are not part of the UW-La Crosse track team please list the number of times you run or jog per week.

APPENDIX C

MALE PEAK TORQUE/BODY WEIGHT DATA AT 60 DEG/SEC

MALE PEAK TORQUE/BODY WEIGHT DATA AT 60 DEG/SEC

Male Control Peak Torque/Body Weight

Subject	Age	Height	Weight	RT KE/BW	LT KE/BW	RT KF/BW	LT KF/BW
1	21	66	157	1.19	1.22	.61	.62
2	21	74	175	.89	.71	.47	.46
3	25	67	132	.81	.89	.42	.45
4	24	72	150	.84	.75	.40	.41
5	18	70	160	.84	.84	.41	.44
6	25	71	157	.87	.87	.51	.46
7	20	70	180	.91	.76	.46	.47
8	24	70	161	.72	.71	.40	.43
Means	22.3	70	159	.89	.84	.46	.47

Male Distance Peak Torque/Body Weight

1	24	68	160	.86	.95	.46	.51
2	19	72	147	1.00	.98	.58	.55
3	21	74	171	.89	.88	.43	.40
4	20	66	125	.91	.88	.58	.54
5	22	70	144	.84	.72	.42	.40
6	20	74	156	1.04	.89	.51	.45
7	21	75	145	1.10	1.06	.63	.58
8	21	69	158	.97	.94	.53	.54
9	21	71	153	.93	.87	.48	.47
Means	21	71	151	.95	.91	.51	.49

Male Sprint Peak Torque/Body Weight

1	20	69	170	.97	.82	.62	.56
2	19	68	146	1.21	1.12	.62	.53
3	18	71	179	.76	.74	.54	.42
4	22	72	179	1.20	.90	.46	.54
5	20	71	172	1.03	.90	.48	.48
6	19	72	162	1.16	.85	.63	.55
7	20	71	171	.85	.99	.50	.49
Means	19.7	70.6	168.4	1.03	.90	.55	.51

APPENDIX D

FEMALE PEAK TORQUE/BODY WEIGHT DATA AT 60 DEG/SEC

FEMALE PEAK TORQUE/BODY WEIGHT DATA AT 60 DEG/SEC

Female Control Peak Torque/ Weight

Subject	Age	Height	Weight	RT KE/BW	LT KE/BW	RT KF/BW	LT KF/BW
1	20	66	140	.84	.77	.33	.39
2	21	63	166	.51	.49	.27	.23
3	23	66	118	.64	.62	.36	.31
4	21	63	141	.74	.64	.35	.33
5	22	64	137	.85	.78	.39	.39
6	20	64	130	.89	.83	.47	.44
7	23	67	140	.85	.81	.42	.39
8	25	65	117	.85	.82	.49	.48
Means	21.9	64.8	136.1	.77	.72	.38	.37

Female Distance Peak Torque/Body Weight

1	20	66	123	.98	.89	.46	.47
2	19	66	134	.66	.76	.47	.46
3	20	63	128	.59	.57	.34	.33
4	19	68	125	.65	.66	.38	.37
5	22	65	115	.56	.53	.34	.33
6	19	64	124	.73	.73	.41	.40
7	21	63	98	.69	.69	.34	.32
8	21	68	130	.66	.67	.38	.36
Means	20.1	65.4	122.1	.73	.72	.41	.39

Female Sprint Peak Torque/Body Weight

1	18	64	117	.66	.76	.42	.43
2	18	67	131	1.05	.98	.41	.44
3	20	66	119	.73	.69	.50	.46
4	19	66	127	.69	.64	.42	.34
5	19	65	135	.64	.64	.30	.36
6	21	65	120	.74	.73	.37	.42
7	19	68	136	.84	.79	.45	.40
8	22	68	145	.73	.72	.42	.30
Means	19.5	66.1	128.8	.76	.74	.41	.39